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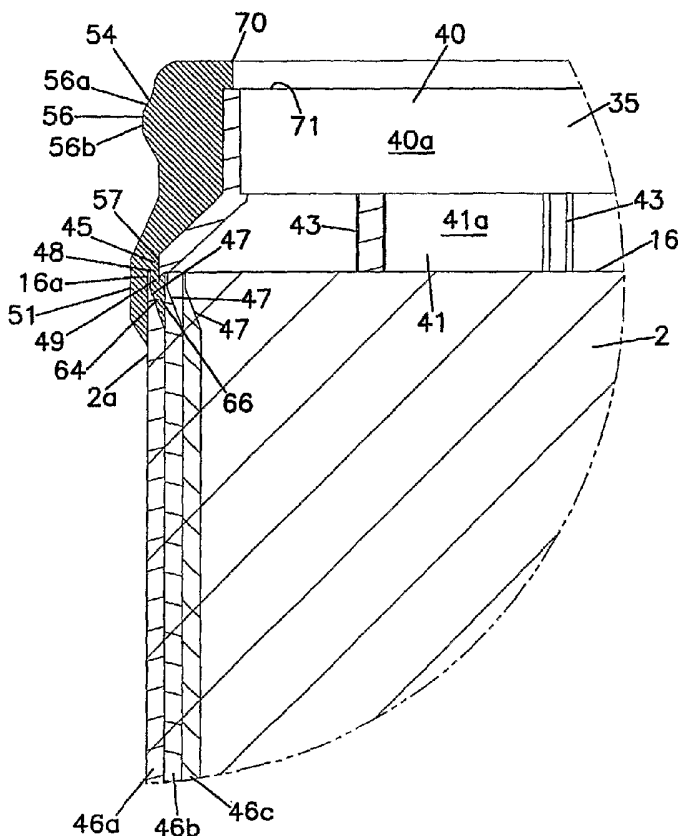
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[Continued on next page]

(54) Title: FILTER ELEMENT COMPRISING A SEAL ARRANGEMENT AND METHOD FOR MAKING THE SAME



(57) Abstract: A filter element arrangement is provided which includes a media pack(2) comprising Z-filter media, a preform(35) and an overmold(48,51,54) sealing a portion of the interface between the preform and the media pack, and also forming an air cleaner seal for the filter element. The overmold preferably comprises molded, foamed, polyurethane. A variety of media pack shapes can be used. A method of forming the filter element includes positioning the media pack in a mold together with the preform, and allowing uncured foaming urethane to rise and cure to cover an interface between the media pack and the preform. An air cleaner comprising the filter element is also provided.

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FILTER ELEMENT COMPRISING A SEAL ARRANGEMENT AND METHOD FOR MAKING THE SAME

### **Cross-Reference to Related Application**

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The present application includes, with some edits and additional information, the disclosure of U.S. provisional application 60/532,783 filed December 22, 2003. A priority right is claimed to that provisional application, to the extent appropriate. The complete disclosure of U.S. provisional application  
10 60/532,783 is incorporated herein by reference.

### **Field of the Invention**

The present invention relates to air cleaners with removable and  
15 replaceable, i.e., serviceable, filter element or cartridge components. Although other applications are possible, the invention described is particularly useful in air cleaners for use in filtering intake air for engines (used for example in: vehicles, construction, agricultural and mining equipment; and, generator systems). The invention specifically concerns seal arrangements provided on serviceable filter elements or  
20 cartridges, for such air cleaners. The invention also concerns methods of assembly and use.

### **Background**

25 Air streams carry contaminant material therein. In many instances, it is desired to filter some or all of the contaminant material from the air stream. For example, air flow streams to engines for motorized vehicles or for power generation equipment, construction equipment or other equipment, gas streams to gas turbine systems and air streams to various combustion furnaces, carry particulate  
30 contaminant therein. It is preferred for such systems that the selected contaminant material be removed from (or have its level reduced in) the air or gas. A variety of air filter arrangements have been developed for contaminant reduction. In general, however, continued improvements are sought.

### Summary

According to the present disclosure a filter element or cartridge is provided, for use in air filtering. In general the filter element or cartridge comprises a media pack including opposite inlet and outlet ends. The media pack defines: a set of inlet flutes open at the inlet end of the media pack to passage of air to be filtered therein, the inlet flutes being closed preferably at a location within a distance of 10% of the total length of the inlet flutes from the outlet end of the media pack; and, a set of outlet flutes closed to passage of air to be filtered therein preferably at a distance within 10% of the total length of the inlet flutes from the inlet end of the media pack and open the passage of filtered air therefrom at the outlet end of the media pack. The element or cartridge further includes: a preform positioned adjacent a first one of the inlet and outlet ends of the media pack; and, an overmold formed of seal material having a first portion sealing at a joint or interface between the preform and a first end of the media pack at which the preform is positioned; and, a second portion oriented to form an air cleaner seal, between the filter element (or cartridge) and an air cleaner, when the filter element is installed for use. The first and second portions of the overmold are integral with one another, in a preferred, convenient, arrangement.

In certain preferred applications, the media pack is a coiled z-filter media arrangement; and, the overmold comprises foamed polyurethane. The media pack can have a variety of shapes and configurations. Two examples depicted are: an oval shape, for example having a racetrack perimeter or cross-sectional shape; and, a circular perimeter or cross-sectional shape. A variety of alternate shapes, are possible.

The combination of the preform and the overmold, form a preferred seal arrangement for a filter element. Methods of preparation and use are also provided. Also, arrangements for use are generally described.

### Brief Description of the Drawings

Fig. 1 is a side elevational view of a filter element according to a first embodiment of the present disclosure.

Fig. 2 is a top view of the filter element component of Fig. 1.

Fig. 3 is a cross-sectional view taken along line 3-3, Fig. 2.

Fig. 4 is an enlarged fragmentary view of a portion of Fig. 3.

Fig. 5 is an enlarged, perspective view of a component used in the filter element of Fig. 1.

5 Fig. 6 is a cross-sectional view of the component of Fig. 5, taken along line 6-6 thereof.

Fig. 7 is a side elevational view of a filter element according to a second embodiment of the present disclosure.

Fig. 8 is a top view of the element shown in Fig. 7.

10 Fig. 9 is a cross-sectional view of the arrangement depicted in Fig. 8, taken along line 9-9 thereof.

Fig. 10 is an enlarged, fragmentary, view of a portion of Fig. 9.

Fig. 11 is a fragmentary schematic, cross-sectional view of a mold arrangement useable to form a seal component of the arrangement depicted in either  
15 Fig. 1 or Fig. 7.

Fig. 12 is a schematic cross-sectional view of the mold of Fig. 11, depicted with a pool of non-cured polymeric seal material therein.

Fig. 13 is a view of the mold of Fig. 12 with certain pre-formed filter element componentry positioned therein.

20 Fig. 14 is a view of Fig. 13 with a media component positioned therein.

Fig. 15 is a view of Fig. 14, with the seal material foamed and substantially cured.

25 Fig. 16 is a view of preform and media pack component in a mold according to the process of Figs. 11-15.

Fig. 17 is an optional end piece useable in the component of Fig. 1.

Fig. 18 is a cross-sectional view of the optional piece of Fig. 1.

Fig. 19 is a fragmentary, schematic, perspective view of z-filter media useable in arrangements according to the present disclosure.

30 Fig. 20 is a schematic, cross-sectional view of a portion of the media depicted in Fig. 19.

Fig. 21 is a schematic view of examples of various corrugated media definitions.

Fig. 22 is a schematic view of a process for manufacturing media useable according to the present disclosure.

Fig. 23 is a schematic cross-sectional view and optional end dart for media flutes useable in arrangements according to the present disclosure.

5 Fig. 24 is a schematic perspective view, analogous to Fig. 19, of a media material useable in the filter elements of Fig. 1 and Fig. 7, shown with a flow direction opposite to.

Fig. 25 is a schematic view of a system using an air cleaner having a filter cartridge component according to the present disclosure.

10 Fig. 26 is a fragmentary, cross-sectional view showing a plug in a central core of the filter cartridge of Fig. 9.

### **Detailed Description**

#### 15 **I. General Information**

The present disclosure relates to filter elements (sometimes called cartridges) useable in air cleaner assemblies. In general, the preferred filter elements of concern herein are those in which: (a) the media of the elements comprises a first corrugated sheet of media attached to a second sheet of media (typically a flat media or nearly flat media) to form a single facer; and (b) in which the single facer combination is either wound or stacked, to create a media arrangement comprising a plurality of inlet flutes open at an inlet end face of the filter media and closed at or near (typically within 10% of the total length of the inlet flutes of) the outlet face of the media; and, a plurality of outlet flow flutes seal closed at or near the inlet face of the media (i.e., typically within 10% of the total length of the outlet flutes of the inlet face), and open at the outlet end face of the media. Such media arrangements are well known and are described for example in U.S. 5,820,646; 5,772,883; 5,902,364; 5,792,247; 6,190,432 and 6,350,291, the complete disclosures of these six U.S. patents being incorporated herein by reference. Herein, such media will sometimes be referred to as z-filter media; and, media packs formed from such media as z-filter media packs. A characteristic of such media packs, and the ones described herein is that they are closed to passage of unfiltered air through the packs, between the opposite end faces.

Many variations of such media can be used, with the principles according to the present disclosure. For example, the end seals of the flutes (flute seals) can be provided in a variety of ways, including through utilization of sealant beads; darting, folding or other arrangements for distorting the shape of the flute at the end and/or closing and sealing the flute ends; and through combinations thereof. Not all flutes need to be sealed closed in the same way. The particular approach to sealing is generally a matter of choice, not specifically related to the general principles described herein (except as indicated below) in connection with provision of seals between the serviceable filter element and a housing or housing component, in use.

Another variable is the specific shape of the flutes. Tapered flutes in accord with PCT Application No. WO 97/40918 and PCT Publication Number WO 03/47722 and other flute shapes can be used, with arrangements according to the principles disclosed. Of course, straight (non-tapered) flutes can, and often will, be used.

Another variable with respect to the media arrangement, is whether the media is configured in a "coiled" arrangement or a "stacked" arrangement. The principles described herein will typically be applied in connection with "coiled" arrangements, for reasons which will be apparent from the following discussions. However, certain of the principles could be applied in connection with arrangements that are stacked.

Herein the term "coiled" and variants thereof, when used to refer to a media pack form from z-filter media, is meant to refer to a media pack formed by coiling a single combination strip of media or single facer, made from a strip of corrugated media secured to flat or nearly flat sheet (the combination being a single facer), in order to form the media pack. Such coiled media can be made in a variety of shapes including: round or cylindrical; oval, for example racetrack; square; or rectangular with rounded corners; and, they can even be configured in conical or similar arrangements. Examples of selected ones of these are described in U.S. 6,350,291 and U.S. provisional application Serial Number 60/467,521, filed May 2, 2003, the complete disclosures of which are incorporated herein by reference.

Herein the term "stacked arrangements" and variants thereof generally refers to media packs that are not formed from a single combination strip of media that is coiled, but rather to media packs formed from a plurality of strips of

media or single facer (corrugated media secured to flat or nearly flat media); the strips being secured to one another in a stack or block form. Stacked arrangements are described for example in U.S. 5,820,646, at Fig. 3, incorporated herein by reference.

5                   In general, z-filter media pack arrangements as described, are used in serviceable filter elements (or cartridges), i.e., filter elements (or cartridges) that are removable and replaceable with respect to an air cleaner in which they are used. Generally, such z-filter media packs are provided with sealing arrangements for engagement with portions of air cleaner parts such as a housing, in use. Herein,  
10 such seals are referred to as "air cleaner seals" or "housing seals," or by variants thereof. A variety of such air cleaner seals are known. One type, involving an outside or outwardly directed radial seal, is described in U.S. 6,350,291 at Ref. #250, Fig. 5.

Other types of seals useable with z-pack media are axial pinch seals,  
15 as described for example in U.S. 6,348,085; 6,368,374 and U.S. Publication US 2002/0185007 A1, incorporated herein by reference; and, internally directed radial seals, as described for example in U.S. Provisional 60/457,255 filed March 25, 2003 at Fig. 12, the complete disclosure of which is incorporated herein by reference.

In general z-pack media and its preparation are characterized in more  
20 detail herein below, in Section VII.

## II. An Example Element, Figs. 1-6.

The reference numeral 1, Fig. 1, generally depicts a serviceable filter  
25 element (sometimes called a cartridge) according to the present disclosure. The filter element 1 depicted, comprises a z-filter media pack 2 having an air cleaner seal arrangement 3 positioned thereon.

Again, herein, the term "air cleaner seal arrangement" and variants  
thereof is generally meant to reference a seal arrangement 3 provided on a  
30 serviceable filter element 1 in such a manner that, when the filter element 1 is installed in an air cleaner for use, the seal arrangement 3 provides for an air seal with appropriate componentry or portions of air cleaner, typically an air cleaner housing. The term "serviceable element" in this context, is meant to refer to a filter element 1 which is removable and replaceable with respect to other portions of an air cleaner.



The particular air cleaner seal arrangement 3 depicted comprises an outside radial seal member. By the term "outside radial seal member" in this context, it is meant that the surface 6 which forms a seal with an air cleaner component, in use, is directed radially outwardly, rather than radially inwardly with respect to the portion of the serviceable filter element 1 on which it is mounted. The principles described herein could be applied with alternate orientations and types of seals, but the particular seal configuration characterized is a convenient, advantageous, example.

In general, during operation, air flow through the z-filter media pack 2 is shown by inlet arrow 9 and exit arrow 10. It is a characteristic of z-filter media packs, that air flow therethrough is generally such that the inlet flow arrow and exit flow arrow are generally parallel to one another. That is, the only turns the air needs to make in passage through the element 1 are minor turns in flow through media pack 2, since the air flow flutes are generally parallel to one another, and parallel to the direction of inlet and outlet flow. It is noted that an opposite direction of air flow to that shown by arrows 9 and 10 is possible, but this particular direction of air flow shown, in use, is advantageous. When constructed and oriented for use in this manner, the media pack 2 has an inlet end or flow face 15 and an opposite exit end or flow face 16.

For the example shown, the inlet flow face 15 and exit flow face 16 are each substantially planar and are substantially parallel with one another. Although alternate arrangements are possible, the principles disclosed herein are particularly well considered for this application.

Fig. 2 is a top plan view of filter element arrangement 1. Referring to Fig. 2, the z-filter media 2 and seal arrangement 3 are provided with an oval outside perimeter shape, in this instance corresponding to two similar, opposite, curved ends 20, 21 spaced apart by two opposite, generally straight, sides, 22, 23. Herein this specific oval configuration will generally be referred to as a "racetrack" shape. Racetrack shaped z-filter media pack elements are described in the prior art, for example, in U.S. 6,350,291 at Fig. 10. It will be seen that many of the principles of the present disclosure can be applied in elements having media packs with alternate peripheral shapes, for example circular, as described herein below. Another variation in the oval shape would one in which the opposite sides are not straight, but are curved somewhat, with less curvature than the ends. Another shape which is

possible, is a shape which has two pairs of opposite, generally straight, sides which may or may not have a slight curvature to them, with four substantially curved corners. An example of this type of element is described in U.S. provisional application 60/457,255, in Fig. 22, the complete disclosure of which is incorporated  
5 herein by reference.

The various shapes identified in the previous paragraph, indicate that the principles herein can be applied to a wide variety of coiled shapes, not just the ones shown in the figures.

Referring to Fig. 1, the filter element 1 includes an optional end piece  
10 or skid skirt 30 thereon, at an opposite end of the media 2 from the seal arrangement 3. The optional end piece or skid skirt 30 can be used to provide engagement between element 1, and structure in a housing, during use, to facilitate installation. Examples of such end pieces are shown and described, in PCT Publication number WO 03/095068, published November 20, 2003, at Figs. 4 and 8, the complete  
15 disclosure of PCT publication WO 03/095068 being incorporated herein by reference. The optional end piece 30 is discussed again below, in section V in association with description of Figs. 17 and 18.

