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(71) Applicant (for all designated States except US): **DON-ALDSON COMPANY, INC.** [US/US]; 1400 West 94th Street, P.O. Box 1299, Minneapolis, MN 55440-1299 (US).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **SPEARS, Rodger, I.** [US/US]; 3209 West 84th Street, Bloomington, MN 55431 (US).

(74) Agent: **BRUESS, Steven, C.**; Merchant & Gould P.C., P.O. Box 2903, Minneapolis, MN 55402-0903 (US).

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(54) Title: Z-FILTER MEDIA PACK ARRANGEMENT; AND, METHODS

(57) Abstract: A filter cartridge arrangement for use in an air cleaner is described. The filter cartridge comprises a coiled media arrangement, having a seal arrangement molded directly to the coiled media arrangement. Methods of molding the seal arrangement in place are described. Also described are methods of forming a central seal plug, and methods for attaching a handle to the arrangement. A method for sealing lead and tail ends of a single facer strip, from which a media pack of the filter cartridge can be formed, is also described.



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Z-FILTER MEDIA PACK ARRANGEMENT; AND, METHODS

This application is being filed on 25 July 2005, as a PCT International Patent application in the name of Donaldson Company, Inc., a U.S. national corporation, applicant for the designation of all countries except the US, and Rodger I. Spears, a U.S. citizen, applicant for the designation of the US only, and claims priority to U.S. Provisional Application Serial No. 60/591,280, filed July 26, 2004.

Field of the Disclosure

The present disclosure relates to filter media for use in filtering liquids or gases. The disclosure particularly relates to media packs that use z-filter media which comprises a fluted media sheet secured to facing sheet, formed into a media pack. Specifically, the disclosure relates to formation of such media packs and their inclusion in serviceable filter cartridge arrangements, typically for use in air cleaners. Methods of assembly and use are also described.

Background

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

Summary

According to the present disclosure, features useable in preferred filter cartridges, such as air filter cartridges are provided. The features can be used together to provide a preferred filter cartridge, however some advantageous cartridges can be constructed to use only selected ones of the features. In addition, methods of construction and use are provided.

According to one aspect of the present disclosure, an air filter cartridge arrangement is provided. In general the air filter cartridge arrangement comprises a z-filter media pack having opposite first and second ends, with inlet and

outlet flutes extending therebetween. The media pack is generally formed from a fluted sheet of media secured to a facing sheet of media. Typically the media pack is coiled.

5 The media pack has first and second opposite flow faces or ends, one operating as an inlet flow face and the other as an outlet flow face. The media pack has a sidewall, extending axially between the end faces. Typically, especially if coiled, the media pack includes a central core volume.

10 Although alternatives are possible, in one arrangement shown and described, the air filter cartridge includes a housing seal arrangement molded on to the media pack sidewall and positioned at a location along the media pack sidewall, from the first flow face, a distance of less than 40% of the length of extension of the sidewall between the opposite flow faces. Preferably it is positioned at a distance of less than 30% of that length, from the first flow face. The housing seal arrangement can be positioned adjacent the first flow face. Preferably at least 40% of the media
15 pack axial length is not covered by molded material integrally molded with the housing seal arrangement. By "integrally molded" in this context, reference is meant to regions of molded material mold from the same resin pool.

Typically and preferably the housing seal arrangement is a radial seal. Typically and preferably it is positioned to begin at a location within 20 mm of the
20 first flow face. The preferred radial housing seal arrangement is configured to taper downwardly in thickness, in extension toward the second flow face. To accomplish this, it can be provided with an outer, annular, stepped sealing surface.

In one embodiment shown, the radial housing seal arrangement includes a tip positioned remotely from the first end surface, the tip being spaced
25 outwardly from the media pack sidewall, by a gap. The gap would be an artifact from a particular preferred method of formation described herein.

In certain applications of the techniques described herein, the media pack is provided with an adhesive sheet, such as a label, thereon tacking a tail end of the coiled media against itself. In some arrangements the housing seal arrangement
30 is molded in extension over a portion of the adhesive sheet, securing the adhesive sheet to the media pack, preferably leaving a portion of the adhesive sheet exposed to view.

An optional plug arrangement is described for positioning within the central core volume of the media pack. Although alternatives are possible, in one
35 arrangement shown the plug arrangement preferably extends axially, through the media pack, a distance of no more than 40% of the axial length of the media pack, typically and preferably no more than 30% of that length. In one application

described, the plug arrangement is positioned aligned with, or adjacent, the same flow face of the media pack of the housing seal arrangement.

In certain applications, an optional polymeric bead can be positioned at the media pack on a sidewall thereof, spaced toward the second end face from the housing seal arrangement. Preferred locations and shapes can be used, with respect to wear on the media pack in use.

Also described herein are methods of assembling an air filter cartridge. One method described herein involves positioning a circumferential seal bead on a sidewall of a z-filter media pack arrangement having opposite flow faces. The step of positioning is described as including positioning the seal bead at a location within a distance, along a sidewall from the first flow face, of no more than 40% of the axial length of the sidewall. In follow up a step of positioning a mold ring, preferably a continuous, integral, mold ring, against the seal bead by passage over the first flow face of the media pack is described. The mold ring is configured for formation of a housing seal arrangement.

In follow up to positioning or placing of the mold ring, is a step of molding a housing seal arrangement within the mold and around the media pack, preferably with at least a portion of the housing ring being sealed directly to the media pack, in particular directly to the facing sheet (i.e., with a portion of the seal arrangement in physical contact with the facing sheet). There is a follow-up step of removing the mold ring from around the media pack by passage over the second flow face of the media pack.

An option described with respect to the process, is positioning an adhesive sheet over a portion of the media pack, for example over some or all of a tail end of the media coil, on the sidewall. In such an instance, the step of positioning the mold ring could preferably involve positioning the mold ring such that at least a portion of the resulting molded housing seal arrangement extends over at least a portion of the adhesive sheet, preferably leaving a portion of the adhesive sheet accessible to view.

Also described herein as a method of sealing a tail end and a lead end of sections of a media strip comprising a fluted sheet secured to a facing sheet; the sealing being between the fluted sheet and the facing sheet. The method described involves inserting a line of sonically weldable polymeric material into at least one flute, and typically two adjacent corrugation flutes of the fluted sheet, between the fluted sheet and the facing sheet. In follow up there is a step of sonically welding the involved flute(s) closed to form a closed section of media, the step typically involving both application of sonic energy and crushing energy to the fluted sheet in this region. A follow-up step of cutting the media along the closed section of the

media is provided, to create at least one sealed end, typically adjacent lead and tail ends, of adjacent sections of media strip.

While herein a variety of techniques, features and methods are described with respect to a particular embodiment shown, it is noted that not all air
5 filter cartridges need to have all of the features described herein, or be made with all of the advantageous processing conditions, to achieve some advantage according to the present disclosure.

Brief Description of the Drawings

10 Fig. 1 is a fragmentary, schematic, perspective view of z-filter media useable in arrangements according to the present disclosure.

Fig. 2 is a schematic, cross-sectional view of a portion of the media depicted in Fig. 1.

15 Fig. 3 is a schematic view of examples of various corrugated media definitions.

Fig. 4 is a schematic view of a useable process for manufacturing media according to the present disclosure.

Fig. 5 is a cross-sectional view of an optional end dart for media flutes useable in arrangements according to the present disclosure.

20 Fig. 6 is a perspective view of a filter cartridge according to the present disclosure.

Fig. 7 is a schematic cross-sectional view of the filter cartridge of Fig. 6.

25 Fig. 8 is a cross-sectional view analogous to Fig. 7, showing a mold piece for molding a seal arrangement of the filter cartridge of Figs. 6 and 7.

Fig. 9 schematically depicts steps in a process of forming a filter cartridge according to Figs. 6 and 7.

30 Fig. 10 depicts a step of forming a portion of a lead end seal and tail end seal for media strips useable in the arrangement of Figs. 6 and 7.

