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(54) **Title:** FILTER ELEMENT COMPRISING A WINDING CORE WITH A PRESSURE RELIEF NOTCH FORMED IN AT LEAST ONE SIDE THEREOF

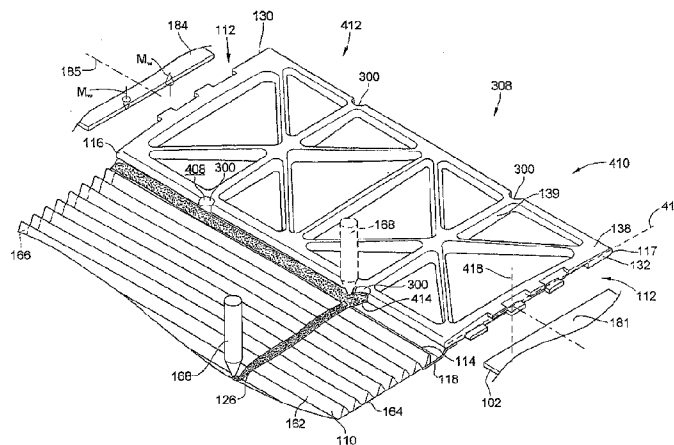


FIG. 16

(57) **Abstract:** A filter element including a winding core (308), a sheet of fluted filter media (110), a relief notch (300), and an adhesive. The winding core has a pair of ends (130, 132) spaced apart from each other and extending laterally between a pair of opposed sides (134, 136). The sheet of fluted filter media (110) is wound around the sides of the winding core (308). The relief notch is formed in one of the sides (134, 136) of the winding core. The adhesive (126) is received at least partially in the relief notch (300) and secures the fluted filter media (110) to the winding core (308). A method of making a filter element with a winding core having relief notches is also disclosed.



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FILTER ELEMENT COMPRISING A WINDING CORE WITH A PRESSURE RELIEF NOTCH FORMED IN AT LEAST ONE SIDE THEREOF

## FIELD OF THE INVENTION

**[0001]** This invention relates to fluid filters for removing particulate matter from a flow of fluid in liquid or gaseous form, including filters of the type used for filtering inlet air supplied to machinery such as engines and compressors.

## BACKGROUND OF THE INVENTION

**[0002]** In one commonly utilized form of a filter element, the filter element defines a longitudinal axis and first and second axial ends of the filter element, with the filter element including a central core, and a length of fluted filter media wound about the central core, with the flutes of the media oriented substantially longitudinal, to thereby provide for filtration of a flow of fluid passing axially through the filter element. Such filter elements are typically installed within a housing, or duct, in such a manner that the filter element can periodically be removed for cleaning or replacement with a fresh filter element. A seal between the filter element and the housing is typically provided, in such a manner that none of the fluid flowing through the housing can bypass the filter element, to thereby ensure that all fluid passing through the housing must enter one axial end of the filter element and exit from the opposite axial end of the filter element.

**[0003]** Where possible, filter elements of the type described above are typically formed into a right circular cylindrical shape, with the filter media being wound about a round central core. In some applications, however, it is necessary to form filter elements into non-cylindrical shapes, to fit space constraints of the particular application. For example, in a so-called "race track shaped" element, the cross-sectional shape of the filter element is race track shaped, having a pair of curved (in some embodiments, semi-circular, ends joined by a pair of straight segments). In such race track shaped filter elements, and in filter elements having other non-circular cross-sectional shapes, such as oval or rectangular, for example, the length of fluted filter material is wound about a non-circular central core. Such non-circular central cores may have cross-sections that are substantially rectangular in shape.

**[0004]** In one prior approach to providing a race track shaped filter element, as disclosed in U.S. Patents 7,001,450 B2; 6,746,518 B2 and 6,547,857 B2, to Gieseke et al., fluted filter media is coiled about a rectangular shaped center board. The center board

includes a corrugated region, which purportedly helps to hold the fluted media in place during winding of the filter element.

**[0005]** As is well known in the art, and stated in the patents to Gieseke, fluted filter media typically exhibits an inherent shape memory which can cause the media to bow outwardly, radially, away from the center board. In a filter element having a cylindrical central core, this inherent curvature memory is typically not problematic, in that the curvature of the media will not interfere with, and may actually assist in, pulling the media down onto the core, or onto a previously wound layer of the media. For cores in race track shaped elements, however, such as the center board used in the Gieseke patent, the inherent tendency of the filter media to bow outward may make it difficult to create a secure, tight, seal between the first layer of the media and the center board.