Referring to Fig. 2, seal arrangement 3 comprises: a rigid preform part or insert 35; and, a molded seal component 36. By the term "preform part" and  
20 variants thereof, as used in this context herein, it is meant that part 35 is formed prior to formation of the molded seal component 36 to form the seal arrangement 3. Indeed, in a typical manufacturing process for filter element 1, as described below: media pack 2 would be preformed; part 35 would be preformed; and, the two parts (2, 35) would be placed together in a mold, for formation of the molded seal  
25 component 36. Herein, the molded seal component 36 is sometimes referred to as an "overmold," or by variants thereof. Among other things, as will be understood from the following descriptions, the term "overmold" in this context indicates that the molded seal component 36 is molded in place on the media pack 2 and preform 35, and is not itself preformed.

30 Attention is now directed to Fig. 3. Fig. 3 is a cross-sectional view taken along line 3-3, Fig. 2. The cross-section of Fig. 3 is through the shorter or narrower dimension of the element 1, Fig. 1. However, similar features will be viewable, if the cross-section were taken along the longer axis, i.e., line Y-Y, Fig. 2.

The media pack 2, Fig. 3, is a coiled media pack. In general the media pack 2 comprises a corrugated media sheet secured to a facing sheet, often a flat or nearly flat sheet, to form a strip or single facer, which is itself coiled in the configuration shown. Thus, the media pack 2 comprises a single strip of the corrugated sheet facing (typically flat or non-corrugated) sheet, or single facer, coiled and configured as shown. In Fig. 2, although the media pack 2 is shown schematically, the outer three coils are indicated. Referring to Fig. 1, the outside tail end of the outer most coil is shown at 37. For the embodiment shown, tail end 37 is sealed and secured in position, by a hot melt sealant strip 38, although alternatives are possible.

Referring again to Fig. 3, it is noted that there is no center board, center gap, center piece or center seal schematically shown in the media pack 2. The media pack 2 is simply shown schematically with respect to this point. Center boards can be used, for example as described in U.S. 6,348,084, incorporated herein by reference. Interdigitated center strips can be used, for example as described in U.S. Provisional Application Serial Number 60/467,521, filed May 2, 2003. Center seals can also be used, for example as described in U.S. Provisional Application Serial Number 60/467,521, filed May 2, 2003. No specific choice from among these, and variants, is meant to be indicated with respect to Fig. 3. However, as is apparent from a review of the figures and further description herein, a center of the media pack 2 would be sealed closed, in some manner, to prevent the flow of unfiltered air between the two opposite end faces 15, 16; i.e., so unfiltered air cannot flow outwardly from an end face.

Referring to Fig. 3, the preform part 35 depicted includes three sections generally comprising: housing seal support section 40; media engagement periphery or skirt 41; and, media face cross piece arrangement 43.

Attention is directed now to Fig. 4. Fig. 4 is a fragmentary enlarged view of a portion of Fig. 3. In Fig. 4 it can be seen that no portion of preform 35 extends around the outer periphery or side 2a of the media pack 2. This will be preferred, for arrangements according to the present disclosure, although alternatives are possible. For the particular arrangement depicted in Fig. 3, media engagement portion 41 includes an edge 45 which is brought into engagement with flow face 16 of the z-filter media pack 2 and which for the example shown does not project to, or beyond, an outer perimeter edge 16a of flow face 16, although alternatives are

possible. The particular preform 35 depicted includes a small ridge 45a, Fig. 6 which projects slightly into media pack 2. Preferably ridge 45a is no greater than 1 mm and comes to a fine point, to help contain flow of rising urethane, during formation of the overmold 36, and desirably from extending across flow face 16.

5                   As described above in reference to Fig. 3, it is noted that the particular z-filter media pack 2 depicted comprises a coiled media arrangement. In Fig. 4, the outer three coils 46a, 46b and 46c are formed. The ends of coils 46a, 46b and 46c, adjacent surface 16, are shown comprising ends folded or darted closed at 47. Such folding or darting is described, for example, in U.S. Provisional  
10   Application Serial Number 60/467,521, filed May 2, 2003, incorporated herein by reference.

                  Referring still to Fig. 4, molded seal component 36 is positioned with a portion 48 overlapping and sealing a joint 49 where preform part 35 engages flow surface 16 of the media pack 2. Preferably the molded seal component 36 includes a  
15   portion 51 which extends beyond the joint 49 in a direction away from flow face 16 (toward opposite flow face 15, Fig. 3) a distance of at least 5 mm, preferably at least 8 mm, and typically a distance within the range of about 9 mm to 18 mm, inclusive.

                  In general, portions 48 and 51 of the molded seal component 36, provide then, for a sealing between the media pack 2 and the preform part 35 at this  
20   location, and also for sealing around and against media pack 2, adjacent face 16, to inhibit undesired, contaminated, air flow at this region. Typically, if the media pack does not include a covering or coating of some type, portions 48 and 51 will contact the single facer sheet of the media directly. In other cases, material on the media pack will be between the media and portions 48 and 51. In both instances, portions  
25   48 and 51 engage the media pack 2.

                  Referring to Fig. 1, and in particular to hot melt seal strip 38, preferably the strip 38 is continuous and terminates, underneath region 51 of overmold 36, at a location spaced at least 4 mm from face 16, Fig. 4. Typically an extension of 6-12 mm of strip 38 will be positioned underneath overmold 36. The  
30   termination of strip 38 at least 4 mm from surface 16 ensures that over a distance of at least 4 mm, the seal material of overmold 36 is sealed directly to the media pack 2 adjacent end face 16. This will help avoid leak between the overmold 36 and the media pack 2 at this location.

Referring to Fig. 4, molded seal component or overmold 36 further includes air cleaner seal portion 54. Air cleaner seal portion 54 includes a radial outer surface 56, configured in a preferred manner, for sealing with an air cleaner component. The particular surface 56 is depicted, as a stepped surface portion 56a having a shape similar to the shape of the seal surface portion at reference 250 depicted in U.S. patent 6,350,291 at Fig. 7, the complete disclosure of which is incorporated herein by reference.

From review of Fig. 3, it can be seen that portion 40 of preform part 35 is positioned to back up housing seal 56 and stepped portion 56a of molded seal composition or overmold 36. Thus, preform part 35, in part, serves a function of providing for rigid backup to the strength of the seal when air cleaner seal portion 54 is compressed in the thickness (preferably at least 10% in thickness at the portion of most compression) upon installation in an air cleaner, with compression being of surface 56 toward portion 40. Preferably, the distance of compression is within the range of 1.5 - 2.8 mm, at the thickest part 56b of seal 56, more preferably about 1.9 - 2.5 mm. As can be seen from a review of Fig. 3, portion 40 is positioned to operate as a backup to the seal, because it projects outwardly (axially) from one of the flow faces 15, 16.

The recess of surface 40 across face 16, from outer periphery 2a of the media pack 2, provides that the filter element 1 can be installed in air cleaners that are originally configured, for example, to receive elements such as element 450, Fig. 15 of U.S. patent 6,350,291, incorporated herein by reference. Of course alternate configurations are possible. Of course surface 40 is preferably positioned so the supported housing seal 56 projects at or outwardly from the outer perimeter of the media pack, in preferred arrangements.

Media engagement portion 41 is configured to extend radially outwardly, in extension between portion 40 and edge 57. Media engagement portion 41 is configured as a radially outwardly directed skirt, from region 40. This outward extension means that ends of outlet flutes in the z-filter media pack 2, at region 60, Fig. 3, are not closed to passage of air therefrom, during filtering operation. If region 41 was not positioned as a flared, diagonal, skirt, but rather section 40 extended to point 61, flutes in region 60 would be blocked by extension 41, for air flow therefrom. This would lead to increased restriction, and less efficient use of the media. Preferably angle X, Fig. 6, is within the range of 20°-70°, to accommodate

the desired skirt. The angle X is the angle between the inside surface of skirt 41 and the media face 16.

Referring to Fig. 4, it is noted that for the particular arrangement shown skirt 41 is sized and positioned to leave region 64 in face 16 (corresponding to the otherwise open ends of exit flutes in an outer flute wrap 46a in the media pack 2), exposed to receive a portion of molded seal component 36 therein, as indicated at 66. This can provide for advantage. In particular, this allows some of overmold 36 to rise into the media pack 2, as described below, during molding.

It is noted that for the preferred element 1 depicted in Fig. 4, no portion of the molded seal component 36 is positioned along interior surface 40a of section 40. Further, preferably no portion of molded seal component 36 is provided along inner surface 41a of region 41, except possibly for some bleed or flash immediately adjacent edge 45. This latter prevents undesired levels of flash across surface 16 and provides for a convenient manufacture. Section 40 could be configured, and overmold 36 formed, to allow sealant in region 40a, but this would not be preferred.

Still referring to Fig. 4, media face cross piece arrangement 43 extends across media face 16, in engagement with region 41 of preformed part 35. Media face cross piece arrangement 43 prevents the media pack 2 from telescoping, in the direction of arrow 10, Fig. 1, during use.

A variety of cross piece configurations are useable. In Fig. 2, the particular cross piece arrangement 43 depicted, comprises: a grid of parallel extensions 43a between opposite sides 22, 23; interconnected by diagonal framework 43b.

In Fig. 5, a perspective view is provided, showing preformed part 35. It can be seen that the preform part 35 can be formed as a single integral unit, for example through injection molding or other molding processes. It is preferably formed from a polymer such as a (33% for example) glass filled nylon material.

Referring again to Fig. 4, molded overmold or seal component 36 includes a portion 70 overlapping part of end 71 of preform part 35. This is an artifact from a preferred molding operation, as described below.

Referring to Fig. 4, it is noted that where cross-brace 43 engages skirt 41, the angle of the skirt 41 relative to the face 16 may be interrupted somewhat.

However, in general, at other locations the skirt 41 will have a preferred angle X as characterized above.

It will be understood that the techniques described herein can be applied in a wide variety of element configurations and sizes. The following dimensions are provided as examples only, and to help understand the wide application of the present techniques. The overmold 36, in its thickest location, could be about 10 - 12 mm thick, for example about 11.5 mm. The longest cross-sectional dimension of the racetrack shaped media pack could be about 300 - 320 mm, for example about 308 mm. The shortest cross-sectional dimension of the racetrack shaped element could be about 115 - 125 mm, for example about 121 mm. The length of the straight sides could be about 175 - 195 mm, for example about 188 mm.

Before formation of arrangements such as described above is discussed, and certain advantages relating to the configuration are described, application of the principles in an alternate configuration will be discussed in connection with Figs. 7-10.

### III. The Arrangement of Figs. 7-10

Attention is first directed to Fig. 7. Fig. 7 is a side elevational view of a serviceable filter element (or cartridge) 101. The filter element 101 comprises a z-filter media pack 102 and seal arrangement 103. The element 101 further includes optional end piece 104 at an end 102b of media pack 102 opposite from an end 102a in which seal arrangement 103 is located.

The media pack 102 comprises a coiled single facer having first and second, opposite, flow faces 105, 105a. It would, of course, have an outside tail end, not shown, which would be secured down, for example, with a sealant strip analogous to strip 38 above.

In general, and referring to Fig. 7, surface 106 of seal arrangement 103, is configured to provide a seal, as an outwardly directed radial seal, with a housing or air cleaner component in use (of course alternatives are possible). Surface 106 may be configured, in cross-section, analogously to surface 56, Fig. 4.

Attention is now directed to Fig. 8, in which element 101 is depicted in top plan view. From the view of Fig. 7, it can be seen that element 101 is a

generally circular outer perimeter 108 defined by both the outer circumference of the seal arrangement 103 and media pack 102. In Fig. 8, grid work 109 is viewable, extending across flow face 105; in this instance face 105 preferably being an outlet flow face.

5                   Attention is now directed to Fig. 9, which shows a cross-sectional view through element 101. From Fig. 9, it can be seen that the seal arrangement 103 comprises a preformed part 110 and an overmold or molded seal component 111. The preform part 110 and molded seal component 111 may generally be analogous to the preform part 35 and molded seal component 36 of the embodiment shown in  
10 Figs. 1-5, except made round.

Specifically, element 101 includes a core 113, around which the media pack 102 is wound. Core 113 can be provided in snap fit engagement with a portion 114 of preform part 110. A variety of engagement arrangements can be used, including the one, for example, described at Fig. 5 in U.S. Patent 6,517,598,  
15 incorporated herein by reference. Core 113 is shown in schematic. It would typically be provided with a plug therein. The plug could be integral with a remainder of core 113 or be added thereto. The plug or other closure in core 113 would generally operate to prevent flow between faces 105a, 105 which is not filtered.

20                   In Fig. 10, an enlarged fragmentary view of a portion of Fig. 9 is shown. The preform part 110 includes a housing seal support 116; and, a media pack engagement portion 117, configured as a radially outwardly directed skirt 118; and media face cross piece arrangement 109 (Fig. 8). (At region 114 the inside outward skirt 118 is shown filled because the cross-section is taken through cross  
25 piece grid work 109, Fig. 8.) For element 101, these components generally provide the same basic operation as the analogous components for element 1, Fig. 1.

#### **IV. Process for Assembly of Elements According to Figs. 1-10.**

30                   In general, elements corresponding to element 1, Fig. 1, and element 101, Fig. 6, are formed the processes involving the following:

1.     Preforming the media pack component (2, 102).
2.     Preforming the preformed part (35, 110) of the seal arrangement.



3. Positioning the preform part (35, 110) and media pack component (2, 102) appropriately with respect to one another in a mold.
4. Overmolding a seal material to form the appropriate molded seal component of the arrangement.
5. Demolding.
6. Optionally placing the skid (30, 104) on an end of the element opposite the seal.

10 In this context, the term "overmolding" and variants thereof are meant to refer to molding a molded seal component 36, 111 in position: (a) with a portion of the molded seal component 36 over the outside of joint between the preformed part (35, 110) of the seal arrangement and the media pack (2, 102); and, (b) with a portion of the same seal component 36, 111 (i.e. preferably a portion  
15 integral with a remainder of the overmold) positioned to form an air cleaner seal. Typical and preferred processes will use, for the formation of the molded seal component, a foaming polyurethane, as described below. Herein, a molded seal component 36 which has been made by overmolding as defined, will sometimes be referred to as an overmold. The portions of the overmold seal, are preferably  
20 integral with one another; the overmold 36, 111 being preferably molded from a single pool of polymer.

Typically and preferably, the thickness of the molded seal component, in the region of the seal surface, is configured so that compression of the thickness of the thickest portion of the molded seal component in this region, will be  
25 at least 10%, and typically at least 15%, when the element (1, 101) is installed in an air cleaner for use. This can be accomplished with configurations as shown, using materials as described below.

A typical process is described herein, in connection with Figs. 11-16.

Attention is first directed to Fig. 11. In Fig. 11, reference numeral  
30 180 identifies a mold arrangement useable to form the overmold seal arrangement of the present disclosure. Mold arrangement 180 is shown in fragmentary, cross-section. The portions indicated will provide an understanding of how the overmold seal arrangement can be formed. The remainder of the mold will be configured either round or obround, etc., depending on the particular instance of application.

Referring to Fig. 11, the particular mold arrangement 180 depicted is a multi-part mold 181. That is, the mold 180 includes more than one piece fit together, to form the mold in which the overmolding process occurs. The particular multi-part mold 180 depicted comprises three parts 183, 184 and 185 that are fit  
5 together, to form the mold. Aperture 189, which extends through three parts 183, 184, 185 when they are appropriately aligned, Fig. 11, can be used to receive a pin or similar member to secure the mold together.

In general, part 183 forms the basic mold structure including: an inner reservoir portion 192, in which uncured resin is placed, for the molding  
10 process; inner wall 193, against which a preformed part would be placed in use; shelf 194 on which an edge of the preform part would rest, during the molding process; central wall 195 and shelf 196 which supports additional mold parts as described; and, outer wall 197, which provides an outer support structure to the assembly 180.

The second part 184 comprises a mold insert having an extension 200  
15 with a surface 201 that forms a portion of the outer surface of the molded part of the seal arrangement in use. In this instance surface 201 includes a portion 202 which, in combination with central wall 195 provides a mold undercut 203 molding a particular portion of the sealing surface of the resulting seal portion, as discussed  
20 below in connection with Fig. 15. Part 184 further includes upper extension 205 which rests on shoulder 196.

Finally, part 185 includes inner wall 215 and upper flange 218. The flange 218 extends over portion 205 of center part 184. Inner wall 215 includes a surface 216 which will define selected portions of the seal member, during the  
25 molding process, as discussed below in connection with Fig. 15. Section 217 will cap the mold, and engage media, during a preferred molding operation.