Detailed Description

I. Z-Filter Media Configurations, Generally.

35 Fluted filter media can be used to provide fluid filter constructions in a variety of manners. One well known manner is as a z-filter construction. The term "z-filter construction" as used herein, is meant to refer to a filter construction in which individual ones of corrugated, folded or otherwise formed filter flutes are used to define sets of longitudinal, typically parallel, inlet and outlet filter flutes for

fluid flow through the media; the fluid flowing along the length of the flutes between opposite inlet and outlet flow ends (or flow faces) of the media. Some examples of z-filter media are provided in U.S. patents 5,820,646; 5,772,883; 5,902,364; 5,792,247; 5,895,574; 6,210,469; 6,190,432; 6,350,296; 6,179,890; 5 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 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 10 fluted (typically corrugated) media sheet; and, (2) a facing media sheet. The facing media sheet is typically non-corrugated, however it can be corrugated, for example perpendicularly to the flute direction as described in U.S. provisional 60/543,804, filed February 11, 2004, incorporated herein by reference.

The fluted (typically corrugated) media sheet and the facing media 15 sheet together, are used to define media having parallel inlet and outlet flutes. In some instances, the fluted sheet and non-fluted sheet are secured together and are then coiled to form a z-filter media construction. Such arrangements are described, for example, in U.S. 6,235,195 and 6,179,890, each of which is incorporated herein by reference. In certain other arrangements, some non-coiled sections of fluted 20 media secured to flat 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 reference.

For specific applications as described herein, coiled arrangements are preferred.

25 Typically, coiling of the fluted sheet/facing sheet combination around itself, to create a coiled media pack, is conducted with the facing sheet directed outwardly. Some techniques for coiling are described in U.S. provisional application 60/467,521, filed May 2, 2003 and PCT Application US 04/07927, filed March 17, 2004, each of which is incorporated herein by reference. The resulting 30 coiled arrangement generally has, as the outer surface of the media pack, a portion of the facing sheet, as a result.

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 35 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.

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

5 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
10 end (or face), with flow entering and exiting the filter cartridge in generally the same straight through direction. The term "serviceable" in this context is meant to refer to a media containing filter cartridge that is periodically removed and replaced from a corresponding fluid cleaner. In some instances, each of the inlet flow end and outlet flow end will be generally flat or planar, with the two parallel to one another.

15 However, variations from this, for example non-planar faces are possible.

A straight through flow configuration (especially for a coiled media pack) is, for example, in contrast to serviceable filter cartridges such as cylindrical pleated filter cartridges of the type shown in U.S. Patent No. 6,039,778, incorporated herein by reference, in which the flow generally makes a turn as its passes through
20 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
25 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
30 constructed or formed into a three dimensional network of inlet and outlet flutes; and/or, a filter construction including such media.

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

In general, the corrugated sheet 3, Fig. 1 is of a type generally
35 characterized herein as having a regular, curved, wave pattern of flutes or corrugations 7. The term "wave pattern" in this context, is meant to refer to a flute or corrugated pattern of alternating troughs 7b and ridges 7a. The term "regular" in this context is meant to refer to the fact that the pairs of troughs and ridges (7b, 7a)

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

In the context of the characterization of a "curved" wave pattern of corrugations, the term "curved" is meant to refer to a corrugation pattern that is not the result of a folded or creased shape provided to the media, but rather the apex 7a of each ridge and the bottom 7b of each trough is formed along a radiused curve. Although alternatives are possible, a typical radius for such z-filter media would be at least 0.25 mm and typically would be not more than 3 mm. (Media that is not curved, by the above definition, can also be useable.)

An additional characteristic of the particular regular, curved, wave pattern depicted in Fig. 1, for the corrugated sheet 3, is that at approximately a midpoint 30 between each trough and each adjacent ridge, along most of the length of the flutes 7, is located a transition region where the curvature inverts. For example, viewing back side or face 3a, Fig. 1, trough 7b is a concave region, and ridge 7a is a convex region. Of course when viewed toward front side or face 3b, trough 7b of side 3a forms a ridge; and, ridge 7a of face 3a, forms a trough. (In some instances, region 30 can be a straight segment, instead of a point, with curvature inverting at ends of the segment 30.)

A characteristic of the particular regular, curved, wave pattern corrugated sheet 3 shown in Fig. 1, is that the individual corrugations are generally straight. By "straight" in this context, it is meant that through at least 70% (typically at least 80%) of the length between edges 8 and 9, the ridges 7a and troughs 7b do

not change substantially in cross-section. The term "straight" in reference to corrugation pattern shown in Fig. 1, 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. 1 and as referenced above, the media 1 has first and second opposite edges 8 and 9. When the media 1 is coiled and formed into a media pack, in general edge 9 will form an inlet end for the media pack and edge 8 an outlet end, although an opposite orientation is possible.

Adjacent edge 8 is provided sealant, in this instance in the form of a sealant bead 10, sealing the corrugated (fluted) sheet 3 and the facing sheet 4 together. Bead 10 will sometimes be referred to as a "single facer" bead, since it is a bead between the corrugated sheet 3 and facing sheet 4, which forms the single facer or media strip 1. Sealant bead 10 seals closed individual flutes 11 adjacent edge 8, to passage of air therefrom.

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

Referring to Fig. 1, once the media 1 is incorporated into a media pack, for example by coiling or stacking, it can be operated as follows. First, air in the direction of arrows 12, would enter open flutes 11 adjacent end 9. Due to the closure at end 8, by bead 10, the air would pass through the media shown by arrows 13. It could then exit the media pack, by passage through open ends 15a of the flutes 15, adjacent end 8 of the media pack. Of course operation could be conducted with air flow in the opposite direction.

For the particular arrangement shown herein in Fig. 1, the parallel corrugations 7a, 7b are generally straight completely across the media, from edge 8 to edge 9. Straight flutes or corrugations can be deformed or folded at selected locations, especially at ends. Modifications at flute ends for closure are generally disregarded in the above definitions of "regular," "curved" and "wave pattern."

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

In general, the filter media is a relatively flexible material, typically a non-woven fibrous material (of cellulose fibers, synthetic fibers or both) often including a resin therein, sometimes treated with additional materials. Thus, it can be conformed or configured into the various corrugated patterns, without unacceptable media damage. Also, it can be readily coiled or otherwise configured for use, again without unacceptable media damage. Of course, it must be of a nature such that it will maintain the required corrugated configuration, during use.

In the corrugation process, an inelastic deformation is caused to the media. This prevents the media from returning to its original shape. However, once the tension is released the flute or corrugations will tend to spring back, recovering only a portion of the stretch and bending that has occurred. The facing sheet is sometimes tacked to the fluted sheet, to inhibit this spring back in the corrugated sheet.

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

The media of the corrugated sheet 3 facing sheet 4 or both, can be provided with a fine fiber material on one or both sides thereof, for example in accord with U.S. 6,673,136, 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. 2, in which a z-filter media construction 40 utilizing a regular, curved, wave pattern corrugated sheet 43, and a non-corrugated flat sheet 44, is depicted. The distance D1, between points 50 and 51, defines the extension of flat media 44 in region 52 underneath a given corrugated flute 53. The length D2 of the arcuate media for the corrugated flute 53, over the same distance D1 is of course larger than D1, due to the shape of the corrugated flute 53. For a typical regular shaped media used in fluted filter applications, the linear length D2 of the media 53 between points 50 and 51 will generally be at least 1.2 times D1. Typically, D2 would be within a range of 1.2 - 2.0, 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 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 3, 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. 3.

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);
25	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);
	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 flute, and the corrugation industry standard A and standard B flutes, indicate some convenient variations.

II. Manufacture of Coiled Media Configurations Using Fluted Media, Generally.

40

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

of z-filter media 74, each of which has an edge with a strip of sealant (single facer bead) extending between the corrugating and facing sheet. Of course, if the optional darting process is used, the edge with a strip of sealant (single facer bead) would also have a set of flutes darted at this location.

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

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

Still in reference to Fig. 4, the process also shows the facing sheet 64
20 being routed to the darting process station 71. The facing sheet 64 is depicted as being stored on a roll 106 and then directed to the corrugated sheet 66 to form the Z-media 74. The corrugated sheet 66 and the facing sheet 64 are secured together by adhesive or by other means (for example by sonic welding).

Referring to Fig. 4, an adhesive line 70 is shown used, to secure
25 corrugated sheet 66 and facing sheet 64 together, as the sealant bead. Alternatively, the sealant bead for forming the facing bead could be applied as shown as 70a. If the sealant is applied at 70a, it may be desirable to put a gap in the corrugation roller 95, and possibly in both corrugation rollers 94, 95, to accommodate the bead 70a.