**[0006]** According to Gieseke, the corrugations of the center board alleviate this problem because the fluted media is better able to mate with and engage with the corrugations of the center board than with a flat surface. In practice, however, the corrugated section of the center board of Gieseke may, in fact, make it more difficult to achieve the desired fit between the first layer of fluid media and the outer surface of a non-cylindrical core, by interfering with the ability of the media to move freely while being pulled by a winding tensioning force across the surface of the core during the winding operation. In addition, fluted filter media, of the type typically used in such filter elements, is fabricated from layers of paper-like material by processes which are not amenable to accurate control of dimensional tolerances, with the result being that, in actual practice, the fluted media may not fit well into the corrugations of the center board, thereby causing an additional tendency of the first layer of media to be pushed outward away from the surface of the center board.

**[0007]** As a further difficulty, the corrugations of Gieseke must be closely matched to a given flute profile, thereby making it difficult to utilize different flute spacing and shapes with a given center board, which in turn can drive up inventory and manufacturing costs. Because filter elements of this type are often disposable, so that they may be readily replaced at appropriate intervals, additional manufacturing complexity and cost, resulting in increase replacement cost of the element, is highly undesirable and can be a significant detriment to successful competition in the marketplace.

**[0008]** Because the central core, in a wound filter element, is essentially a non-operating part of the completed filter, it is desirable that the central core be fabricated at minimal cost, utilizing as little material as possible, and have a configuration which can be readily

manufactured in a form that is also readily disposable or incinerable. It is also desirable, in some applications, that the central core be fabricated in a manner which is as light in weight as possible. The center board of the Gieseke patent does not meet these requirements. Although the center board of Gieseke includes a number of holes extending through the thickness of the center board, the center board of Gieseke includes considerable surplus material. This condition is exacerbated by the inclusion of the corrugated section.

**[0009]** The center board of Gieseke also discloses a cutout, at one end of the center board, to be held by a spindle during winding of the filter element. The configuration of the cutout of Gieseke is an inefficient drive mechanism, in that the winding torque from the spindle is apparently applied only to the sidewalls of the cutout, which are located closely adjacent to the winding axis and essentially formed by the thickness of the center board. Such an inefficient drive mechanism may make it difficult to apply sufficient winding torque, without damaging the center board, to maintain a winding tension in the filter media which is high enough to pull the media into intimate contact with the outer surface of the center board or previously wound layers of media.

**[0010]** Another prior approach to forming a race track shaped filter element is shown in U.S. Patent Nos. 7,008,467 B2 and 6,966,940 B2, to Krisko et al. Krisko uses a core construction including a race track shaped non-cylindrical, imperforate, wall member, having opposing walls defining an open volume within the imperforate non-cylindrical member. In cross section, the non-cylindrical member has the appearance, generally, of a flattened cylindrical-shaped tube having flat opposing side walls joined at opposite ends by curved walls, surrounding the open volume. The opposing walls and ends of the non-cylindrical member of the core construction of Krisko are imperforate. The core construction of Krisko further includes structural moldings and plugs located within the open volume, for providing strength, and axially closing off the open volume to ensure that fluid cannot leak through the open volume inside of the non-cylindrical member.

**[0011]** The central core construction of Krisko is even more complex than the center board of Geiseke, as described above. The core construction of Krisko also appears to include a substantial volume of excess material, making such a core construction undesirably expensive to produce and heavier than necessary. The core construction of Krisko also results in a significant amount of extra material which must be disposed of or incinerated when the filter element is replaced.

[0012] It is desirable, therefore, to provide an improved method and apparatus for manufacturing a fluid filter element having filter media wound about a non-cylindrical central core, in a manner which overcomes one or more of the problems discussed above, and/or providing improved utility over the prior art.

#### BRIEF SUMMARY OF THE INVENTION

[0013] In one aspect, a filter element including a winding core, a sheet of fluted filter media, a relief notch, and adhesive is provided. The winding core has a pair of ends spaced apart from each other and extending laterally between a pair of opposed sides. The sheet of fluted filter media is wound around the sides of the winding core. The relief notch is formed in at least one of the sides of the winding core. The adhesive is received at least partially in the relief notch. The adhesive secures the fluted filter media to the winding core.

[0014] In another aspect, a method of forming a filter element is provided. The method includes securing a fluted filter media and a winding core to each other and directing adhesive into a reservoir disposed between the winding core and the fluted media. The method also includes winding the fluted filter media about the winding core and expanding the adhesive within the reservoir. As such, the adhesive engages both the winding core and the fluted filter media and prevents a leak path from forming through the filter element.

[0015] In yet another aspect, a method of forming a filter element is provided. The method includes taping a winding core and a fluted filter media together using tape and applying adhesive between the winding core and the fluted filter media lengthwise along the tape. The method also includes dispensing adhesive into a reservoir formed by the winding core, the fluted media, and the tape. The method further includes dispensing adhesive across the fluted filter media in a direction transverse to flutes in the fluted filter media and winding the fluted filter media about the winding core. The method also includes foaming the adhesive within the reservoir until the adhesive engages the winding core, the fluted media, and the portion of the tape.