Attention is now directed to Fig. 12, in which assembly 180 is depicted with curable material 225 positioned within reservoir 192 up to fill line 226. The material 225 would generally comprise resin which, during a cure process,  
30 will foam and rise as a cure to form the moldable seal component. Typically, during molding and use the material 225 will expand in volume at least 80%, a preferred material increasing about 100%, in volume.

In Fig. 13, the mold assembly 180 having resin 225 therein is shown having preformed part 230 therein. The preform part 230 could correspond, for

example, to preform part 35, Fig. 1. It could also correspond to preform part 110, Fig. 7. However if used with the arrangement of Fig. 7, in some instances it would already be attached to the media pack.

Attention is now directed to Fig. 14 in which the mold arrangement 180 is depicted with preform part 230 and media pack 231 positioned appropriately. It is noted that an outer surface 232 of media pack 231 is sized to engage portion 217 of the mold part 185.

Attention is now directed to Fig. 15. In Fig. 15 the material at 235 is meant to indicate the foamed, risen, substantially cured resin; i.e., the overmold (corresponding to overmold 36, Fig. 1, or overmold 103, Fig. 7). By the term "substantially cured" it is meant that the resin is cured sufficiently to have reached a shape which will generally be maintained, as it further cures. From Fig. 15, some of the following important features relating to the molding operation can be understood:

1. At region 240, the most outwardly projecting portion of the molded seal member 235 (number that above) is formed. Portion 240 then, will form the outer most portion of the outwardly directed radial seal member, i.e., the part that compresses most in use as an air cleaner seal;
2. Surface 241 is a portion of mold undercut, which is used to form a portion of region 240.
3. At region 245, rise of the material 235 around the outside surface 232 of the media pack 231 is capped or stopped by mold piece 185, in particular by region 216 of mold piece 185.

At location 247, some of the resin of overmold 235 has risen into the media pack between an outer most layer 248 of the media pack 231 and the layer underneath. This rise will tend to close off any otherwise open flutes at this location. In general, this will render the outer most layer of the media pack (for example layer 46a, Fig. 4) such that while it can be used for filtering material, air must pass into the next inner layer, before it can exit the media pack. What this means or ensures is that even if the outer most wrap of media pack is damaged during handling or installation, leakage will not result. Thus, in a preferred

arrangement, a third set of flutes, closed at both ends, is present in the media pack. This third set is present, preferably, only in the outermost wrap. These flutes would otherwise be outlet flutes, and will sometimes be referred to by such terms.

5 For the process shown in Figs. 11-16, the media pack is one which has closed ends at the inlet flutes, adjacent the outlet flow face, darted closed, to provide the edges viewable. Alternates of course are possible, including ones that are not darted at all. The overmold material is shown risen up into the open ends of the outlet flutes, at the outlet face of the media, in the region indicated at 247.

10 Along regions 249, 250, the resin material 236 completely lines an outer surface of preform 230, securing it in place. At region 255, material 235 is positioned over a part of an end 256 of preform 230.

In the particular arrangement shown, Fig. 15, the overmold 235 is a single integral member, molded from the resin 225, Fig. 14.

15 Demolding can be accomplished by forcing the element out of the mold 180, in a powered process. Equipment to cause the forcing can engage the cross pieces on the preform 230. Generally the overmold 235 will compress sufficiently, to be pushed past undercuts in the mold. It is anticipated that typically, with materials and configurations described herein, demolding can be accomplished with a force of 110 lbs. or less, typically about 100 lbs. (The demolding force would typically be applied directly to the gridwork of the preform 35, 110.)

20 The optional preform skid skirt at the opposite end of the element, can be applied either before or after molding. In general, if a center plug is used within the media, it would be preformed before the described molding process. However, in some instances a center plug can be molded at the same time as the overmold. This latter would require ensuring that a part of the mold or some other configuration is provided, for appropriate dispensing of the urethane to accomplish this.

It is noted that in some instances, as described above, the preform 230 could be attached to the media pack 231 by snap-fit arrangement.

30 In Fig. 16, the mold 180 is depicted with the media pack 231 and preform 230 positioned therein, at molding. In this instance the media pack 231 is depicted without the option skid skirt mounted therein.

## V. The Optional Skid Skirt

In the discussion above with respect to Fig. 1, it was indicated that the skid skirt 30 was an optional component. This component is depicted in Figs. 17 and 18.

Referring first to Fig. 17, a top plan view, the skid skirt 30 is depicted. In Fig. 18, the skid skirt 30 is depicted in cross-sectional view. Referring to Fig. 18, receiving area 30a for the media pack, can be viewed, along with outside surface 30b configured to engage componentry in a housing, during installation, as desired. From the principles described in Figs. 17 and 18, an analogous, but circular, component can be understood, if desired, for application in a circular arrangement. The skid skirt 30 is typically formed from a glass filled (for example 33% glass filled) nylon, secured in position with an adhesive.

## VI. The Curable Seal Resin

Preferably with such arrangements, the polyurethane formulation chosen provides for a high foam, very soft, molded end cap. In general, the principal issue is to utilize a formulation that provides for an end cap that is such that a robust seal will result under conditions which will allow for hand assembly and disassembly. This generally means that the seal range which has material is a relatively low density, and exhibits appropriate and desirable compression load deflection and compression set.

Although alternatives are possible, preferably the formula chosen will be such as to provide end caps having an as molded density of no greater than 28 lbs./cubic foot (0.45 g/cu. cm.), more preferably no more than 22 lbs./cubic foot (0.35 g/cu. cm.), typically no greater than 18 lbs/cubic foot (0.29 g/cu. cm.) and preferably within the range of 12 to 17 lbs/cubic foot (0.19 - 0.27 g/cu. cm.).

Herein the term "as molded density" is meant to refer to its normal definition of weight divided by volume. A water displacement test or similar test can be utilized to determine volume of a sample of the molded foam. It is not necessary when applying the volume test, to pursue water absorption into the pores of the porous material, and to displace the air the pores represent. Thus, the water volume displacement test used, to determine sample volume, would be an immediate

displacement, without waiting for a long period to displace air within the material pores. Alternately stated, only the volume represented by the outer perimeter of the sample need be used for the as molded density calculation.

In general, compression load deflection is a physical characteristic that indicates firmness, i.e. resistance to compression. In general, it is measured in terms of the amount of pressure required to deflect a given sample of 25% of its thickness. Compression load deflection tests can be conducted in accord with ASTM 3574, incorporated herein by reference. In general, compression load deflection may be evaluated in connection with aged samples. A typical technique is to measure the compression load deflection on samples that have been fully cured for 72 hours at 75°F (24°C) or forced cured at 190°F (88°C) for 5 hours.

Preferred materials will be ones which when molded, show a compression load deflection, in accord with ASTM 3574, on a sample measured after heat aging at 158° F (70°C) for seven days, on average, of 14 psi (0.96 bar) or less, typically within the range of 6-14 psi (0.41 - 0.96 bar), and preferably within the range of 7-10 psi (0.48 - 0.69 bar).

Compression set is an evaluation of the extent to which a sample of the material (that is subjected to compression of the defined type and under defined conditions), returns to its previous thickness or height when the compression forces are removed. Conditions for evaluating compression set on urethane materials are also provided in ASTM 3574.

Typical desirable materials will be ones which, upon cure, provide a material that has a compression set of no more than about 18%, and typically about 8-13%, when measured on a sample compressed to 50% of its height and held at that compression at a temperature of 180°F (82°C) for 22 hours.

In general, the compression load deflection and compression set characteristics can be measured on sample plugs prepared from the same resin as used to form the end cap, or on sample cut from the end cap. Typically, industrial processing methods will involve regularly making test sample plugs made from the resin material, rather than direct testing on portions cut from molded end caps.

Urethane resin systems useable to provide materials having physical properties within the as molded density, compression set and compression load deflection definition as provided above, can be readily obtained from a variety of

polyurethane resin formulators, including such suppliers as BASF Corp., Wyandotte MI, 48192.

In general, with any given industrial process to select the appropriate physical characteristics with respect to the material, the key issue will be management of the desired characteristics and the final product, with respect to mounting and dismounting of the element, as well as maintenance of the seal over a variety of conditions. The physical characteristics provided above are useable, but are not specifically limiting with respect to products that may be considered viable. In addition, various element manufacturers, depending on the circumstances, may desire still further specifications, for example, cold temperature compression deflection, typically measured on the sample cooled to -40°F (-40°C), with the specification being for the pressure required to cause the compression under the ASTM test, for example, being 100 psi (6.9 bar) max.

One example usable material includes the following polyurethane, processed to an end product having an "as molded" density of 14-22 pounds per cubic foot (0.22 g/cu. cm. - 0.35 g/cu. cm.) The polyurethane comprises a material made with I36070R resin and I3050U isocyanate, which are sold exclusively to the assignee Donaldson by BASF Corporation, Wyandotte, Michigan 48192.

The materials would typically be mixed in a mix ratio of 100 parts I36070R resin to 45.5 parts I3050U isocyanate (by weight). The specific gravity of the resin is 1.04 (8.7 lbs/gallon) and for the isocyanate it is 1.20 (10 lbs/gallon). The materials are typically mixed with a high dynamic shear mixer. The component temperatures should be 70-95°F. The mold temperatures should be 115-135°F.

The resin material I36070R has the following description:

- (a) Average molecular weight
- 1) Base polyether polyol = 500-15,000
  - 2) Diols = 0 -10,000
  - 3) Triols = 500-15,000
- (b) Average functionality
- 1) total system = 1.5-3.2
- (c) Hydroxyl number
- 1) total systems = 100-300
- (d) Catalysts
- 1) amine = Air Products 0.1-3.0 PPH

- (e) Surfactants  
 1) total system = 0.1-2.0 PPH
- (f) Water  
 1) total system = 0.2 -0.5%
- 5 (g) Pigments/dyes  
 1) total system = 1-5% carbon black
- (h) Blowing agent  
 1) water.

The I3050U isocyanate description is as follows:

- 10 (a) NCO content - 22.4-23.4 wt%
- (b) Viscosity, cps at 25°C = 600-800
- (c) Density = 1.21 g/cm<sup>3</sup> at 25°C
- (d) Initial boiling pt. - 190°C at 5mm Hg
- (e) Vapor pressure = 0.0002 Hg at 25°C
- 15 (f) Appearance - colorless liquid
- (g) Flash point (Densky-Martins closed cup) = 200°C.

In more general terms, the portion of the resin that forms in the housing seal, should typically be a material that cures to a density of at least 10 lbs./cubic foot (0.16 grams/cc) would be preferred, although materials as low as 5 lbs./cubic foot (0.08 grams/cc) may be acceptable for some light duty applications. Again it would be preferred that the material be one which cures to a density of no greater than about 22 lbs./cubic foot (0.35 grams/cc), as discussed above, and preferably less than this value.

25

## VII. Z-filter Media Generally

Herein above it was discussed in general the media packs usable in the arrangements described, for example as media packs 2, 102, comprise z-filter media packs. It was indicated that a variety of alternate flute shapes and seal types can be used in such media packs.

### A. 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

35



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  
5 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; each of these fifteen cited references being incorporated herein by  
10 reference.

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  
15 perpendicularly to the flute direction as described in U.S. provisional 60/543,804, filed February 11, 2004, incorporated herein by reference.

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  
20 coiled to form a z-filter media construction. Such arrangements are described, for example, in U.S. 6,235,195 and 6,179,890, each of which is incorporated herein by reference. 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, incorporated herein by  
25 reference.

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  
30 application 60/467,521, filed May 2, 2003 and PCT Application US 04/07927, filed March 17, 2004, each of which is incorporated herein by reference. 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, incorporated herein by reference.

10           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 media pack is closed to passage therethrough of unfiltered air. 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.

25           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, incorporated herein by reference, in which the flow generally makes a turn as its 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, incorporated by reference herein.

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. 19, an example of media 401 useable in z-filter media is shown. The media 401 is formed from a corrugated (fluted) sheet 403 and a facing sheet 404.

In general, the corrugated sheet 403, Fig. 19, is of a type generally characterized herein as having a regular, curved, wave pattern of flutes or corrugations 407. The term "wave pattern" in this context, is meant to refer to a flute or corrugated pattern of alternating troughs 407b and ridges 407a. The term "regular" in this context is meant to refer to the fact that the pairs of troughs and ridges (407b, 407a) alternate with generally the same repeating corrugation (or flute) shape and size. (Also, typically in a regular configuration each trough 407b is substantially an inverse of each ridge 407a.) 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 403 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 401 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. 19 the media 401 depicted in fragmentary has eight complete ridges 407a and seven complete troughs 407b.) 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 407a of each ridge and the bottom 407b 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. 19, for the corrugated sheet 403, is that at approximately a midpoint 430 between each trough and each adjacent ridge, along most of the length of the flutes 407, is located a transition region where the curvature inverts. For example, viewing back side or face 403a, Fig. 19, trough 407b is a concave region, and ridge 407a is a convex region. Of course when viewed toward front side or face 403b, trough 407b of side 403a forms a ridge; and, ridge 407a of face 403a, forms a trough. (In some instances, region 430 can be a straight segment, instead of a point, with curvature inverting at ends of the straight segment 430.)

A characteristic of the particular regular, curved, wave pattern corrugated sheet 403 shown in Fig. 19, 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 408 and 409, the ridges 407a and troughs 407b do not change substantially in cross-section. The term "straight" in reference to corrugation pattern shown in Fig. 19, 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, incorporated herein by reference.. 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. 19 and as referenced above, the media 401 has first and second opposite edges 408 and 409. When the media 401 is coiled and formed into a media pack, in general edge 409 will form an inlet end for the media pack and edge 408 an outlet end, although an opposite orientation is possible.

Adjacent edge 408 the sheets 403, 404 are sealed to one another, for example by sealant, in this instance in the form of a sealant bead 410, sealing the corrugated (fluted) sheet 403 and the facing sheet 404 together. Bead 410 will sometimes be referred to as a "single facer" bead, when it is applied as a bead between the corrugated sheet 403 and facing sheet 404, to form the single facer or

media strip 401. Sealant bead 410 seals closed individual flutes 411 adjacent edge 408, to passage of air therefrom.

Adjacent edge 409, is provided sealant, in this instance in the form of a seal bead 414. Seal bead 414 generally closes flutes 415 to passage of unfiltered fluid therein, adjacent edge 409. Bead 414 would typically be applied as the media 401 is coiled about itself, with the corrugated sheet 403 directed to the inside. Thus, bead 414 will form a seal between a back side 417 of facing sheet 404, and side 418 of the corrugated sheet 403. The bead 414 will sometimes be referred to as a "winding bead" when it is applied as the strip 401 is coiled into a coiled media pack. If the media 401 were cut in strips and stacked, instead of coiled, bead 414 would be a "stacking bead."

In some applications, the corrugated sheet 403 is also tacked to the facing sheet 4 at various points along the flute length, as shown at lines 404a.

Referring to Fig. 19, once the media 401 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 412, would enter open flutes 411 adjacent end 409. Due to the closure at end 408, by bead 410, the air would pass through the media shown by arrows 413. It could then exit the media pack, by passage through open ends 415a of the flutes 415, adjacent end 408 of the media pack. Of course operation could be conducted with air flow in the opposite direction, as discussed for example with respect to Fig. 24. The point being that in typical air filter applications, at one end or face of the media pack unfiltered air flow goes in, and at an opposite end or face the filtered air flow goes out, with no unfiltered air flow through the pack or between the faces.

For the particular arrangement shown herein in Fig. 19, the parallel corrugations 7a, 7b are generally straight completely across the media, from edge 708 to edge 709. 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 403, facing sheet 404 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, incorporated herein by reference.

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. 20, in which a z-filter media construction 440 utilizing a regular, curved, wave pattern corrugated sheet 443, and a facing (in this instance non-corrugated) sheet 444, is depicted. The distance D1, between points 450 and 451, defines the extension of facing media 444 in region 452 underneath a given corrugated flute 453. The length D2 of the arcuate media for the corrugated flute 453, over the same distance D1 is of course larger than D1, due to the shape of the corrugated flute 453. For a typical regular shaped media used in fluted filter applications, the linear length D2 of the media 453 between points 450 and 451 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 21, 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. 21.