The type of corrugation provided to the corrugated media is a matter
30 of choice, and will be dictated by the corrugation or corrugation teeth of the corrugation rollers 94, 95. One preferred corrugation pattern will be a regular curved wave pattern corrugation, of straight flutes, as defined herein above. A typical regular curved wave pattern used, would be one in which the distance D2, as defined above, in a corrugated pattern is at least 1.2 times the distance D1 as defined
35 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. 4 can be used to create the center darted section 72. Fig. 5 shows, in cross-section, one of the flutes 68 after darting and slitting.

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

10 Still referring to Fig. 5, two of the folds or creases 121a, 121b will generally be referred to herein as "upper, inwardly directed" folds or creases. The term "upper" in this context is meant to indicate that the creases lie on an upper portion of the entire fold 120, when the fold 120 is viewed in the orientation of Fig. 5. The term "inwardly directed" is meant to refer to the fact that the fold line or
15 crease line of each crease 121a, 121b, is directed toward the other.

In Fig. 5, creases 121c, 121d, will generally be referred to herein as "lower, outwardly directed" creases. The term "lower" in this context refers to the fact that the creases 121c, 121d are not located on the top as are creases 121a, 121b, in the orientation of Fig. 5. The term "outwardly directed" is meant to indicate that
20 the fold lines of the creases 121c, 121d are directed away from one another.

The terms "upper" and "lower" as used in this context are meant specifically to refer to the fold 120, when viewed from the orientation of Fig. 5. That is, they are not meant to be otherwise indicative of direction when the fold 120 is oriented in an actual product for use.

25 Based upon these characterizations and review of Fig. 5, it can be seen that a preferred regular fold arrangement 118 according to Fig. 5 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.

30 A third layer or portion 128 can also be seen pressed against the second layer or portion 124. The third layer or portion 128 is formed by folding from opposite inner ends 130, 131 of the third layer 128.

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

Techniques for providing the optional dart described in connection with Fig. 5, 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 in media packs that result from coiling a single sheet comprising a corrugated sheet/facing sheet combination, i.e., a "single facer" strip. Certain of the techniques can be applied with arrangements that, instead of being formed by coiling, are formed from a plurality of strips of single facer.

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

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

Opposite flow ends or flow faces of the media pack can be provided with a variety of different definitions. In many arrangements, the ends are generally flat and perpendicular to one another. In other arrangements, the end faces include tapered, coiled, stepped portions which can either be defined to project axially outwardly from an axial end of the side wall of the media pack; or, to project axially inwardly from an end of the side wall of the media pack.

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

III. Filter Cartridge Arrangement Utilizing the Z-Filter Media

The reference numeral 200, Fig. 6, indicates an example air filter cartridge according to the present disclosure. An air filter cartridge 200 such as that

shown in the drawings, would typically be used by being inserted within an air cleaner housing of an air cleaner for use to filter air being directed into the engine air intake of an internal combustion engine or other equipment. As such, the air filter cartridge 200 is a serviceable item, and is typically removed and replaced within the operating lifetime of the equipment within which it is used.

In general, the filter cartridge 200 comprises a media pack 201 and a housing seal arrangement 202. Although alternatives are possible, the particular filter cartridge 200 shown also includes a central core volume 203a having central core or plug member 203 projecting therein. (It is noted that in Fig. 6 and in similar figures, the detail of flute ends is not shown.)

The media pack 201 includes opposite flow surfaces 205 and 206. For the particular cartridge 200 depicted, surfaces 205 and 206 are each planar, and are parallel to one another. Alternatives are possible. The media pack 201 also includes an outer sidewall 207, in this instance comprising a portion of facing sheet. Herein the length of the sidewall 207 in extension between surfaces 205 and 206, is generally referred to as an axial length or extension of the sidewall 207. Analogously, a length of central core volume 203a in extension between surfaces 205 and 206, is referred to as the axial length of core volume 203a. The term "axial" in this context, is generally meant to refer to a flow direction through the media pack 201, between opposite flow surfaces 205, 206.

The media pack 201 would typically comprise a coiled strip of z-filter media, in accord with the descriptions of Sections I and II above. Thus, in typical operation, air would flow axially through the media pack 201 in direction from one of the flow surfaces 205, 206 to an opposite one, in normal operation. The direction of air flow through the media pack 201 is a matter of choice. For convenience in describing features herein, end face 205 will be considered the dirty air inlet flow face and flow face 206 will be considered the exit flow face for filtered air. This would be typical, for a cartridge configured like cartridge 200.

In general, the seal arrangement 202 and the housing seal arrangement 202a, is configured to form a seal between the filter cartridge 200 and an air cleaner housing, when the filter cartridge 200 is installed for use. This housing seal arrangement 202, in operation, prevents unfiltered air from bypassing the media pack 201, in normal installation and use in an air cleaner.

Still referring to Fig. 6, it is noted the core or plug arrangement 203 includes projection 210 thereon. The projection 210 provides a convenient structure for manipulating filter cartridge 200 into and out of secure sealing engagement with an air cleaner, during use. For the example shown, projection 210 includes a handle 210a, with a central hole. Alternatively, or in addition, projection 210 can be used to

engage or align with portions of an air cleaner housing, when filter cartridge 200 is installed for use. A variety of shapes of projection 210 can be used, the one 210a shown merely being an example.

In general, for the filter cartridge 200 depicted, the housing seal arrangement 202 is an outside radial seal 202a. By the term "housing" in this context, it is meant that the seal arrangement 202 is configured to seal against a portion of an air cleaner housing, in use. By the term "radial" in this context, it is meant that the seal surface 212 of the seal arrangement 202 is generally a radially directed surface, positioned annularly or peripherally around seal arrangement 202, to form a seal with seal forces directed radially with respect to central core volume 203a (or from a central axis passing through core volume 203a. By the term "outside" in this context, it is meant that the particular surface 212 shown is an annular surface directed radially outwardly from core volume 203a. It is noted that alternate housing seal arrangements could be used.

Attention is now directed to Fig. 7, in which filter cartridge 200 is depicted (schematically) in cross-section. In Fig. 7, media flute detail is not depicted. Referring to Fig. 7, it will be observed the seal arrangement 202 is, at least in part, secured directly to media pack 201, in this instance in part to a portion of the facing sheet. In particular, although alternatives are possible in typical arrangements the seal arrangement 202 will be molded at least partially directly onto the media pack 201, during manufacture; the term "directly" in this context meaning "in physical contact with." A process for accomplishing this is described below. It is noted that particular seal arrangement 202 shown includes a projection tip 219 remote from surface 205 and toward surface 206, that is spaced from media pack 201, by a gap 220. This gap is an artifact from a preferred method of manufacture, described below.

It is noted that opposite from tip 219, housing seal arrangement 202 include edge 221. Edge 221 is a portion of housing seal arrangement 202 directed generally in the direction of end face 205 and from end face 206. Typically tip 221 is positioned, within an axial distance of sidewall 207 from end face 205 toward end face 206, a distance of no more than 20 mm, preferably no more than 10 mm, and, in some preferred instances, tip 221 is aligned with surface 205 as shown in Fig. 7.

Preferably the total axial extension of the housing seal arrangement 202 between edge 221 and tip 219 is no more than 60 mm, more preferably no more than 40 mm, typically no more than 30 mm.

Also from review of Fig. 7, although alternatives are possible it will be understood that the preferred seal surface 212 is irregular; i.e., not flat and smooth. Also, the particular seal surface shown generally tapers inwardly (or

downwardly in thickness) from point 222 toward point 223, i.e., the seal dimension tapers inwardly in a direction of extension along the seal surface 212 from flow face 205 toward flow face 206. Alternately stated, at region 222 seal arrangement 202 is thicker (radially) than it is in region 223.

5 It is also noted that typically the extent of axial extension (distance from edge 221 to tip 219) of seal arrangement 202 along side 201a of media pack 201 is no more than 40% of a distance between surfaces 205, 206, (i.e., the axial length of side 201a) typically no more than 30% of this distance and often no more than 20% of this distance. Preferably at least 40% of the total axial extension of the
10 media pack 201 (typically at a location extending to an opposite end of the media pack 201 from the molded housing seal arrangement 202) is not covered with material molded integral with the housing seal arrangement 202.

 Although alternatives are possible, the particular irregular seal surface 212 shown is stepped in three steps 212a, 212b and 212c. This will facilitate
15 insertion, with the normal insertion direction being in the direction of arrow 225, i.e., in a direction from flow face 205 toward flow face 206. In this context the term "normal insertion direction" with respect to the seal arrangement 202, is meant to refer to direction of axial forces during insertion into sealing relationship with an air cleaner housing, for use.