25

**TABLE A**

(Flute definitions for Fig. 3)

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

30 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  
35 flute, and the corrugation industry standard A and standard B flutes, indicate some convenient variations.

### **B. Manufacture of Coiled Media Configurations Using Fluted Media, Generally.**

40 In Fig. 22, one example of a manufacturing process for making a media strip corresponding to strip 401, Fig. 19 is shown. In general, facing sheet 464 and the fluted (corrugated) sheet 466 having flutes 468 are brought together to



form a media web 469, with an adhesive bead located therebetween at 470. The adhesive bead 470 will form a single facer bead 410, Fig. 19. An optional darting process occurs at station 471 to form center darted section 472 located mid-web. The z-filter media or Z-media strip 474 can be cut or slit at 475 along the bead 470  
5 to create two pieces 476, 477 of z-filter media 474, 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 404a, Fig. 19, are used,  
10 they can be made, as the sheets 464, 466 are brought together.

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

Still in reference to Fig. 22, before the z-filter media 474 is put  
15 through the darting station 471 and eventually slit at 475, it must be formed. In the schematic shown in Fig. 22, this is done by passing a sheet of media 492 through a pair of corrugation rollers 494, 495. In the schematic shown in Fig. 22, the sheet of media 492 is unrolled from a roll 496, wound around tension rollers 498, and then passed through a nip or bite 502 between the corrugation rollers 494, 495. The  
20 corrugation rollers 494, 495 have teeth 504 that will give the general desired shape of the corrugations after the flat sheet 492 passes through the nip 502. After passing through the nip 502, the sheet 492 becomes corrugated across the machine direction and is referenced at 466 as the corrugated sheet. The corrugated sheet 466 is then secured to facing sheet 464. (The corrugation process may involve heating the  
25 media, in some instances.)

Still in reference to Fig. 22, the process also shows the facing sheet 464 being routed to the darting process station 471. The facing sheet 464 is depicted as being stored on a roll 506 and then directed to the corrugated sheet 466 to form the Z-media 474. The corrugated sheet 466 and the facing sheet 464 are secured  
30 together by adhesive or by other means (for example by sonic welding).

Referring to Fig. 22, an adhesive line 470 is shown used to secure corrugated sheet 466 and facing sheet 464 together, as the sealant bead. Alternatively, the sealant bead for forming the facing bead could be applied as shown as 470a. If the sealant is applied at 470a, it may be desirable to put a gap in

the corrugation roller 495, and possibly in both corrugation rollers 494, 495, to accommodate the bead 470a.

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 494, 495. 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  $D2 = 1.25 - 1.35 \times D1$ . 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. 22 can be used to create the center darted section 472. Fig. 23 shows, in cross-section, one of the flutes 468 after darting and slitting.

A fold arrangement 518 can be seen to form a darted flute 520 with four creases 521a, 521b, 521c, 521d. The fold arrangement 518 includes a flat first layer or portion 522 that is secured to the facing sheet 464. A second layer or portion 524 is shown pressed against the first layer or portion 522. The second layer or portion 524 is preferably formed from folding opposite outer ends 526, 527 of the first layer or portion 522.

Still referring to Fig. 23, two of the folds or creases 521a, 521b 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 520, when the fold 520 is viewed in the orientation of Fig. 23. The term "inwardly directed" is meant to refer to the fact that the fold line or crease line of each crease 521a, 521b, is directed toward the other.

In Fig. 23, creases 521c, 521d, will generally be referred to herein as "lower, outwardly directed" creases. The term "lower" in this context refers to the fact that the creases 521c, 521d are not located on the top as are creases 521a, 521b, in the orientation of Fig. 23. The term "outwardly directed" is meant to indicate that the fold lines of the creases 521c, 521d are directed away from one another.

The terms "upper" and "lower" as used in this context are meant specifically to refer to the fold 520, when viewed from the orientation of Fig. 23.

That is, they are not meant to be otherwise indicative of direction when the fold 520 is oriented in an actual product for use.

Based upon these characterizations and review of Fig. 23, it can be seen that a preferred regular fold arrangement 518 according to Fig. 23 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 528 can also be seen pressed against the second layer or portion 524. The third layer or portion 528 is formed by folding from opposite inner ends 530, 531 of the third layer 528.

Another way of viewing the fold arrangement 518 is in reference to the geometry of alternating ridges and troughs of the corrugated sheet 566. The first layer or portion 522 is formed from an inverted ridge. The second layer or portion 524 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. 23, in a preferred manner, are described in PCT WO 04/007054, incorporated herein by reference. Techniques for coiling the media, with application of the winding bead, are described in PCT application US 04/07927, filed March 17, 2004 and incorporated herein by reference.

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  
5 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  
10 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, incorporated herein by reference.

The flute seals (for example from the single facer bead, winding bead  
15 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  
20 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  
25 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, the complete disclosure of which is incorporated herein by reference. When such material is used on only one side of each sheet, it is typically applied on the  
30 side(s) which will form the upstream side of inlet flutes.

Above it was discussed that flow could be opposite to the direction shown in Fig. 19.

In Fig. 24, a schematic depiction of media useable in such z-filter media packs as shown. The schematic depiction of Fig. 24 is generic, and is not meant to indicate unique or preferred seal type or flute shapes.

Referring to Fig. 24, the reference numeral 300 generally indicates a  
5 single facer comprising corrugated sheet 301 secured to flat sheet 302. It is noted that the flat sheet 302 does not have to be perfectly flat, it may comprise a sheet that itself has very small corrugations and other formations therein.

Particular single facer 300 depicted, could be coiled around itself or  
around a core and then around itself, typically with flat sheet 302 to the outside. For  
10 the arrangement shown, edge 310 will form the inlet face in the eventual media pack and end or edge 311 will form the outlet flow faces. Thus arrows 312 represent inlet arrows and arrows 313 represent outlet flow arrows. Sheet 315 is merely meant to schematically represent a flat sheet corresponding to sheet 302, of the next wind.

Adjacent edge 311 is provided a single facer seal arrangement 320.  
15 In this instance the single facer shield arrangement 320 comprises a bead of sealant 321 between corrugated sheet 301 and flat sheet 302, positioned along edge 310 or within about 10% of the total length of the flutes, i.e., the distance between inlet edge 310 and outlet edge 311. A variety of materials and arrangements can be used for the seal arrangement 320. The seal arrangement could comprise a corrugated or  
20 folded arrangement, sealed with a sealant, or sealed by other means. The particular seal arrangement 320 depicted, could comprise a bead of hot melt sealant, although alternatives are possible. The seals at 320 could be darted or folded, as shown for Figs. 4 and 10.

Adjacent end 310 a winding seal 330 is depicted. Winding seal 330  
25 generally provides for a seal between layers adjacent edge 311, as the single facer 300 is coiled. Preferably winding seal 330 is positioned within 10% of the total length of the flutes (i.e., the distance between edge 311 and 310) of edge 310.

If is the very ends (lead and tail) of the single facer need to be sealed  
between the corrugated and flat sheets, sealant can be applied at these locations to do  
30 so.

### **VIII. 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. 25,

generally at 650. In Fig. 25, equipment 652, such as a vehicle 652a having an engine 653 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 652 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 653 powers the equipment 652 upon fuel combustion. In Fig. 25, air flow is shown drawn into the engine 653 at an air intake at region 655. An optional turbo 656 is shown in phantom, as optionally boosting the air intake to the engine 653. The turbo 656 is shown downstream from an air cleaner 660, although alternate arrangement are possible.

The air cleaner 660 has a filter cartridge 662 and is shown in the air inlet stream to the engine 653. In general, in operation, air is drawn in at arrow 664 into the air cleaner 660 and through the filter cartridge 662. Upon passage through the air cleaner 660, selected particles and contaminants are removed from the air. The cleaned air then flows downstream at arrow 666 into the intake 655. From there, the air flow is directed into the engine 653.

In a typical air cleaner 660, the filter cartridge 662 is a serviceable component. That is, the cartridge 662 is removable and replaceable within the air cleaner 660. This allows the cartridge 662 to be serviced, by removal and replacement, with respect to remainder of air cleaner 660, when the cartridge 662 becomes sufficiently loaded with dust or other contaminant, to require servicing.

#### **IX. One Type of Useable Central Core for Round Coiled Media Packs**

Above it was discussed, in connection with the discussion of Fig. 9, the core 113 could be filled with a plug. An example is described below, and shown in Fig. 26. In Fig. 26, a fragmentary portion of media pack 102, Fig. 9, is shown. Referring to Fig. 26, the coiled media pack 102 includes center core 113. The core 113 needs to be sealed against unfiltered air flow therethrough. This is done by center piece, plug or core 721. Core 721 also provides for a lead end seal of the single facer strip which is coiled to form the media pack 102.

More specifically, the media lead end is shown in phantom at 722. For the arrangement shown, between regions 724 and 725, the mold-in-place plug

721 is provided in center 113. Thus, it seals at least a portion of the lead end 724 of the media strip.

Still referring to Fig. 26, in general the preferred plug 721 is a poured and cured core. By this it is meant that the plug 721 results from pouring a fluid resin into center 113 and allowing the resin to cure. A variety of shapes and sizes for the plug 721 are possible.

Typically when used as a lead end seal, the plug 721 will be configured to extend along, or engulf, at least 80% of the lead end seal length, typically at least 90% of that length. In some instances, for example in the instance shown in Fig. 26, the plug 721 may be configured to cover or enclose the entire lead end 722.

The plug 721 can be configured with recesses as shown, or it can be configured to have no recesses or even to have one or more projections extending outwardly from the element.

When the plug 721 is provided with recesses as shown, typically region 724 will be spaced from end face 105 at least 2 mm, and region 725 will be spaced from end 105a by at least 2 mm.

Region 727 extends from region 724 toward face 105, and terminates at face 105 as shown, or spaced therefrom within a preferred distance. This region defines an outer seal wall 728 with a hollow center 729. The seal wall 728 continues the sealing of the lead end 722 of the media pack 102. Region 727 can be viewed as a concave end to plug 721. Herein, region 727 will sometimes be referred to as a concave end with an axially outwardly projecting end skirt 728.

Skirt 728 is not required to terminate at end face 105, although such termination is shown in the arrangement of Fig. 26. It can terminate short thereof and can still accomplish much of its function of sealing the lead end 722, for example, by terminating at or adjacent the winding bead seal or single facer seal in this region.

Analogously, between region 725 and surface 105a, region 734 is provided, with outer seal area 735 and inner center recess 736. The seal area 735 provides, among other things, for sealing of the lead end 722 of the media 102 between region 725 and surface 105a. The seal area 735 can be seen as a concave end to plug 721. Herein, region 725 will sometimes be referred to as a concave end with an axially outwardly projecting end skirt 735. In some instances end skirt 735

is not required to terminate adjacent end face 105a, as shown. Rather skirt 735 can terminate short of end face 105a, and still accomplish an appropriate seal of the lead end 102 at this location, by terminating adjacent or in cooperation with a winding bead or seal bead at this location.

5                    Still referring to Fig. 26, although not shown, structure could be embedded within plug 721. For example, a hollow core or other structure from a winding process could be left within region 113, to be engulfed within core 721 as a result of a molding operation.

                    The plug 721 can be molded-in-place, from a resin port into core 113.  
10    As an example, a plug could be provided projecting into core 113 from end face 105, having an appropriate shape. The resin could be poured in place, and a second plug put in place projecting into core 113 from end face 105a. A foamed urethane could be used in the resin for example, which would rise and form the shape shown. This molding operation could be conducted before the molding operation discussed above  
15    in connection with Figs. 11-16. In the alternative, the mold arrangement 180 could be provided with the appropriate plug projecting into the central core 113 of the media pack involved, with the opposite end being formed by an appropriate plug.

                    With respect to the core, urethane having an as molded density of no more than 15 lbs. per cubic foot (0.24 grams/cc), and sometimes no more than 10  
20    lbs. per cubic foot (0.16 grams/cc), can be used, although alternatives of higher density, can be used. It is anticipated that the as molded density would typically be at least 5 lbs./cubic foot (0.08 grams/cc).



What is claimed is:

1. A filter element comprising:
  - (a) a media pack including opposite inlet and outlet ends; the media pack  
5 defining:
    - (i) a set of inlet flutes open at the inlet end of the media pack to  
passage of air to be filtered therein; the inlet flutes being  
closed at a location at or near the outlet end of the media  
pack;
    - 10 (ii) a set of outlet flutes closed to passage of air to be filtered  
therein at a location at or near the inlet end of the media pack  
and open to passage of filtered air therefrom at the outlet end  
of the media pack; and
    - (iii) the media pack being closed to flow of unfiltered air into the  
15 inlet end and then outwardly from the opposite outlet end  
without filtering;
  - (b) a preform positioned adjacent a first one end of the inlet and outlet  
ends of the media pack;
    - (i) the preform having a housing seal support section projecting  
20 outwardly from a first one of the inlet and outlet ends of the  
media pack;
  - (c) an overmold formed of a sealing material having:
    - (i) a first portion sealing an interface between the preform and  
25 the first end of the media pack at which the preform is  
positioned; and,
    - (ii) a second portion oriented to form an air cleaner seal having a  
radially directed seal portion providing a radial seal between  
the filter element and an air cleaner, in use;
    - (iii) the first and second portions of the overmold being integral  
30 with one another.
2. A filter element according to claim 1 wherein:
  - (a) the media pack is a coiled pack having an outer sidewall;

- (b) no portion of the preform extends around the outer sidewall of the media pack; and,
- (c) the overmold extends along the media pack sidewall a distance of at least 5 mm from the first end of the media pack.
- 5
3. A filter element according to any one of claims 1 and 2 wherein:
- (a) the overmold comprises foamed polyurethane.
4. A filter element according to any one of claims 1-3 wherein:
- 10 (a) the preform is positioned adjacent the media pack outlet end.
5. A filter element according to any one of claims 1-4 wherein:
- (a) the preform includes the housing seal support portion and a radially outwardly directed skirt portion;
- 15 (i) the housing seal support portion and the radially outwardly directed skirt portion being integral with one another; and
- (ii) the radially outwardly projecting skirt portion having an outermost edge positioned at the interface between the preform and the media pack.
- 20
6. A filter element according to claim 5 wherein:
- (a) the radially outwardly directed skirt extends at an angle within the range of 20 to 70°, from the media pack.
- 25 7. A filter element according to any one of claims 1-6 wherein:
- (a) the preform includes a media face cross-piece arrangement integral therewith.
8. A filter element according to any one of claims 1-7 wherein:
- 30 (a) the preform comprises a molded nylon piece.
9. A filter element according to any one of claims 1-8 wherein:
- (a) the media pack has an oval shaped cross-section.

10. A filter element according to claim 9 wherein:  
(a) the media pack comprises a racetrack shaped cross-section having two, opposite, curved ends and two, opposite, generally straight sides.
- 5 11. A filter element according to any one of claims 1-8 wherein:  
(a) the media pack has a circular cross-section.
12. A filter element according to any one of claims 1-11 wherein:  
(a) the media pack has an outside tail end edge secured down by a strip  
10 of sealant.
13. A filter element according to claim 12 wherein:  
(a) the strip of sealant terminates at a location spaced at least 4 mm from  
the media pack outlet end; and, at a location underneath the  
15 overmold.
14. A filter element according to any one of claims 1-13 wherein:  
(a) inlet flute ends, adjacent the outlet end of the media pack, are closed  
by a sealant bead.  
20
15. A filter element according to any one of claims 1-14 wherein:  
(a) inlet flute ends, adjacent the outlet end of the media pack, are closed  
by a single facer sealant bead.
- 25 16. A filter element according to any one of claims 1-15 wherein:  
(a) inlet flute ends, adjacent the outlet end of the media pack, are closed  
by media darts.
17. A filter element according to any one of claims 1-16 wherein:  
(a) outlet flutes, adjacent the inlet end of the media pack, are closed by a  
30 winder bead of sealant.
18. A filter element according to any one of claims 1-17 wherein:  
(a) the media pack includes an outermost wrap of single facer; and

- (b) a portion of foamed urethane, integral with a remainder of the overmold, is positioned closing outlet ends of otherwise open outlet flutes, adjacent an outlet face and in the outermost wrap of single facer.

5

- 19. A filter element according to any one of claims 1-18 wherein:
  - (a) the preform includes a rib thereon, directed toward an outlet face of the media pack.
  
- 10 20. A method of forming an element according to any one of claims 1 - 19, the method including steps of:
  - (a) positioning an uncured foaming urethane in a reservoir of a mold;
  - (b) positioning a preform and an end of a media pack in the mold, with a portion of the mold pressed against an outside surface of the media pack at a location spaced at least 5 mm from the end of the media pack in the mold; and
  - 15 (c) allowing the uncured foaming urethane to rise and cure to form an overmold around the preform and covering an interface between the media pack and the preform.
  
- 20 21. A method according to claim 20 including a step of:
  - (a) allowing a portion of the urethane which forms the overmold to rise into selected ones of otherwise outlet flutes of the media pack.
  
- 25 22. An air cleaner comprising:
  - (a) an air cleaner housing; and
  - (b) a serviceable filter element comprising:
    - (i) a media pack including opposite inlet and outlet ends; the media pack defining:
      - 30 (A) a set of inlet flutes open at the inlet end of the media pack to passage of air to be filtered therein; the inlet flutes being closed at a location at or near the outlet end of the media pack;

- 5
- (B) a set of outlet flutes closed to passage of air to be filtered therein at or near the inlet end of the media pack and open to passage of filtered air therefrom at the outlet end of the media pack; and
- (C) the media pack being closed to flow of unfiltered air into the inlet end and then outwardly from the opposite outlet end without filtering;
- (ii) a preform positioned adjacent a first one end of the inlet and outlet ends of the media pack;
- 10 (A) the preform having a housing seal support section projecting outwardly from a first one of the inlet and outlet ends of the media pack;
- (iii) an overmold formed of a sealing material having:
- (A) a first portion sealing an interface between the preform and the first end of the media pack at which the preform is positioned; and,
- 15 (B) a second portion oriented to form an air cleaner seal having a radially directed seal portion providing a radial seal between the filter element and an air cleaner, in use;
- 20 (C) the first and second portions of the overmold being integral with one another.
- (c) the filter element being removably sealed to the air cleaner by a radial seal between the second portion of the overmold and the air cleaner.

FIG. 1

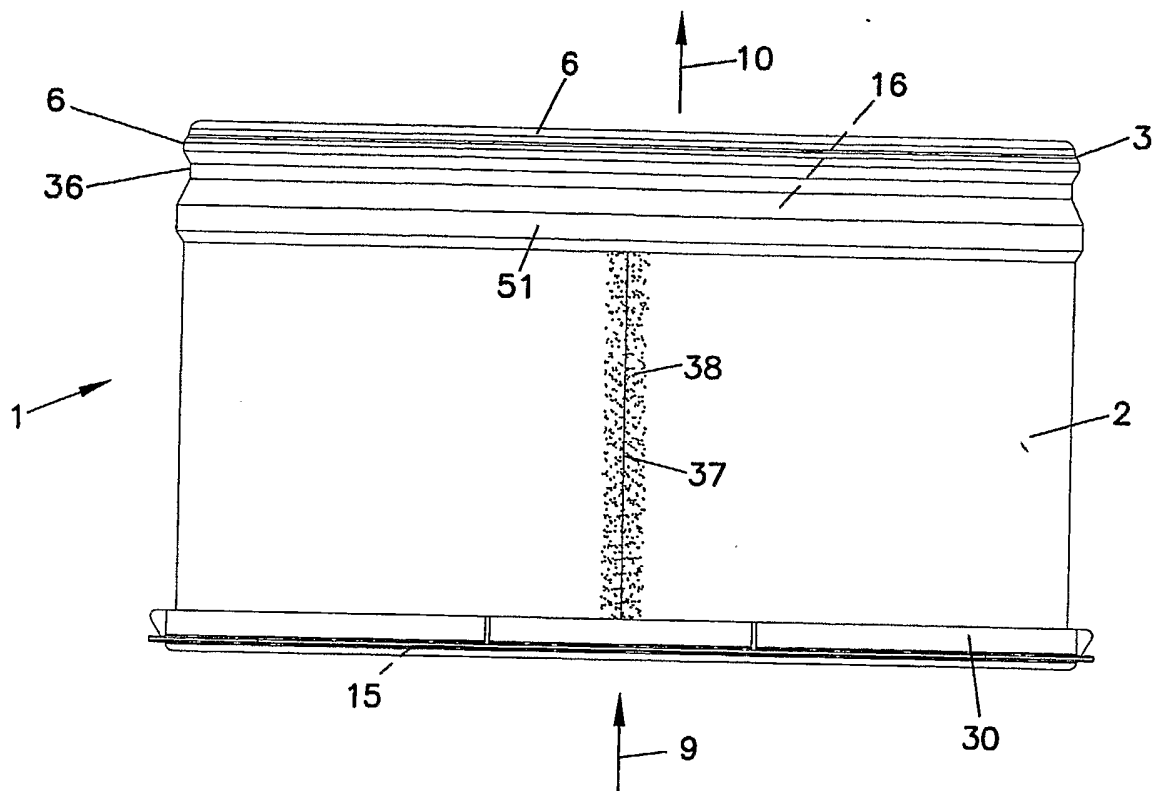
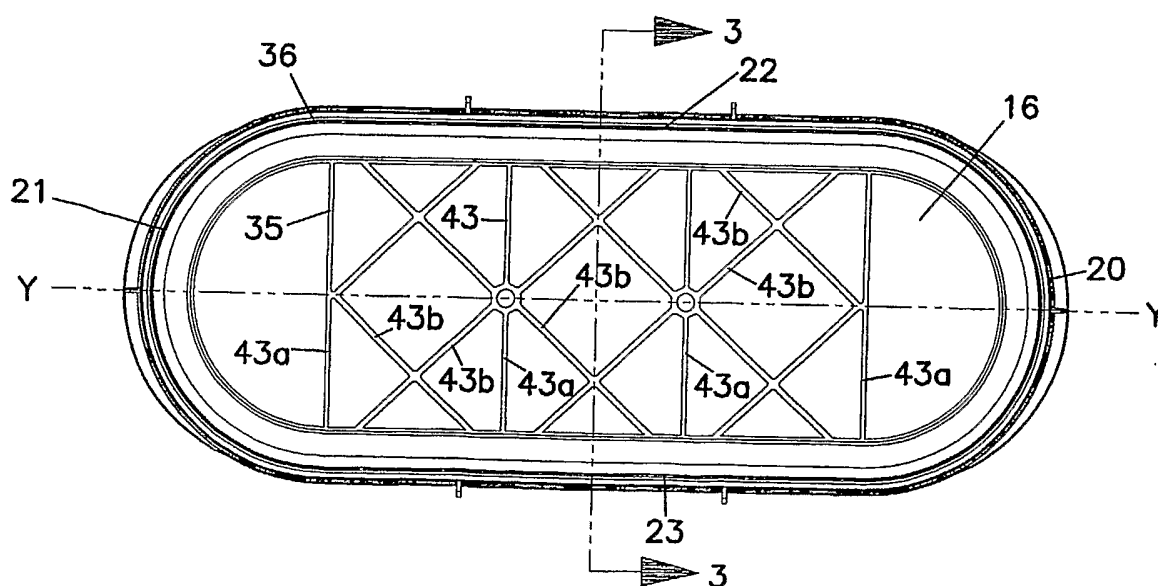


FIG. 2



2/17

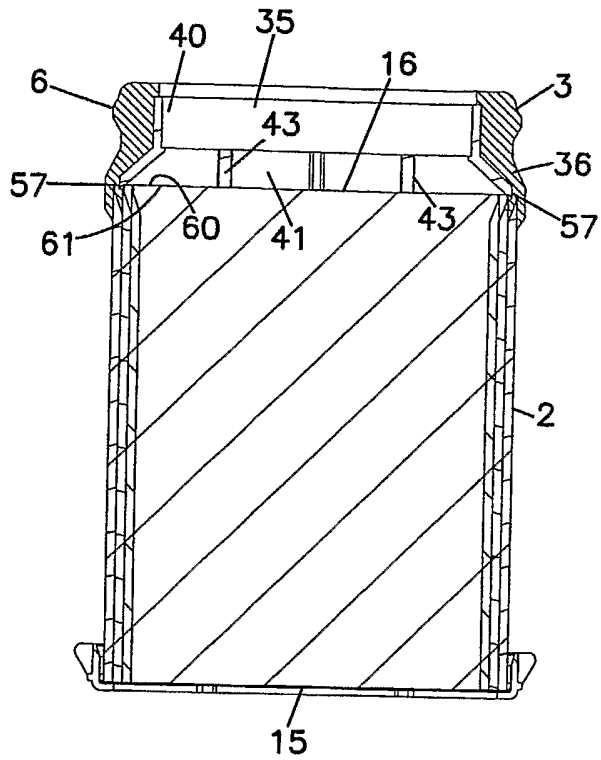
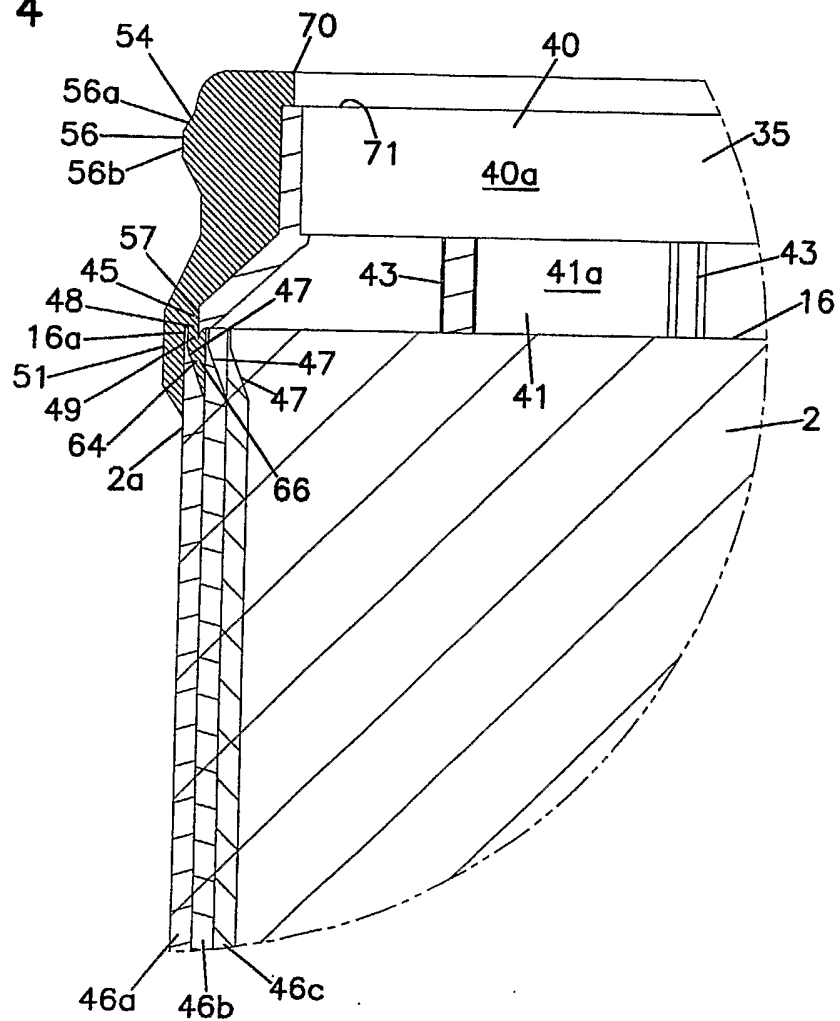