20 Still referring to Fig. 7, optional plug 203 is viewable in cross-section, comprising plug material 227 having projection 210 embedded therein.

 Attention is now directed to Fig. 8. In Fig. 8 the filter cartridge is depicted during a step of manufacture with mold piece 230 thereon. Seal arrangement 202, Fig. 7, would typically be molded, by placing an appropriate
25 curable resin in interior 231 of mold piece, between the mold piece 231 and the media pack 201. The mold piece 230 is temporarily secured in position on media pack 201, by resting on axial bead 233. This operation is described in greater detail, in connection with Fig. 9.

 The housing seal arrangement 202 can be formed from a variety of
30 polymeric materials. In many applications polyurethane material will be chosen. In some instances polyurethane foam will be preferred; the polyurethane being selected such as to form a housing seal arrangement 202 having an as-molded density, preferably, of no greater than 30 lbs/cu. ft. (0.48 g/cc) and typically no greater than 22 lbs/cu. ft. (0.35 g/cc), usually at least 5 lbs/cu.ft. (0.08 g/cc) and typically at least
35 10 lbs/cu.ft. (0.16 g/cc). Typically the resulting hardness is no greater than 30 Shore A and typically no greater than 25 Shore A and often within the range of 12-22 Shore A. It is noted that even harder materials can be utilized, but they are generally not preferred when housing seal arrangement 202 is a radial seal due to: (a) cost and

weight concerns; and (b) the preference for the material to crush or compress in radial thickness, when cartridge 202 is positioned for use in a housing of an air cleaner.

Referring now to Fig. 9, at station 240 a media pack 241 (with
5 opposite end faces 247, 248) useable for a media pack 201 in filter cartridge 200, Fig. 6, is provided. Although alternatives are possible, the media pack 241 depicted is cylindrical, comprising a strip of single facer material 242 coiled in this instance in a cylindrical shape, with tail end 243. Tail end 243 is shown secured down by label or adhesive sheet 245. The term "label or adhesive sheet" is meant to refer to a
10 sheet of material that may for example having printing and/or pictorial information thereon, and which has a side with adhesive thereon securing the label or sheet against the media pack 201. The label or adhesive sheet 245 may be, for example, a printed label having a pressure sensitive adhesive thereon, although alternatives are possible.

15 At station 250, media pack 241 is shown with bead 251 having been positioned thereon, spaced from end 247. Typically bead 251 will be formed from a thixotropic material such as a hot melt or polyurethane material. It would typically be spaced from end 247, by a distance of at least 5 mm and typically at least 10 mm, and usually not more than 50 mm, and typically not more than 40 mm.

20 Also in Fig. 9, at station 250, is positioned mold ring 230. The preferred mold ring 230 depicted is a continuous circular, integral piece. By "integral" in this context, it is meant that the mold ring 230 is a single piece with no joints, seams, or separation points therein. In operation, the mold ring 230 would be lowered over end 247, until inner projection 255 engages bead 251, as shown in Fig.
25 8. If appropriate thixotropic material is chosen for bead 251, a sufficient seal will form between the mold ring 230 and the media pack 241 at this location, to hold liquid resin within the mold ring 230 during a molding process. Useable thixotropic materials include thixotropic urethane materials. Referring to Fig. 8, the interior wall 231 of mold ring 230, which forms the side surface of the annular wall around
30 mold 253, is appropriately configured to form outside surface 212 of the seal arrangement 202.

Once the mold ring 230 is in position, a liquid resin (to be cured to form the housing seal arrangement 202), will be poured into the mold ring 230, through upper (open) end 257. After the resin cures, it will form the selected seal
35 arrangement 202, Fig. 6, molded directly to the media pack 241. Also, in region 259, the seal ring will engulf the tail end 243, sealing the tail end 243 at this location, between the outer most tip of the media strip and the next underneath coil.

In some applications, region 259 is positioned in overlap with a winding bead of the media pack 241.

If desired, the thixotropic bead 251 and seal arrangement 202 can be positioned to engage (overlap) an end portion 260 of the label or sheet 245. As a result, the end portion 260 of the label or sheet 245 will be further secured on the media pack 241, after molding of the housing seal arrangement 202. An advantage from this, is that the adhesive of the label or sheet 245 is not solely relied upon, to maintain the label or sheet 245 secured to the media pack 201, through the lifetime of use of the filter cartridge 200. Rather the label or sheet 245 cannot easily be separated from the remainder of the media pack 201, due to the fact that the label or sheet 245 is partly secured under thixotropic bead 251 and/or housing seal arrangement 202.

At station 270, filter cartridge 200 is shown, with ring 230 having been removed by passage past (over) end surface 248 in the direction of arrow 271. Thus the mold ring 253 is inserted over one end surface 247 of the media pack 241 and is removed over the other end surface 248. The thixotropic material of the bead 251 will have been chosen such that the mold 230 does not become adhered to it, and the mold 230 can be pushed pass the thixotropic material to be removed as shown at station 270. In some instances, the thixotropic bead will be stripped or partially stripped during removal of the mold.

It is also noted that between stations 240 and 250, optional core or plug arrangement 203 has been positioned within central core volume 203a of the media pack 241. To accomplish this, referring to Fig. 9, the handle 210 would be pushed into end 203b of the core volume 203a. Flared prongs 273, Fig. 8, can be used to hold the handle 210 in position. Core material 227 would be poured into the region 275 as a liquid, and be allowed to cure in this region, to form the plug 203. Although alternatives are possible, preferably region 275 is positioned in overlap with the winding bead of the media pack 201. As a result material 227 will seal a lead end of the media pack, between the end of the lead end and the next outer coil, at this region.

In the alternative, plug arrangement 203 could be preformed molding resin to handle arrangement 210. The preform plug could then be pushed into core volume 203a. The seal could result from additional adhesive applied around the outside of the preformed plug arrangement, or with reliance upon winding bead sealant at this location.

It is noted that for the embodiment shown, the projection 210 is positioned adjacent a same end of the media pack 201 as the housing seal arrangement 202. Alternatives are possible.

In general, the lead end and tail end of the media pack also should be sealed between the corrugated sheet and the facing sheet, of the single facer strip. A process for accomplishing this is shown schematically in Fig. 10.

Referring to Fig. 10, at 280 a continuous strip of single facer material is shown comprising corrugated (or fluted) sheet 281 secured to facing sheet 282. At station 285 a strip 286 of material are shown inserted into at least one, and typically into two adjacent, corrugations (flutes) 287. The strips 286 would typically comprise an ultrasonically weldable polymeric material, inserted as a long strip for example similar to a fish line. Useable materials include nylon, polypropylenes and/or polyethylene lines, typically 0.025 - 0.080 inch in diameter (0.6 - 2 mm). The strips 286 preferably extend completely through corrugations 287.

At station 290 the ultrasonic (sonic) welding horn 291 is shown having welded and compressed corrugations (flutes) 287 closed, at region 295. The strips 286, will have been deformed and welded, to seal the corrugations (flutes) 287 closed.

At station 300, the resulting strip 301 is shown cut into section 303 and 304. As an example, section 303 could comprise a strip of single facer material with sealed tail end 305, and section 304 could comprise a strip of single facer material with lead end 306.

Each of the strips would be sealed at its opposite ends, by a similar process. Each of the strips could then be coiled to form the media pack coil 241, Fig. 9.

Of course alternate methods of sealing the lead and tail ends can be used, including application of a sealant such as a hot melt or other liquid sealant across the material at these locations.

Attention is now directed to Fig. 7. In Fig. 7 at 290, in phantom lines, is shown an optional end bead. The optional end bead 290 could be applied after the molding process for housing seal arrangement 202, to a location on side wall 207, adjacent end face 206 of the media pack 201. Such a bead 290 could be used to provide an engagement with an air cleaner housing, to inhibit rubbing between the media pack 201 and the air cleaner housing at this location. The bead 290 could be applied from a hot melt material, or for example, a molded material such as polyurethane. It could be molded in position, by using a mold if desired; or it could be applied as a bead. If desired it can be applied at a location which will extend over a portion of label or sheet 251, Fig. 6, to further secure the label or sheet 251 in position. The optional bead 290 could be located at end 207a or spaced therefrom.

What is claimed is:

1. An air filter cartridge comprising:
 - (a) a media pack having opposite flow faces, a sidewall extending therebetween and a plurality of inlet flutes and outlet flutes extending between the opposite flow faces;
 - (i) the media pack comprising a coiled strip of fluted media secured to facing media;
 - (b) an outwardly directed, radial, housing seal arrangement molded at least partially directly onto the media pack sidewall in contact with the facing media; the outwardly directed, radial, housing seal arrangement having a distance of extension, along the media pack sidewall from the first flow face, of less than 40% of a length of extension of the sidewall between the opposite flow faces; and,
 - (c) at least 40% of the media pack side wall, in extension from one of the flow faces, not being covered by material integrally molded with the housing seal arrangement.
2. An air filter cartridge according to claim 1 wherein:
 - (a) the radial housing seal arrangement is positioned within a distance of 20 mm the media pack first flow face; and,
 - (b) the radial housing seal arrangement is configured to taper downwardly in thickness.
3. An air filter cartridge according to any one of claims 1 and 2 wherein:
 - (a) the radial housing seal arrangement is configured to taper downwardly in thickness in extension toward the second flow face.
4. An air filter cartridge according to any one of claims 1-3 wherein:
 - (a) the radial housing seal arrangement has a stepped, annular, seal surface.
5. An air filter cartridge according to any one of claims 1-4 wherein:
 - (a) the radial housing seal arrangement includes a tip spaced outwardly from the media pack sidewall by a gap.
6. An air filter cartridge according to any one of claims 1-5 including:
 - (a) an adhesive sheet securing down a tail end of the coil;

- (i) at least a portion of the adhesive sheet being secured underneath the housing seal arrangement.
7. An air filter cartridge according to any one of claims 1-6 wherein:
- 5 (a) the media pack includes a central core volume; and
- (b) the filter cartridge includes a plug arrangement secured in the central core volume.
8. An air filter cartridge according to any one of claims 1-7 wherein:
- 10 (a) the media pack includes no second housing seal arrangement thereon.
9. An air filter cartridge according to any one of claims 1-8 wherein:
- (a) the housing seal arrangement comprises molded polyurethane foam.
- 15 10. An air filter cartridge according to any one of claims 1-9 wherein:
- (a) the housing seal arrangement comprises molded polyurethane having an as-molded density of no greater than 0.48 g/cc.
11. An air filter cartridge according to any one of claims 1-10 wherein:
- 20 (a) the housing seal arrangement comprises molded polyurethane having an as-molded density of at least 0.08 g/cc and no greater than 0.35 g/cc.
12. A filter cartridge according to any one of claims 1-11 wherein:
- 25 (a) the opposite flow faces of the media pack are planar.
13. A filter cartridge according to any one of claims 1-12 wherein:
- (a) the media pack includes a winding bead; and,
- (b) the housing seal arrangement is positioned in overlap with the
- 30 winding bead of the media pack.
14. A method of assembling an air filter cartridge; the method including steps of:
- (a) positioning a circumferential seal bead on a sidewall of a media pack comprising a coil of fluted media secured to a facing sheet to define
- 35 the media pack with opposite first and second flow faces with a plurality of inlet and outlet flutes extending therebetween;

- 5 (i) the step of positioning including positioning the seal bead within a distance, along the sidewall from the first flow face, of no more than 40% of the axial length of the sidewall;
- (b) placing a mold ring against the seal bead by passage over the first flow face of the media pack;
- 10 (c) molding a housing seal arrangement within the mold, around the media pack and at least partially to a portion of the facing sheet; and,
- (d) removing the mold ring from around the media pack by passage of the mold ring over the second flow face of the media pack.
- 15 15. A method according to claim 14 wherein:
- (a) the step of molding includes molding the housing seal arrangement over a portion of an adhesive sheet secured to an outside of the media pack, while leaving a portion of the adhesive sheet in view.
- 20 16. A method of sealing a tail end and a lead end of adjacent sections of media comprising a fluted sheet secured to a facing sheet; the method including steps of:
- (a) inserting a line of sonically weldable polymeric material into at least one selected flute of the fluted sheet, between the fluted sheet and the facing sheet;
- (b) sonically welding the at least one selected flute closed to form a closed section of media; and
- 25 (c) cutting the media along the closed section of media.
17. A method according to claim 16 wherein:
- (a) the step of inserting includes inserting a line of sonically weldable polymeric material into two adjacent selected flutes.