FIG. 3

FIG. 4



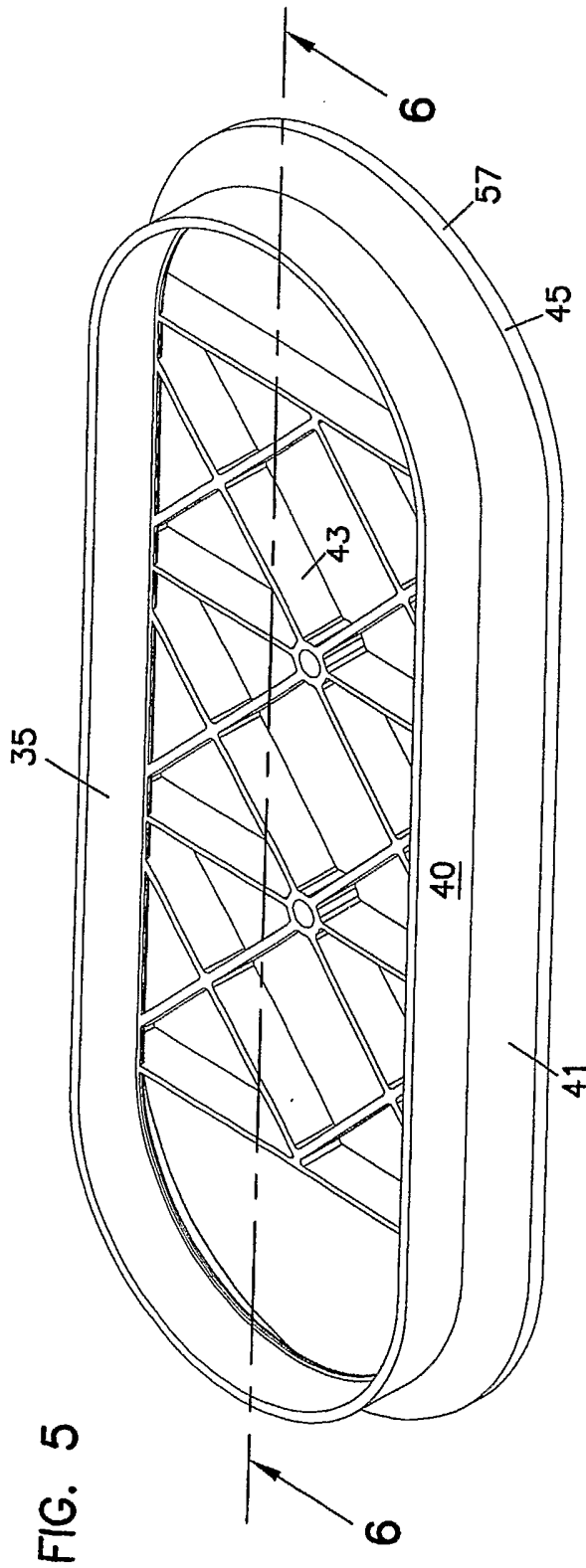


FIG. 5

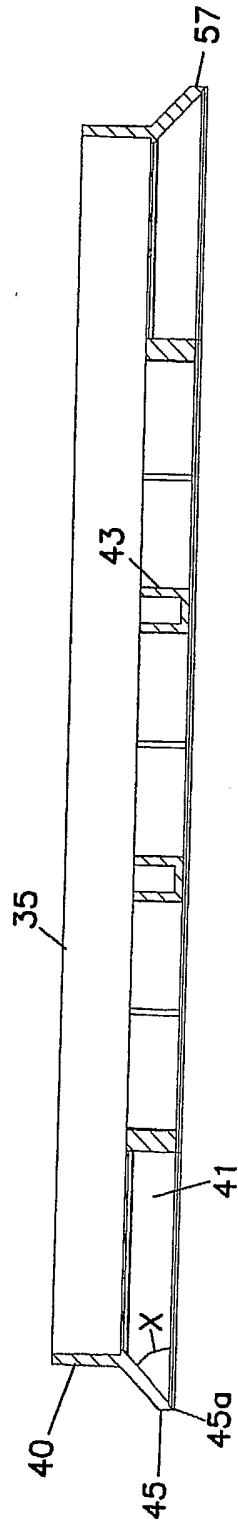


FIG. 6



FIG. 7

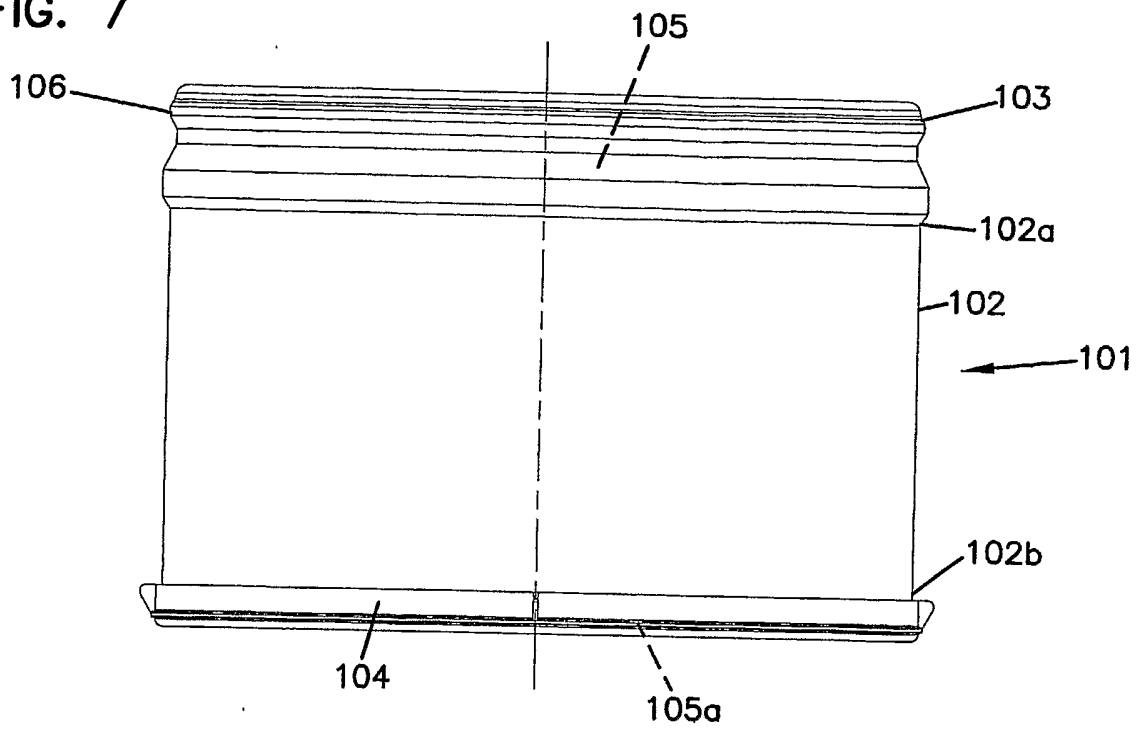


FIG. 8

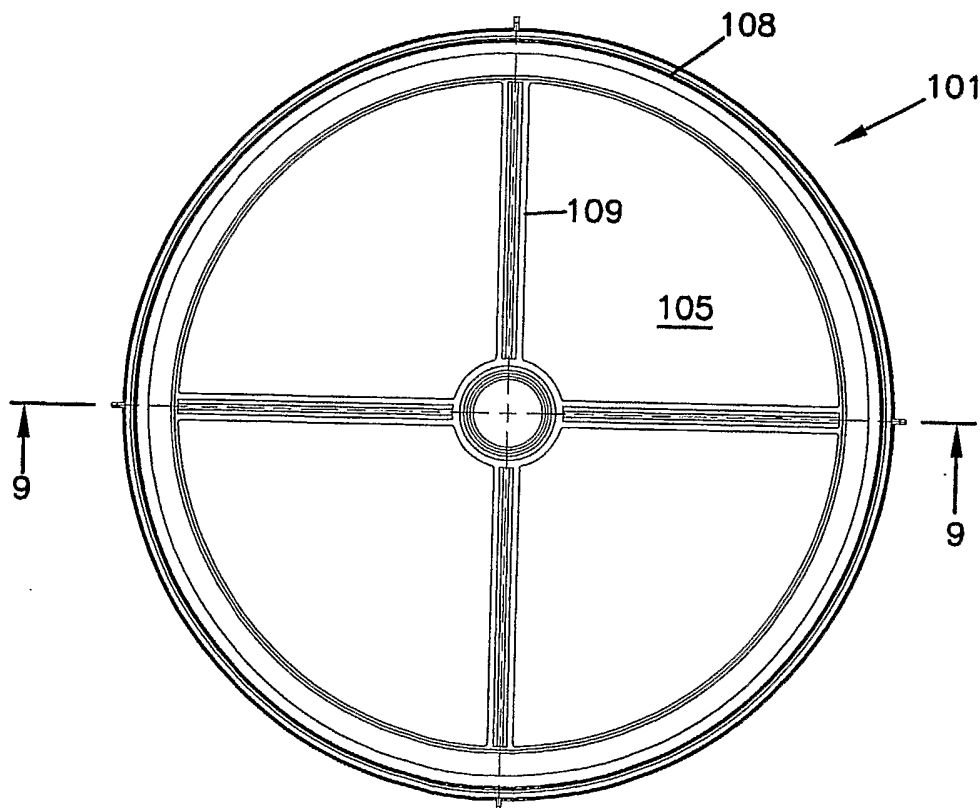


FIG. 9

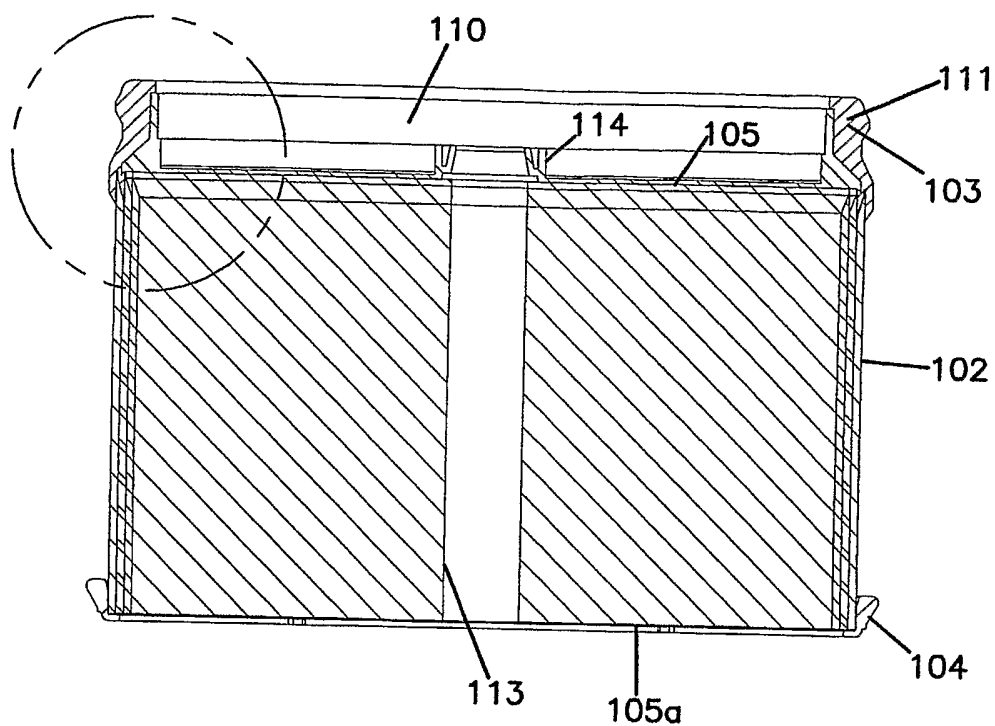


FIG. 10

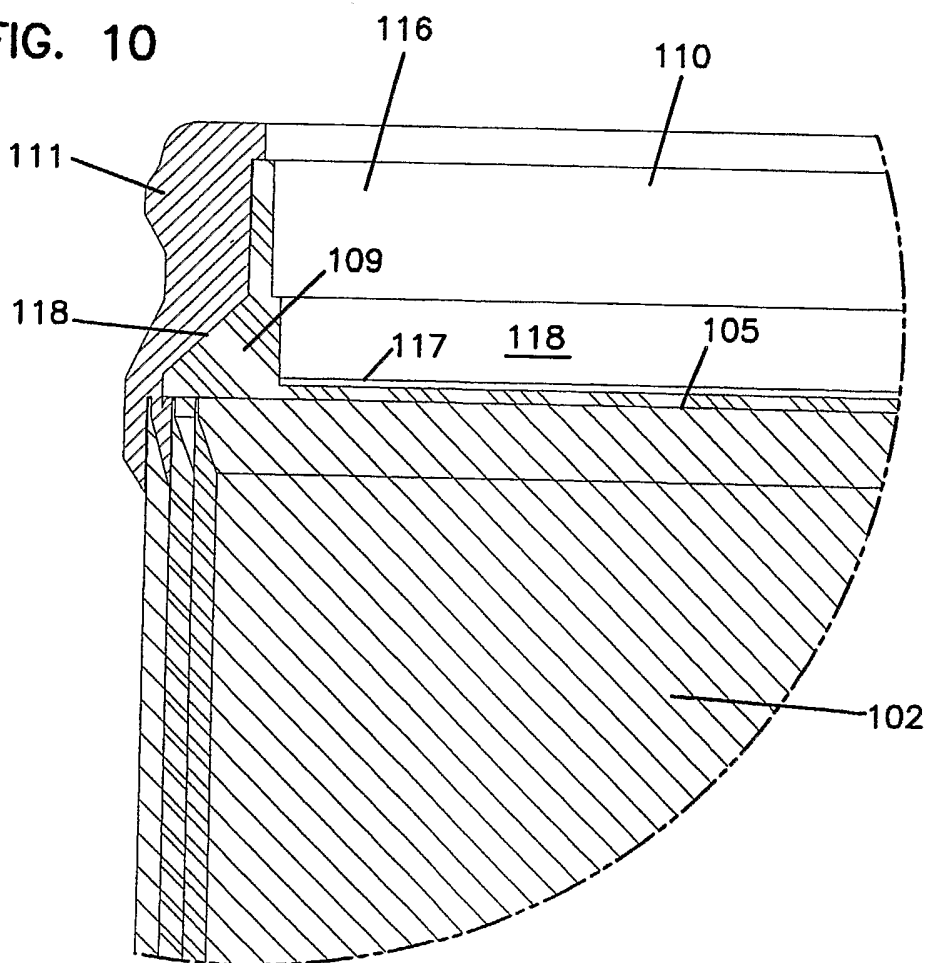


FIG. 11

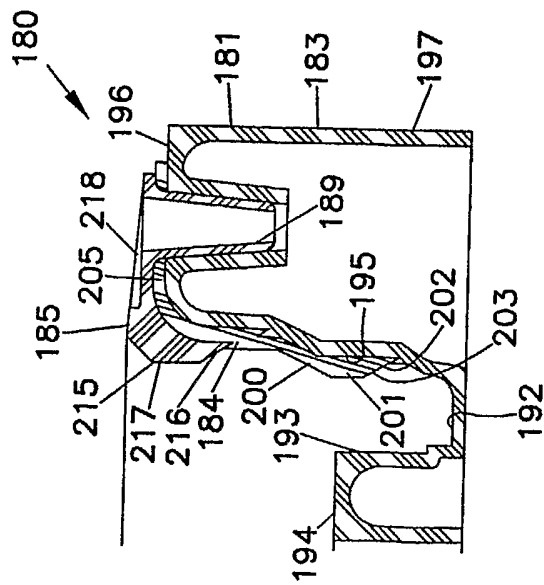


FIG. 12

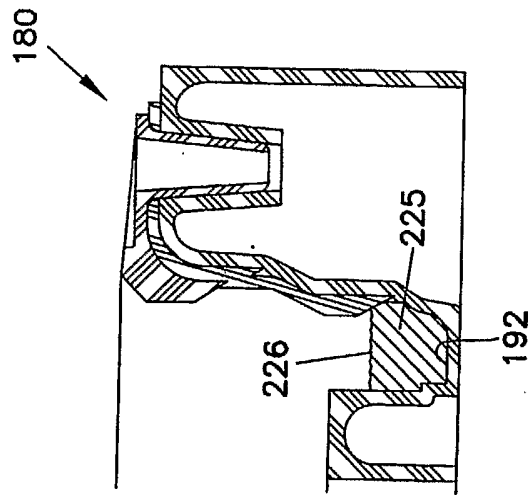


FIG. 13

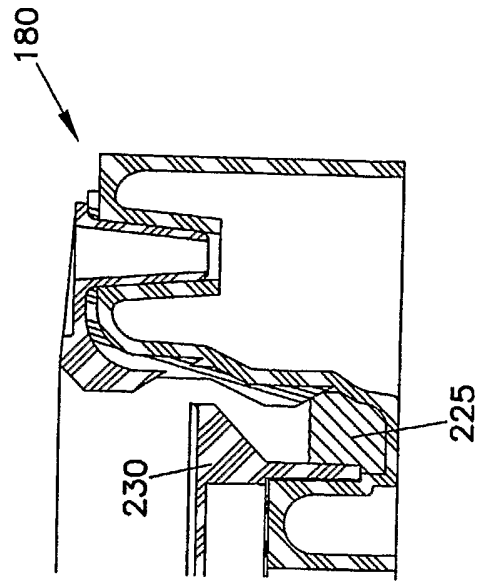


FIG. 14

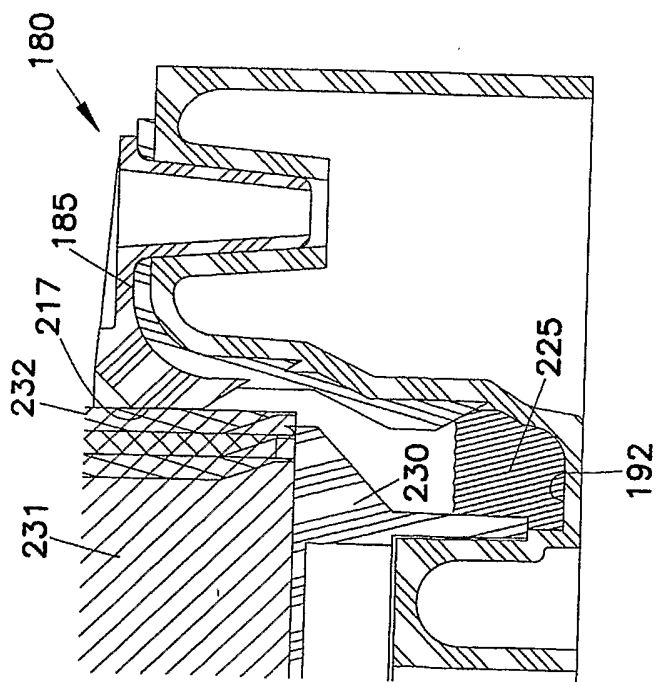
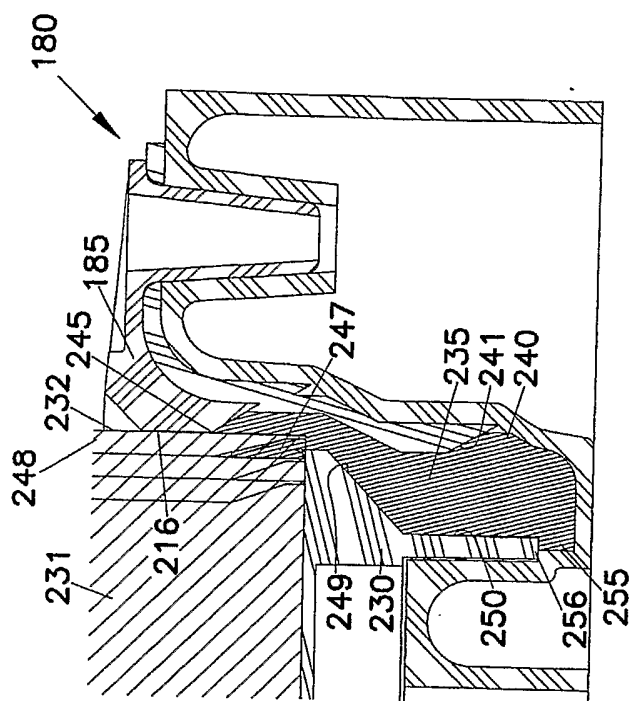
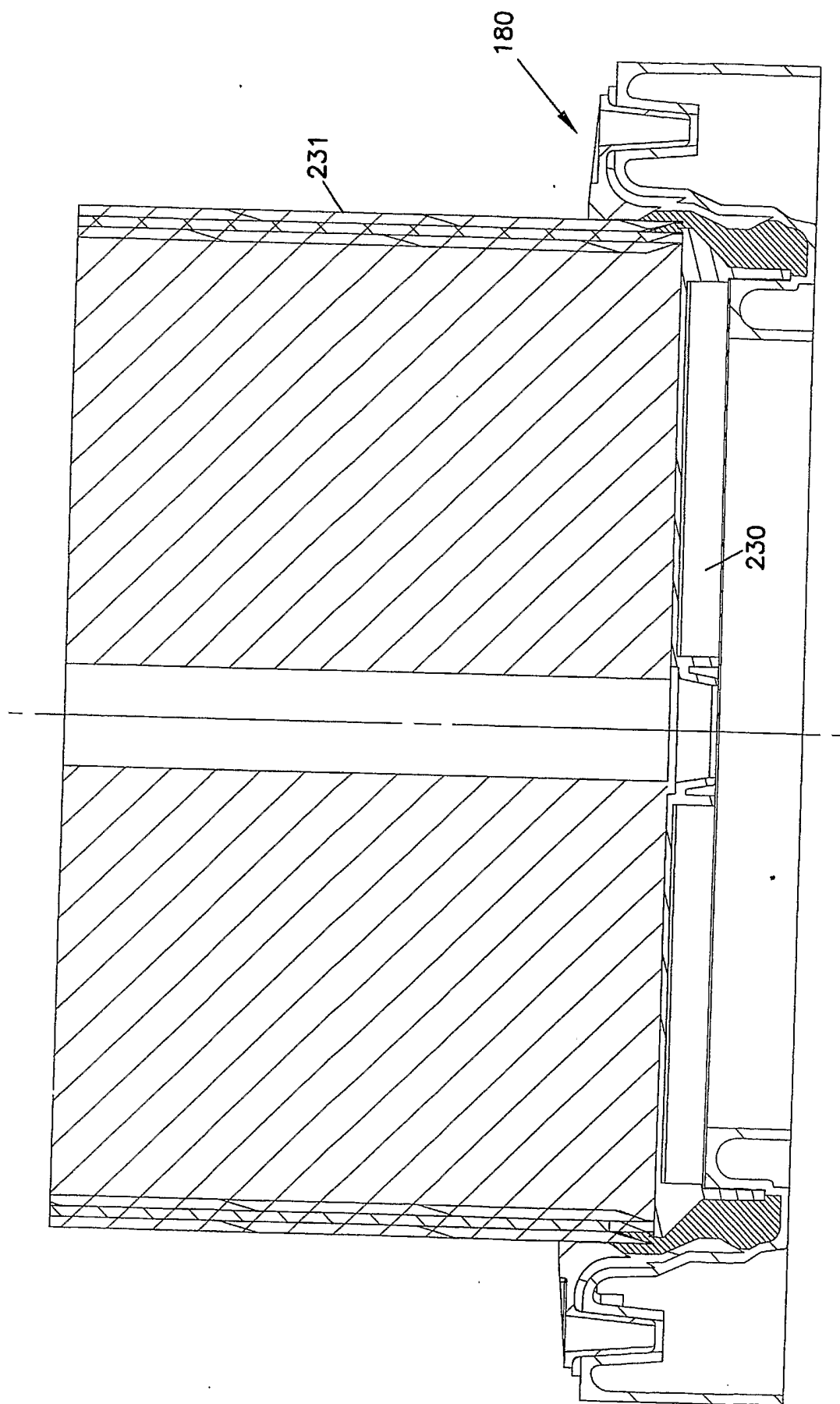