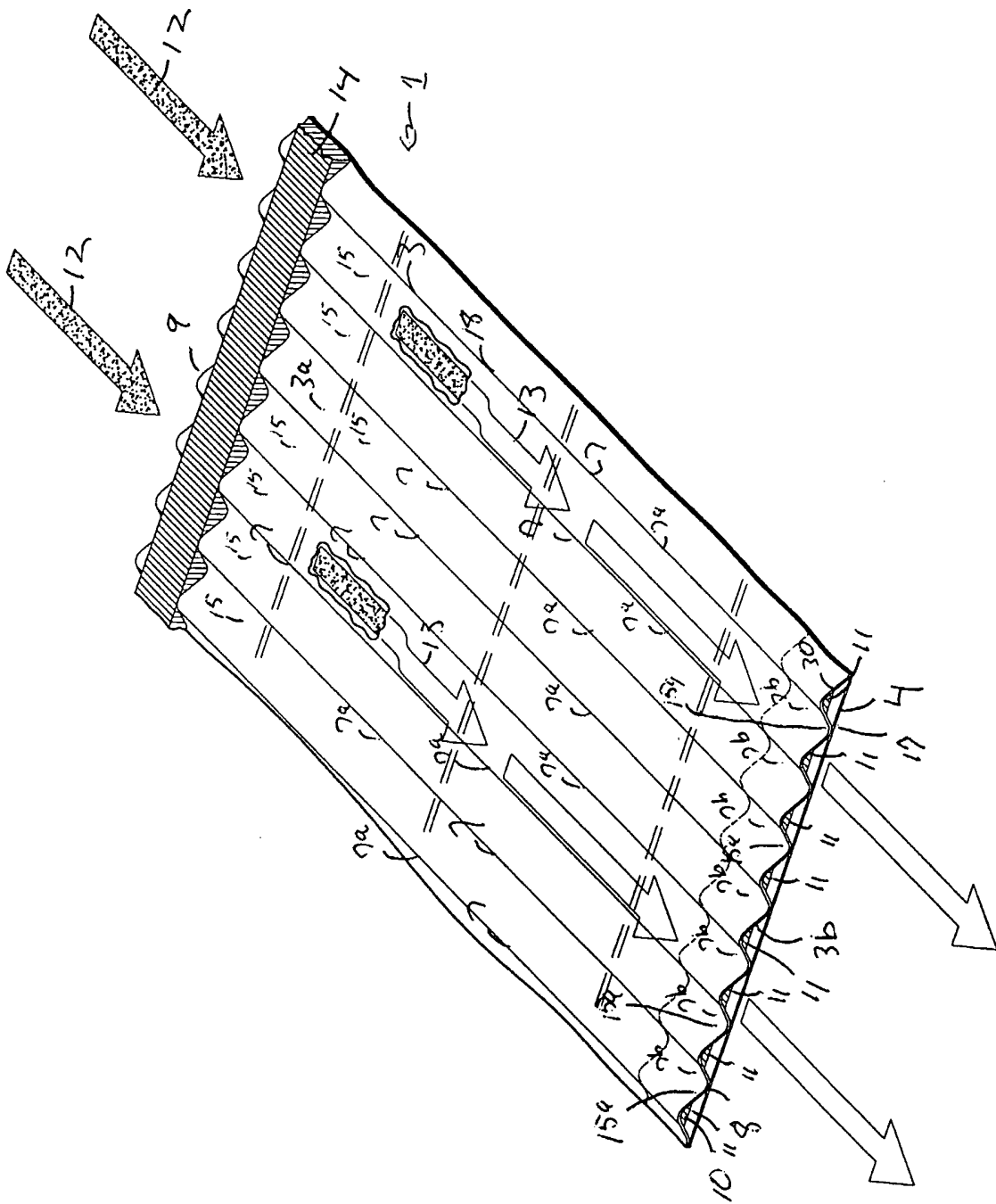


FIG. 1

FIG. 2

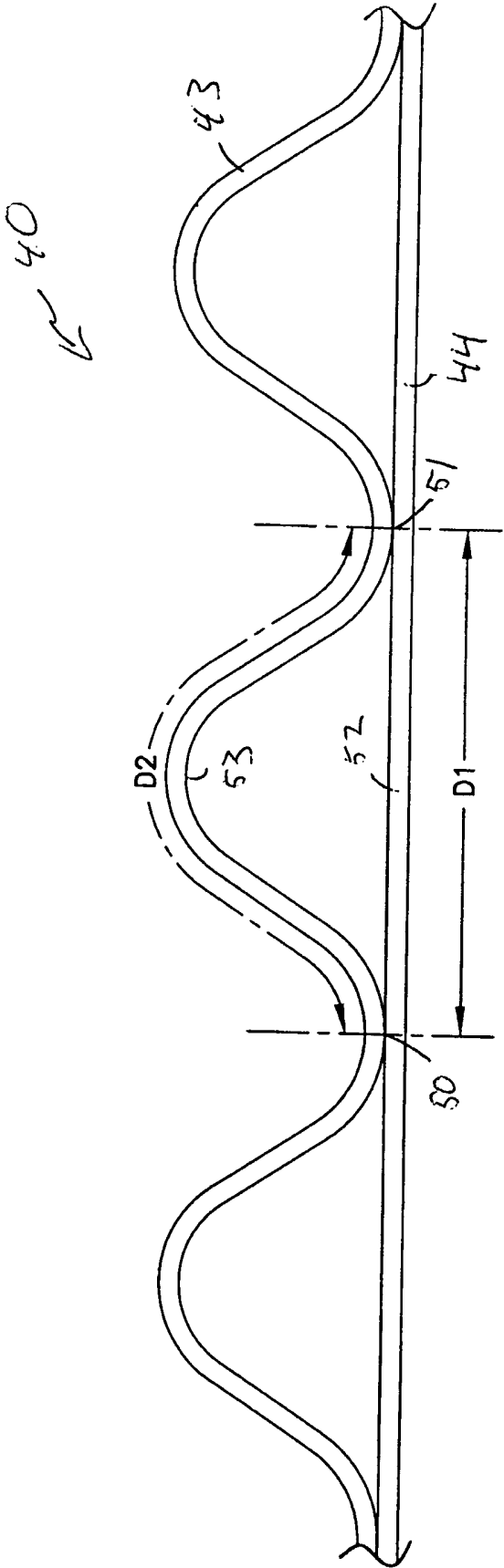
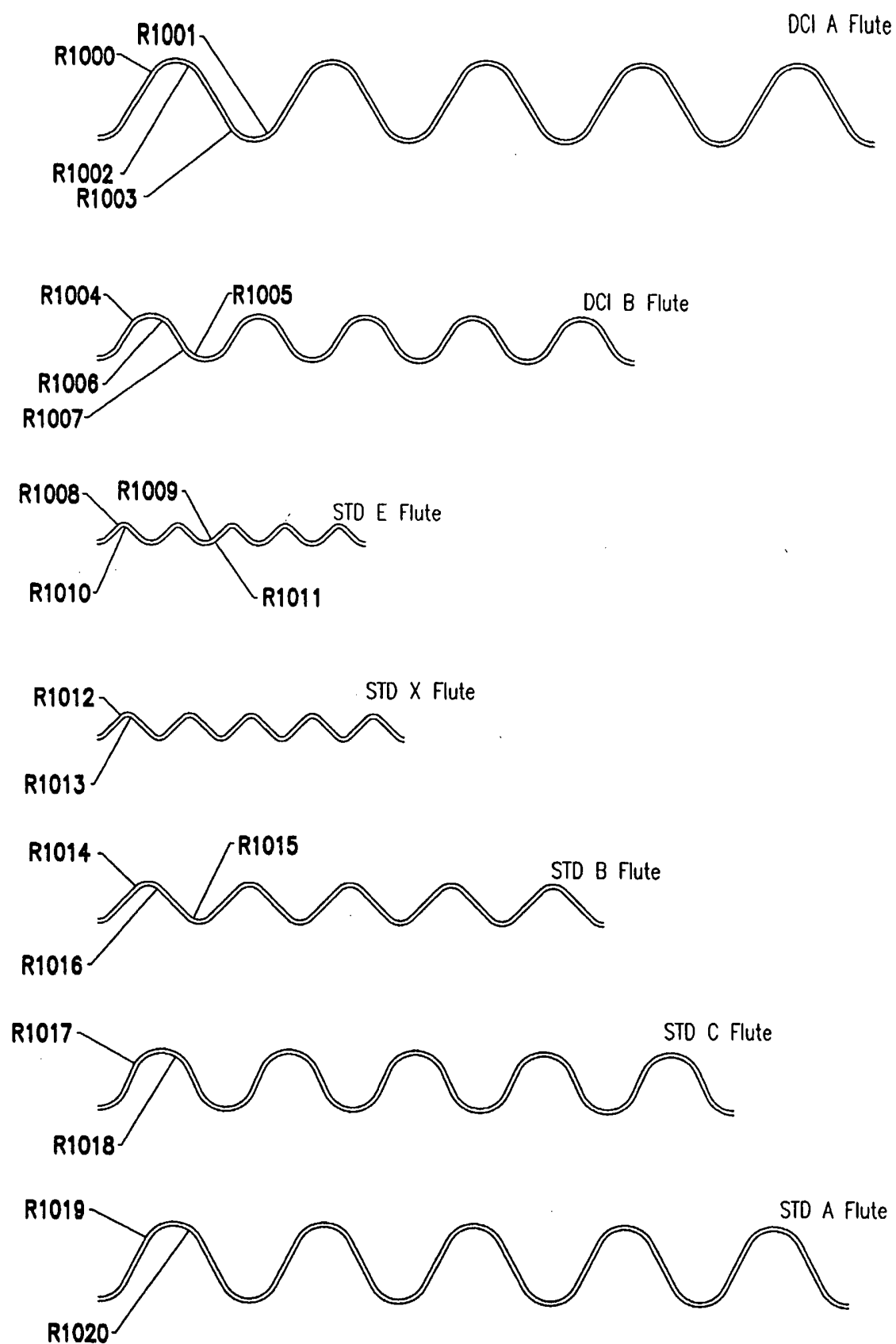
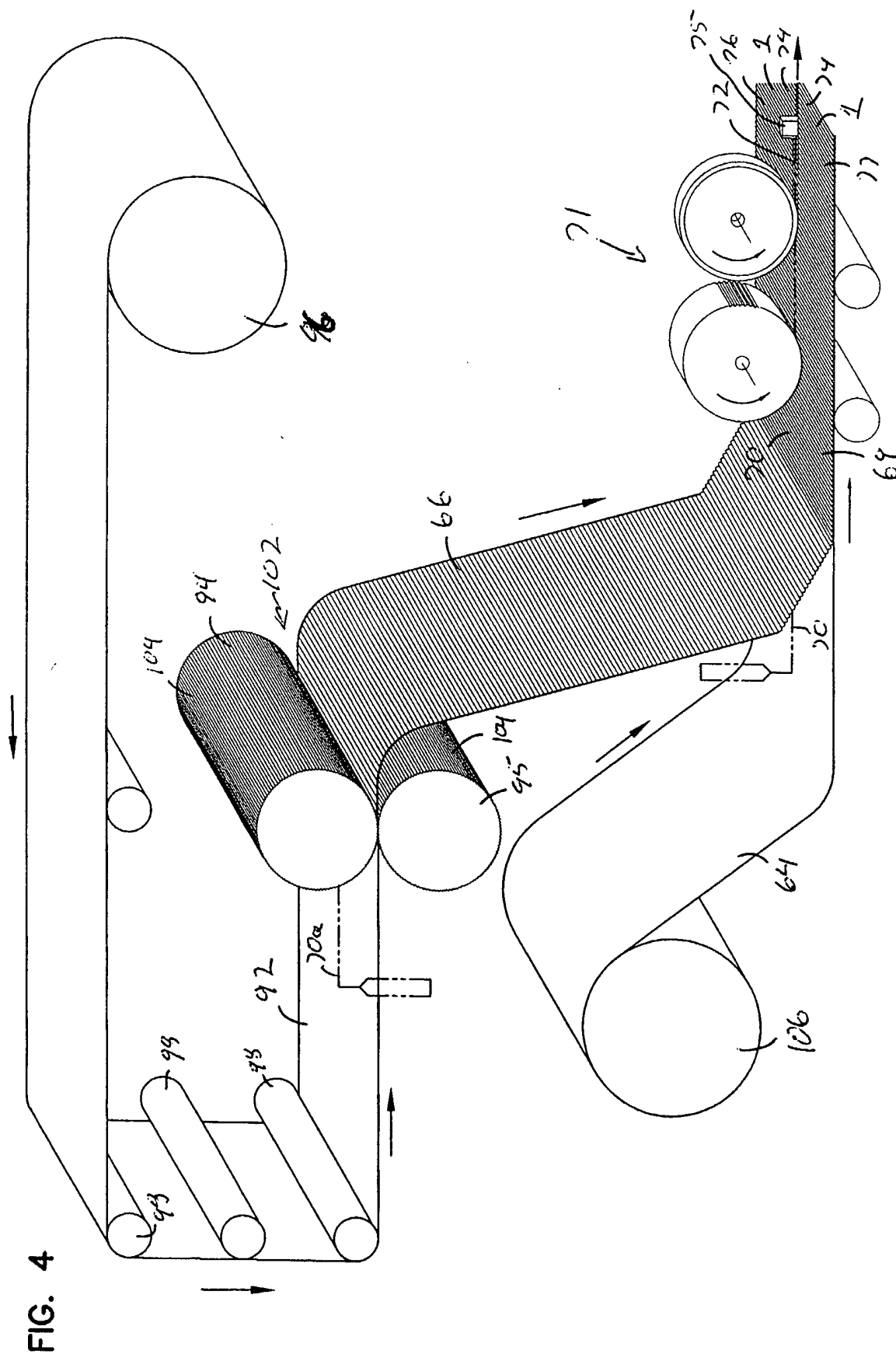


FIG. 3





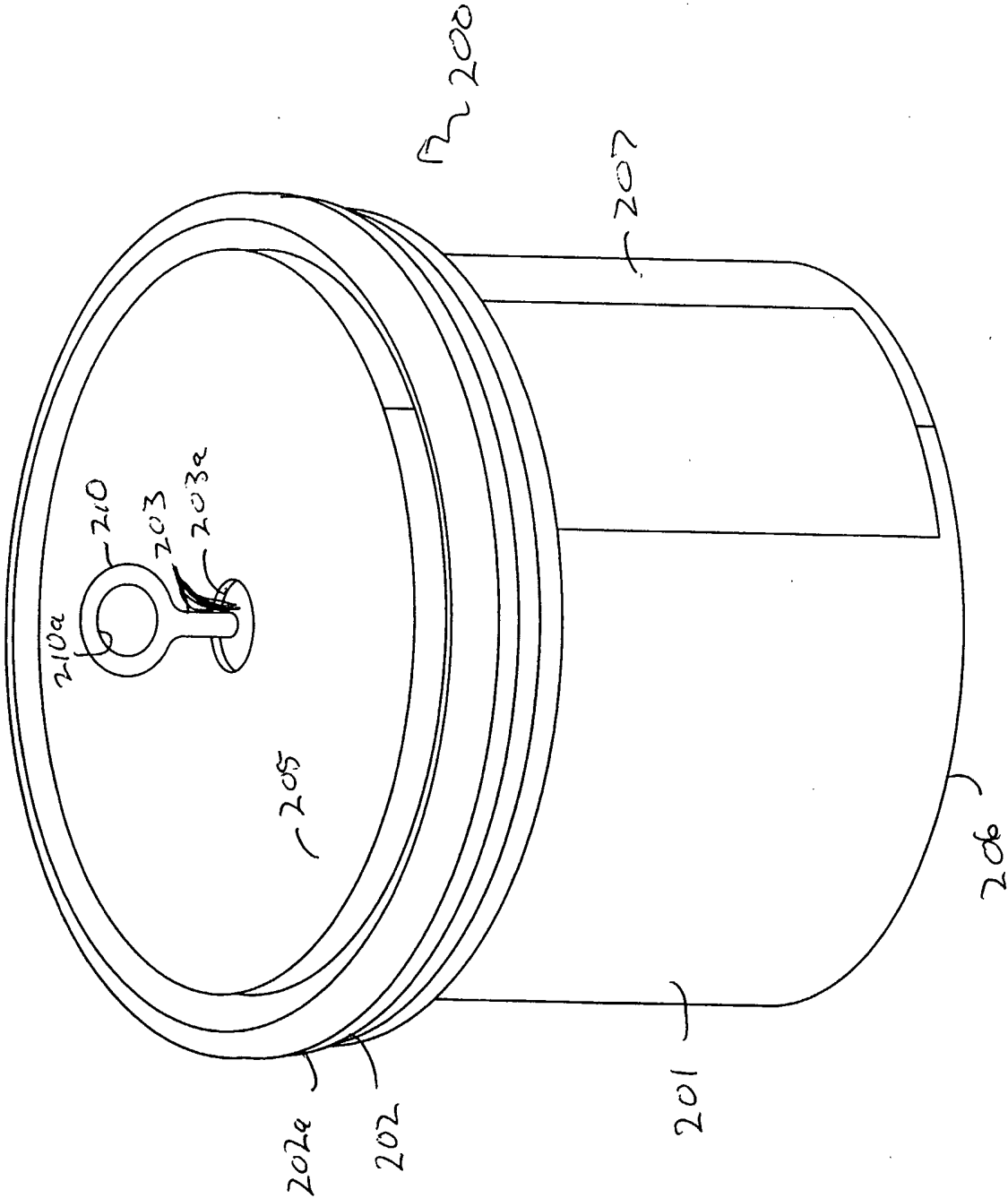
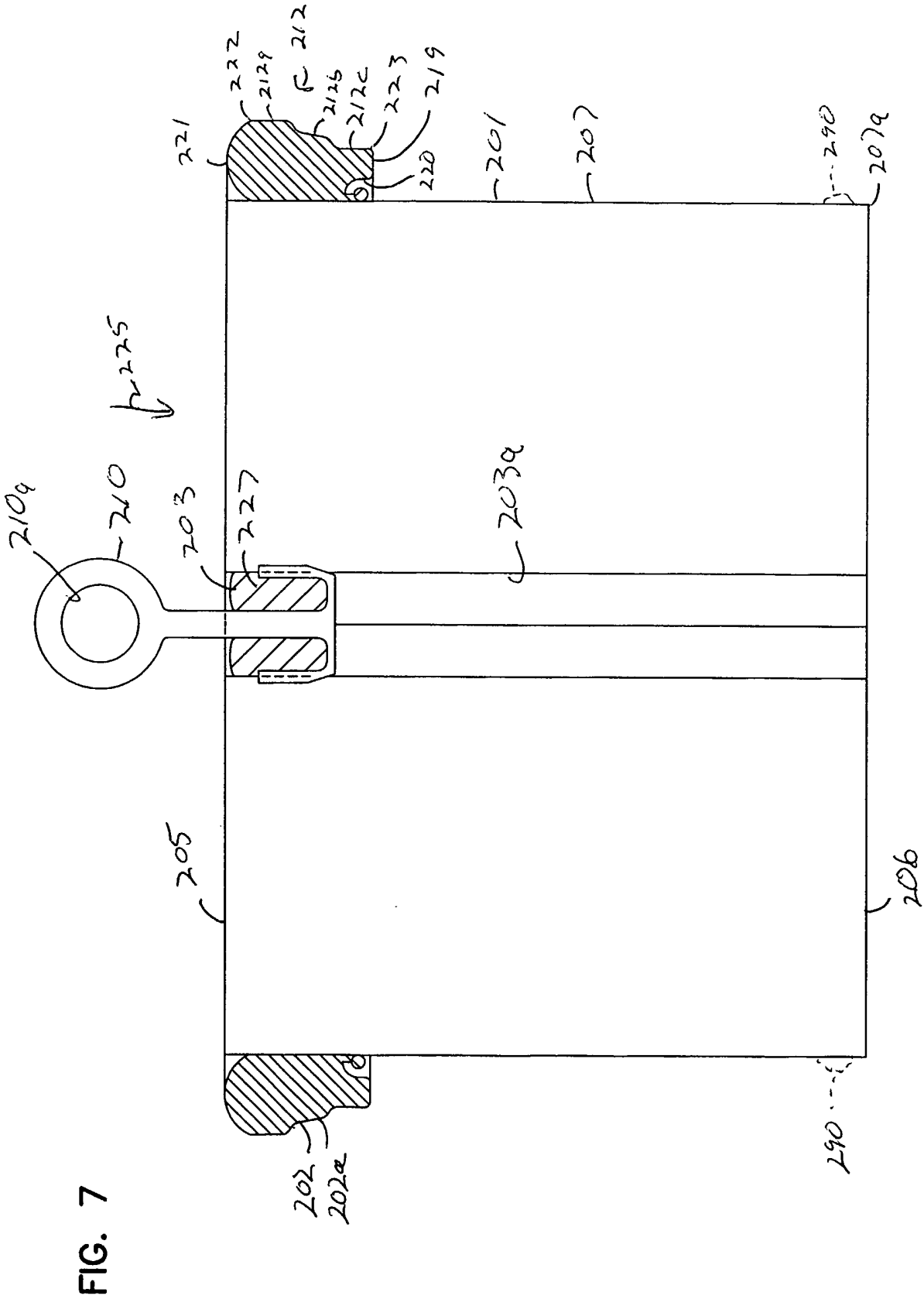