FIG. 15



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FIG. 16



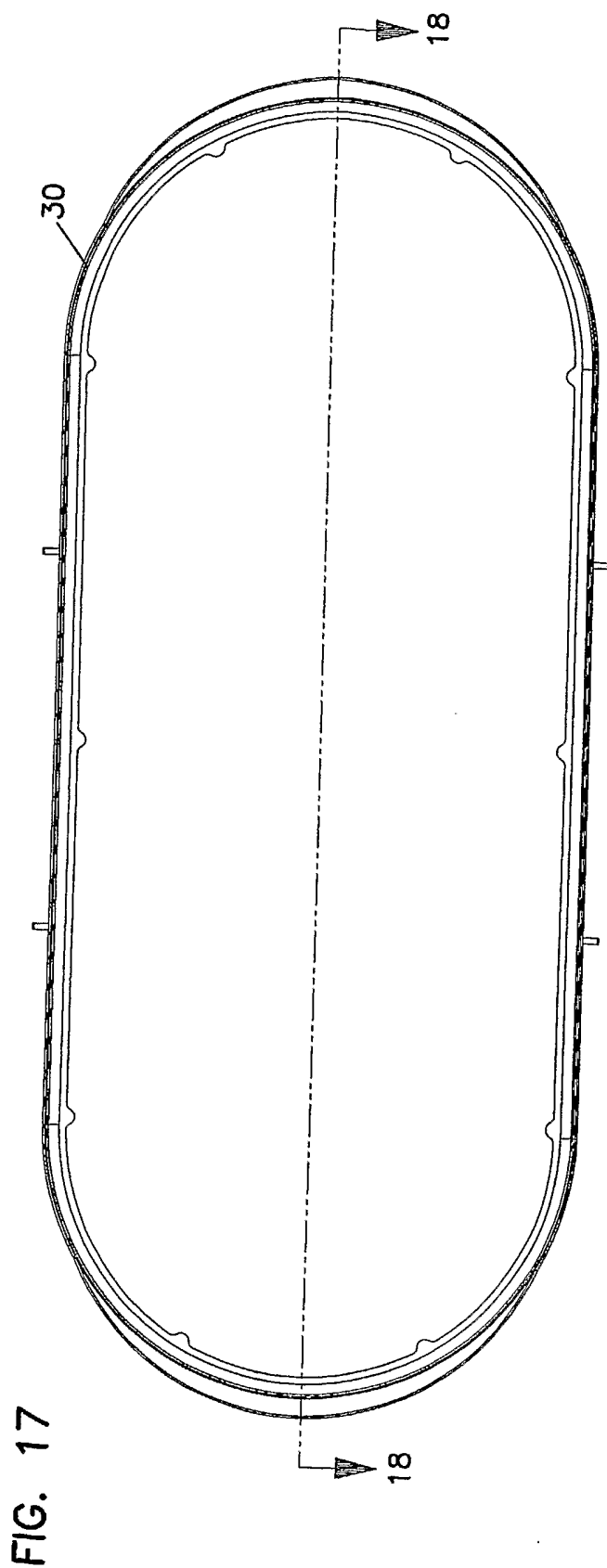


FIG. 17

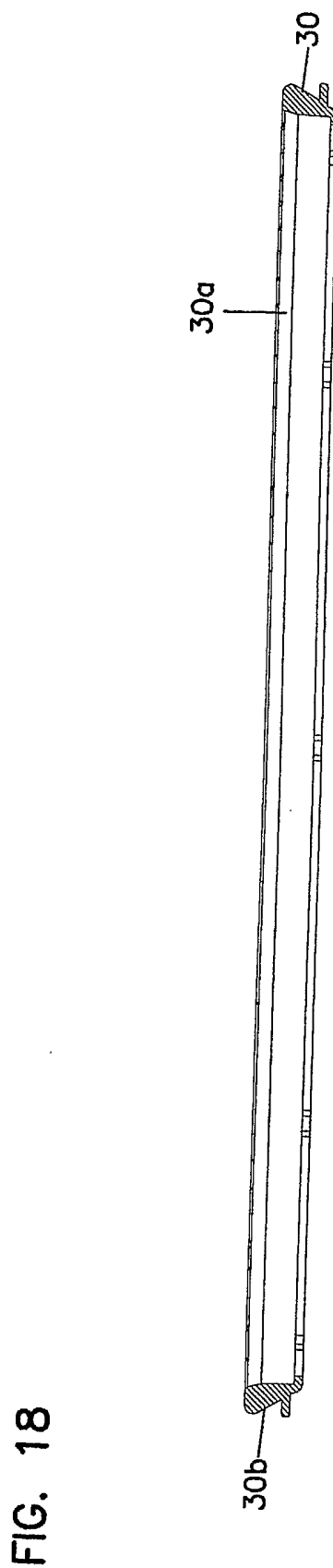


FIG. 18

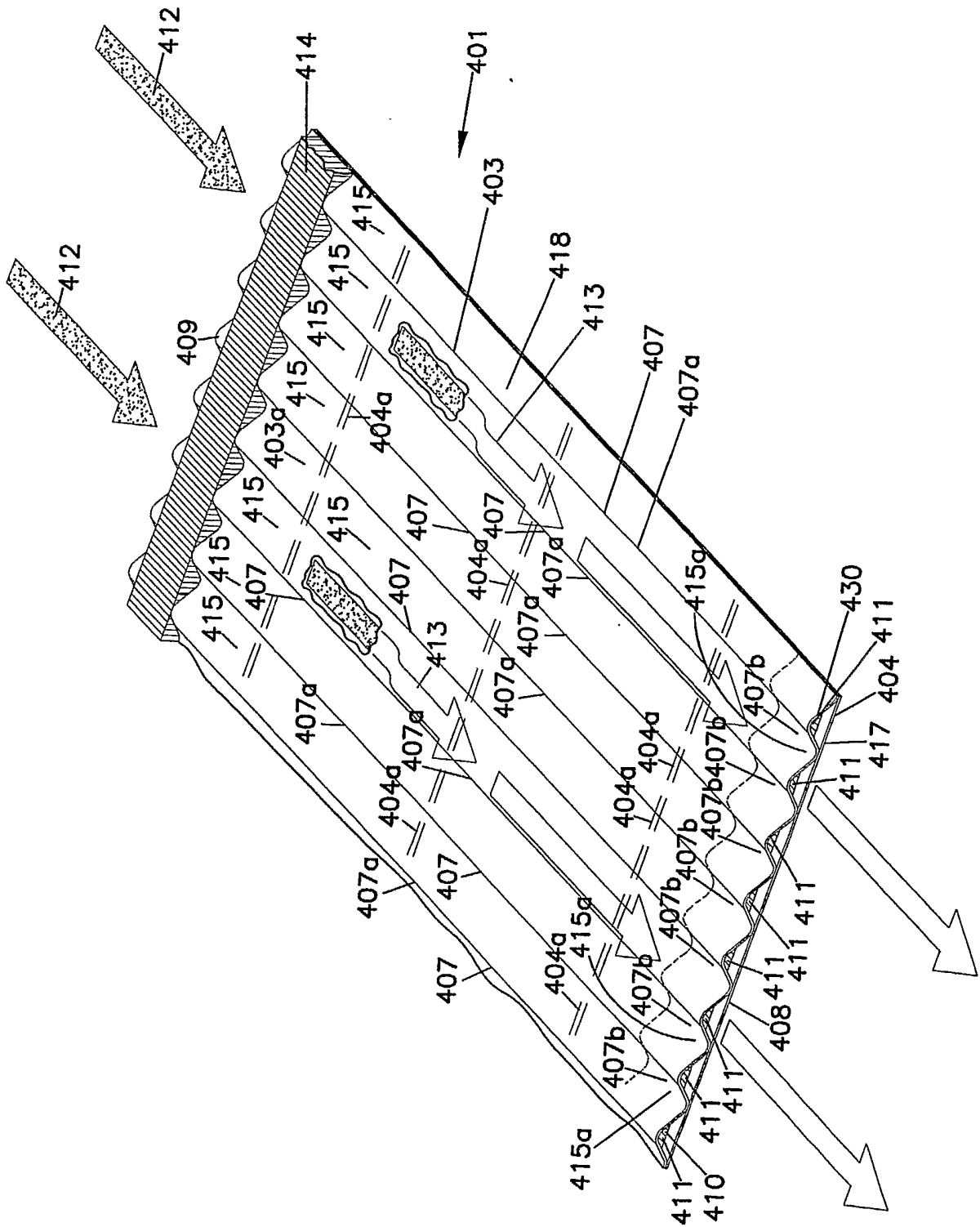


FIG. 19

FIG. 20

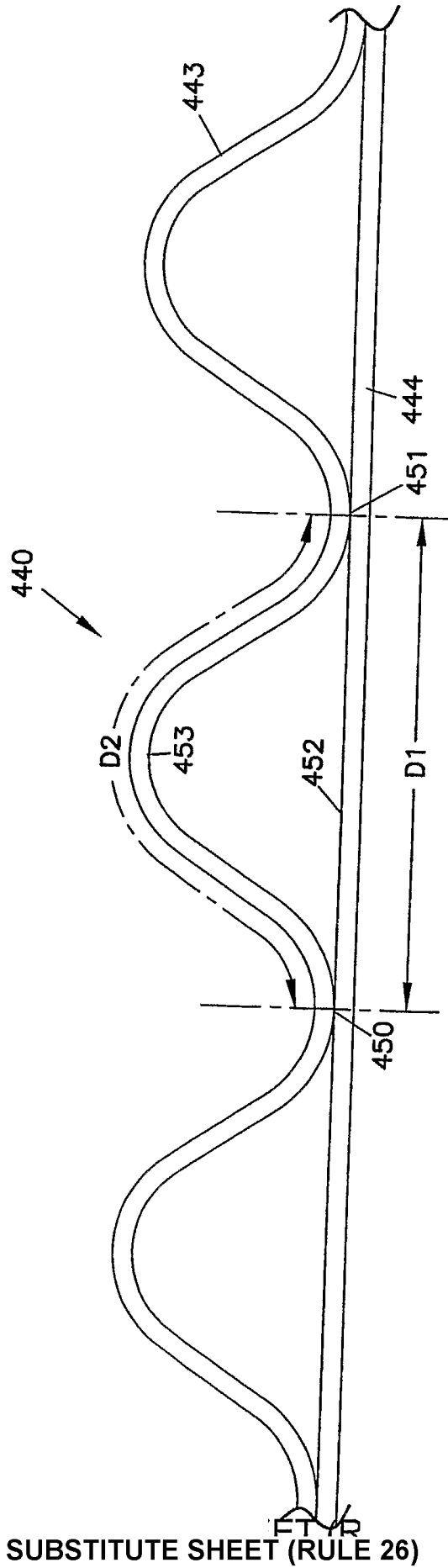
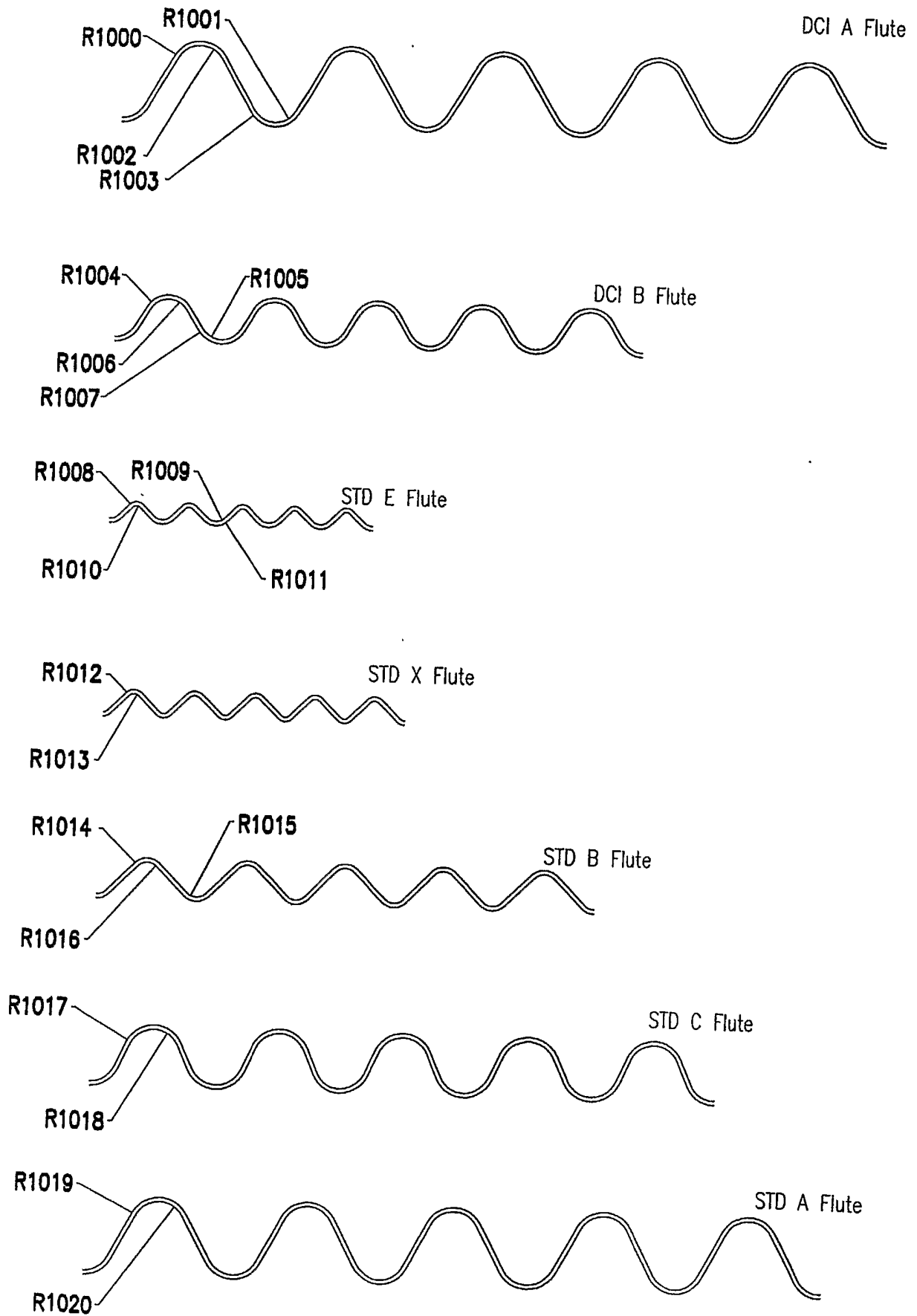