FIG. 6



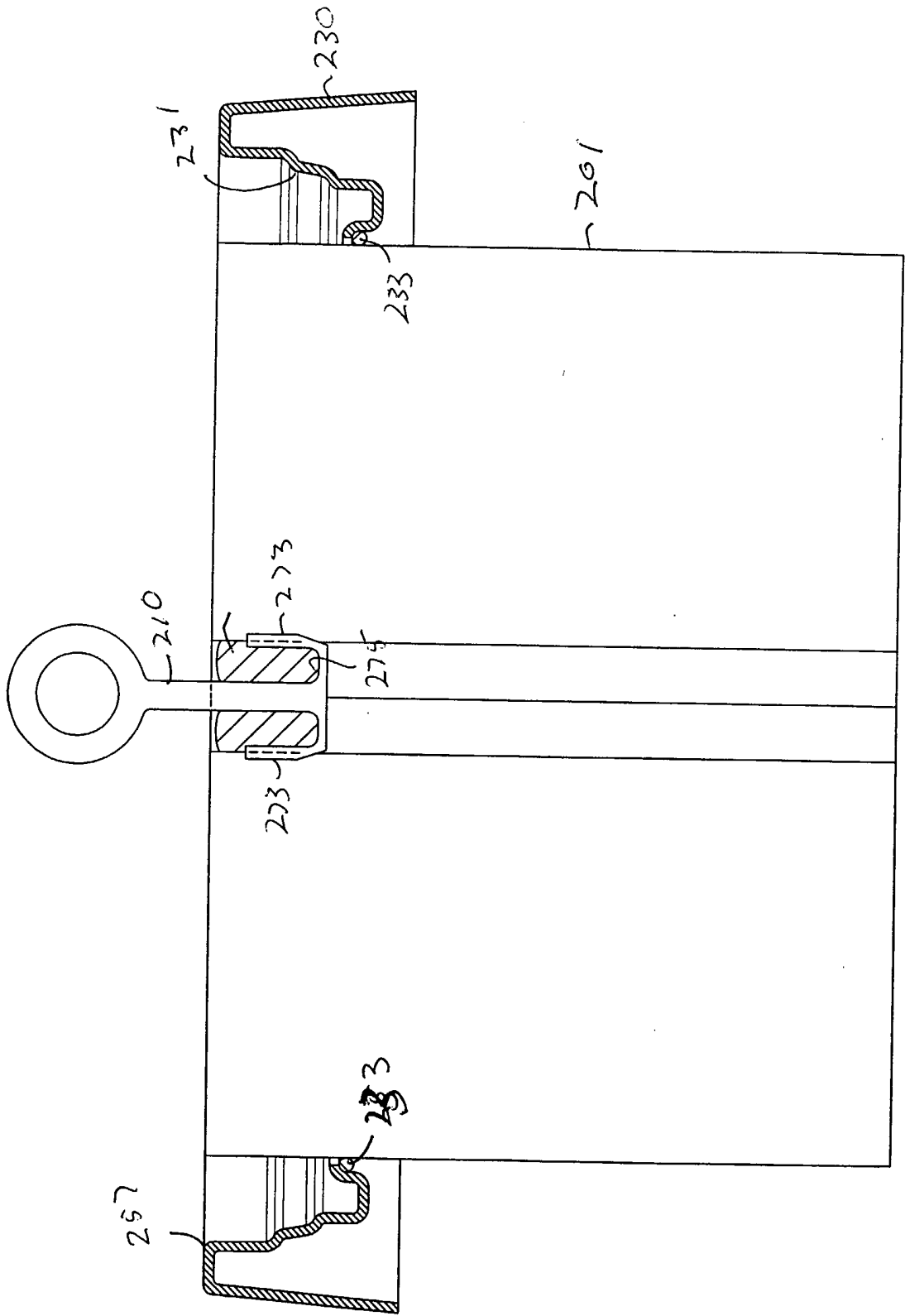


FIG. 8

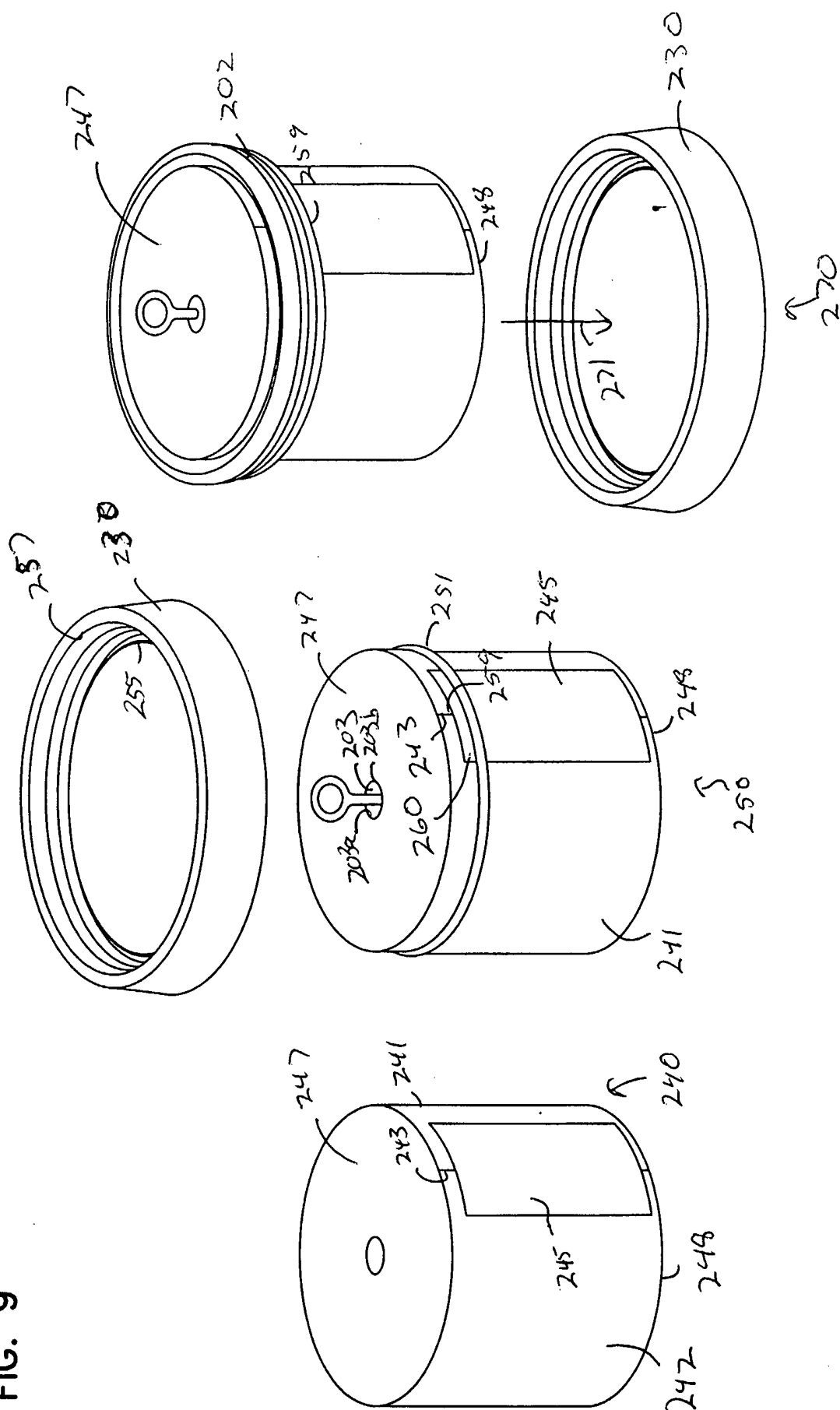


FIG. 9

FIG. 10