FIG. 21



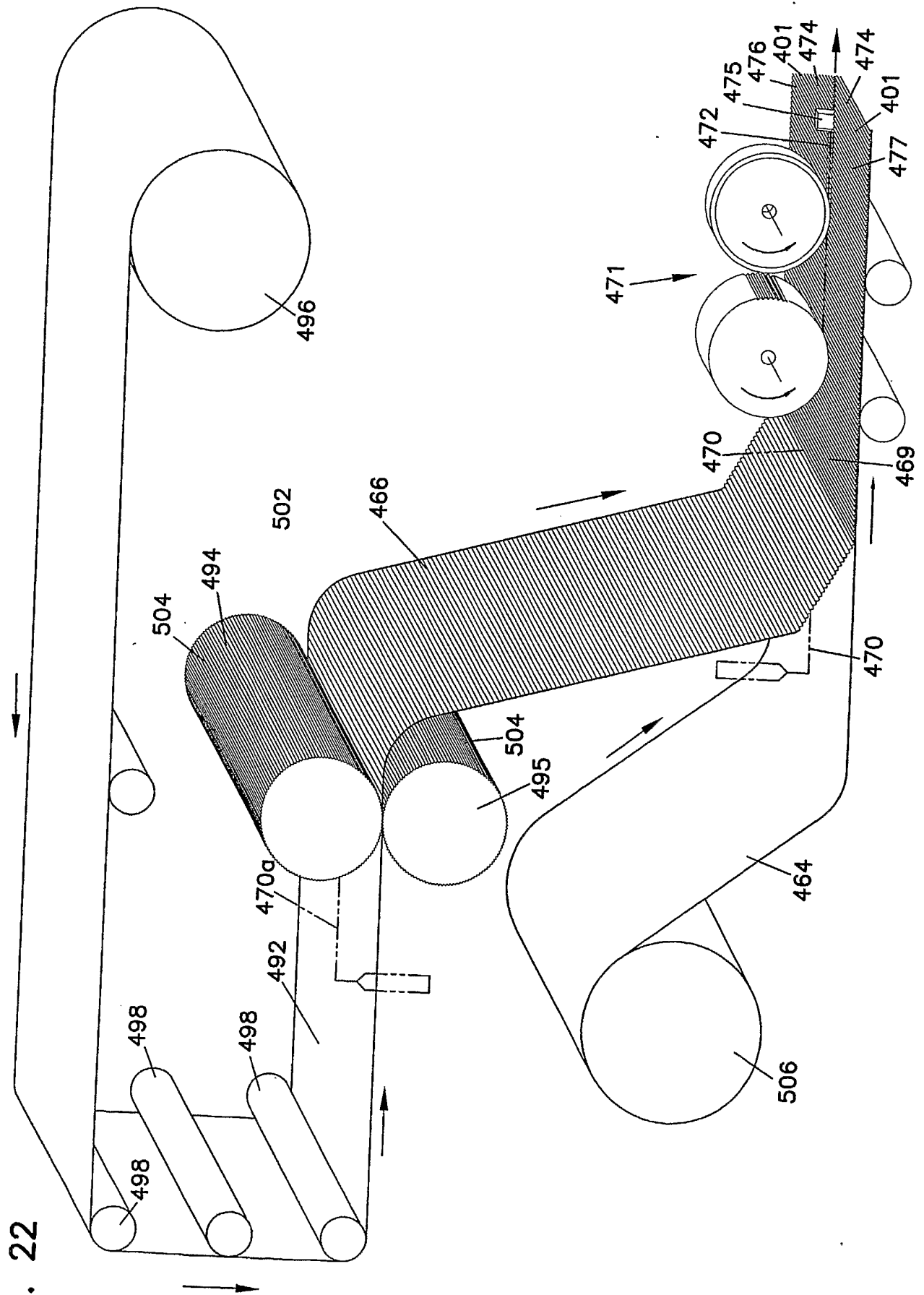
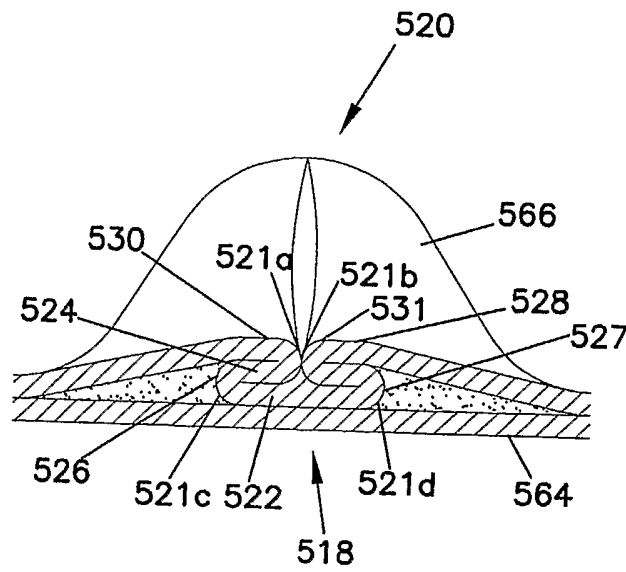


FIG. 22

FIG. 23



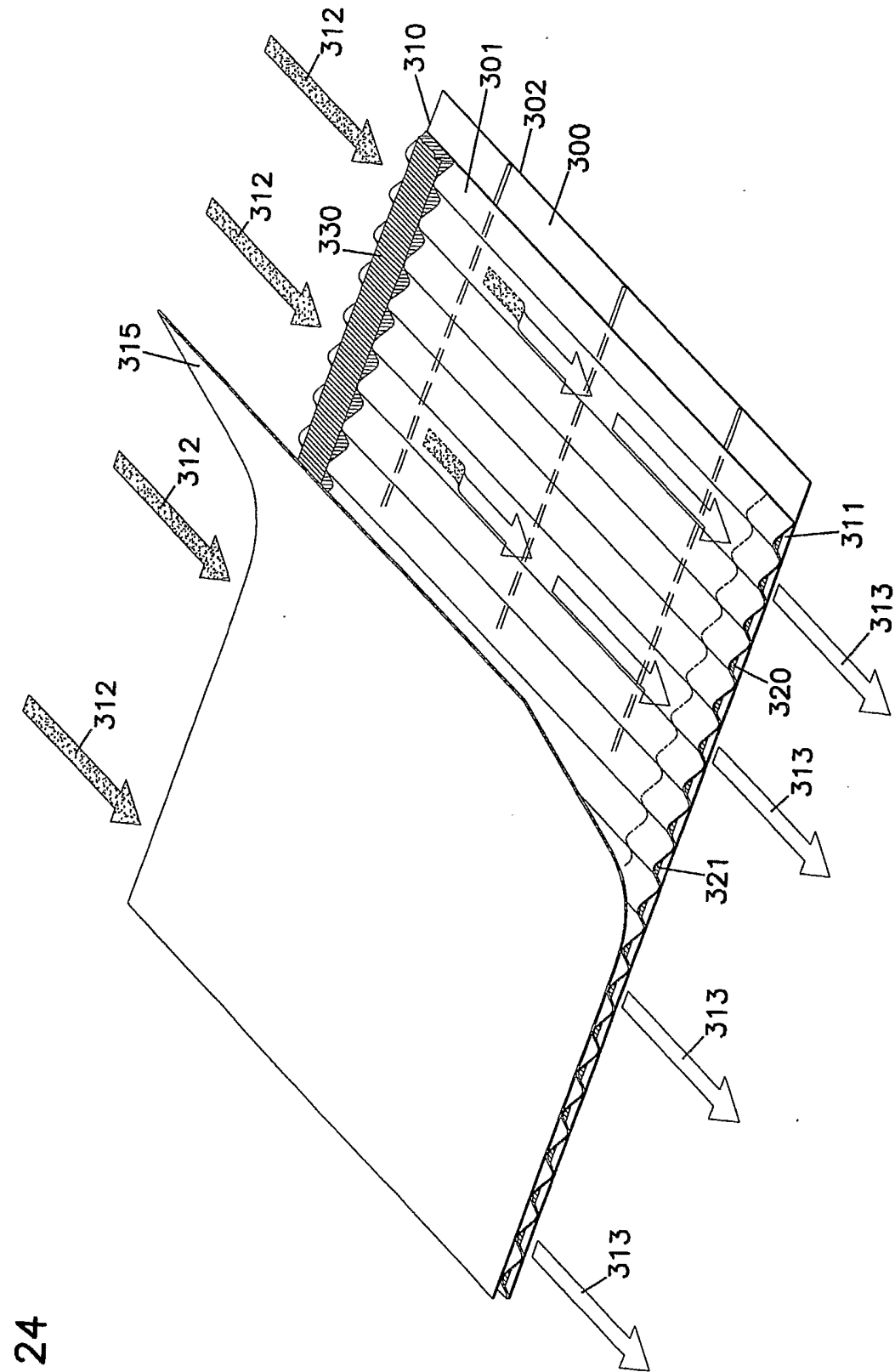


FIG. 24

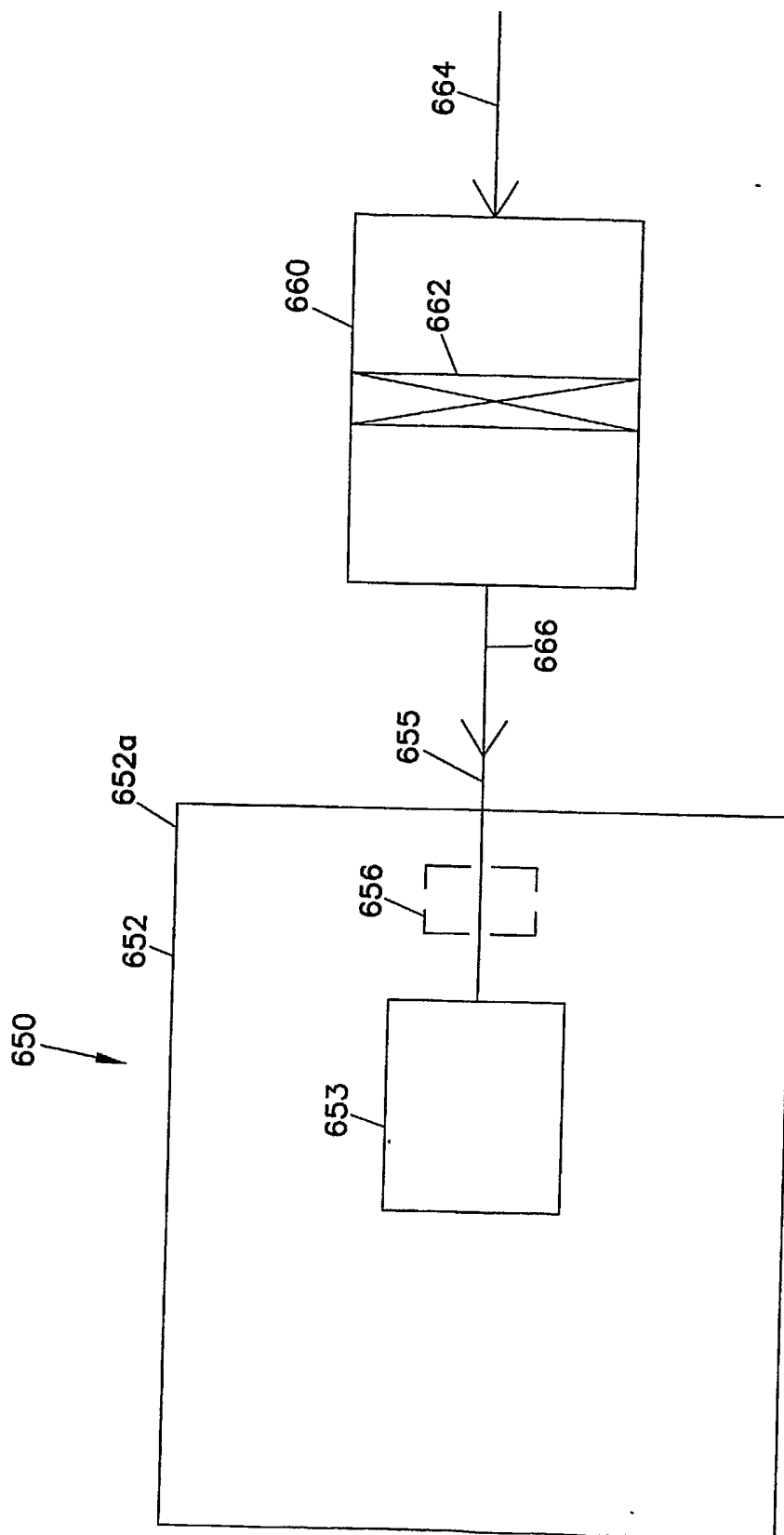
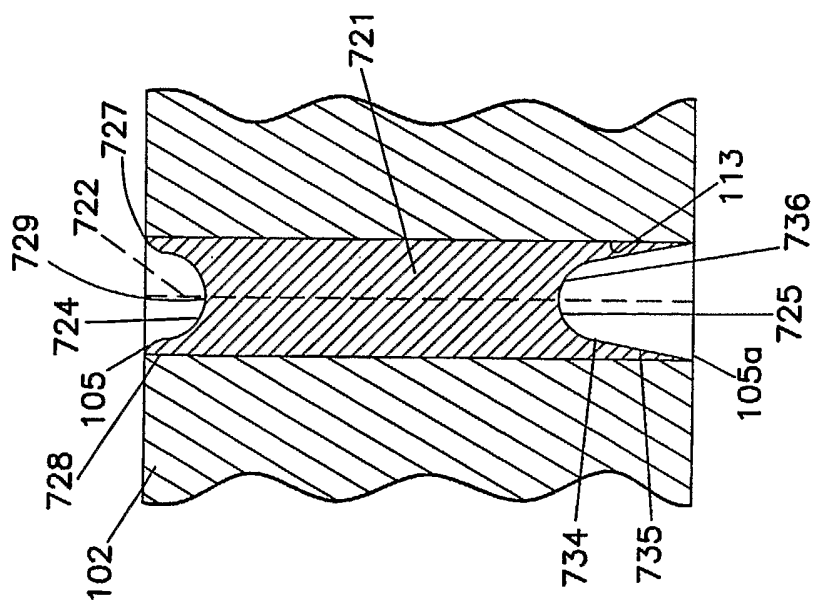


FIG. 25

FIG. 26



# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US2004/043012

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 B01D46/52 F02M35/024

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 F02M

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 03/095068 A (DONALDSON COMPANY, INC.) 20 November 2003 (2003-11-20) page 6, line 9 - page 10, line 21 -----	1-22
X	US 6 350 291 B1 (GIESECKE ET AL) 26 February 2002 (2002-02-26) cited in the application column 2, line 43 - column 8, line 56 column 14, line 65 - column 16, line 2 -----	1-22
X	US 6 179 890 B1 (RAMOS ET AL) 30 January 2001 (2001-01-30) column 2, line 45 - column 3, line 17 column 9, line 54 - column 10, line 45 column 12, line 22 - column 14, line 40 -----	1-22

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Patent family members are listed in annex.

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Information on patent family members

International Application No

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