[0016] Other aspects, objectives and advantages of the invention will be apparent from the following detailed description taken in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

- [0017] The accompanying drawings incorporated in and forming a part of the specification illustrate several aspects of the present invention and, together with the description, serve to explain the principles of the invention. In the drawings:
- [0018] FIG. 1 is a perspective illustration of an exemplary embodiment of a filter element, according to the invention having a length of fluted filter media wrapped about a winding frame;
- [0019] FIGS. 2–5 are orthographic views of the winding frame of the exemplary embodiment of the filter element shown in FIG. 1;
- [0020] FIG. 6 is a perspective view of an exemplary embodiment of a winding feature of the winding frame shown in the exemplary embodiment of the filter element of FIG. 1;
- [0021] FIGS. 7 and 8 are alternate embodiments of a winding feature, in accordance with the invention, of a winding frame according the invention;
- [0022] FIGS. 9–11 are illustrations of the attachment of leading and trailing edges of the filter media to a leading edge and a trailing edge, respectively, of the winding frame in the exemplary embodiment of the filter element shown in FIG. 1;
- [0023] FIG. 12 is a perspective illustration of details of construction of the exemplary embodiment of the filter element shown in FIG. 1;
- [0024] FIG. 13 is a rolled-out illustration of the manner of applying a bead of adhesive/sealant during construction of the exemplary embodiment of the filter element shown in FIG. 1; and
- [0025] FIG. 14 is an alternate embodiment of an apparatus for constructing the exemplary embodiment of the filter element shown in FIG. 1.
- [0026] FIG. 15 is an orthographic view of one embodiment of the winding frame used to construct a filter element as shown in FIG. 1;

[0027] FIG. 16 is a perspective illustration of details of construction of a filter element as shown in FIG. 1 using the winding frame of FIG. 15;

[0028] FIG. 17 is a cross section of the winding frame of FIG. 15;

[0029] FIG. 18 is a rolled-out illustration of the manner of taping the winding frame to the fluted filter media and applying a bead of adhesive/sealant during construction of a filter element as shown in FIG. 1 using the winding frame of FIG. 15; and

[0030] FIG. 19 is an illustration of a step in the construction of a filter element as shown in FIG. 1 using the winding frame of FIG. 15 where the winding frame has been pivoted onto the fluted filter media.

[0031] While the invention will be described in connection with certain preferred embodiments, there is no intent to limit it to those embodiments. On the contrary, the intent is to cover all alternatives, modifications and equivalents as included within the spirit and scope of the invention as defined by the appended claims.

#### DETAILED DESCRIPTION OF THE INVENTION

[0032] FIG. 1 shows a first exemplary embodiment of the invention in the form of a filter element 100 defining a longitudinal axis 102 and first and second axial ends 104, 106 of the filter element 100. The exemplary embodiment of the filter element 100 includes a winding frame 108, and a length of fluted filter media 110 wound about the frame 108, with the flutes of the fluted filter media being oriented substantially longitudinally to the longitudinal axis of the filter element 100, to thereby provide for filtration of a flow of fluid passing axially through the filter element 100.

[0033] As shown in FIGS. 1-7, and described in more detail below, the winding frame 108 of the exemplary embodiment 100 of the filter element is a substantially open, truss-like structure, having a smooth advantageously shaped outer periphery, allowing the media 110 to be effectively pulled into intimate contact with the outer periphery of the winding frame 100 by a winding tension force applied to the media 110, during construction of the filter element 100. The frame 108 also includes a pair of winding features 112, extending substantially axially outward from opposite axial ends of the frame 108, and configured in a manner allowing a winding torque to be applied to the frame 108, for rotation of the frame about a winding axis extending substantially parallel to the longitudinal axis 102 of the filter

element, as the media 110 is wound onto the frame 108. As will be understood from the detailed description below, the winding features 112 of the winding frame 108 of the exemplary embodiment of the filter element 100 are configured to interface with a driver element of a winding machine in a manner facilitating attachment and alignment of the winding frame 108 with the driver, and for allowing a winding torque from the driver to be transmitted more efficiently and effectively to the winding frame 108 than was achievable with the center boards and core constructions of prior filter elements.

**[0034]** As shown in FIGS. 9-14, and described in greater detail below, a leading edge 114 of the length of fluted filter media 110 is joined to a leading edge 116 of the winding frame 108 by a length of securing tape 118. The leading edge 114 of the fluted filter media 110 is cut on a peak 120 of the fluted media 110, to create a half peak 122 of the media 110 opening outward toward the leading edge 114 of the media. The half peak 122 is filled with a bead of adhesive sealant 124, to preclude leakage of fluid longitudinally through the half peak 122 from the first to the second axial ends 104, 106 of the filter element 100. The filter media 110 is further secured and sealed to the frame 108, and between successive layers of the filter media 110 by an additional bead of adhesive/sealant 126, applied in a manner described in more detail below.

**[0035]** As will be understood, by those having skill in the art, utilization of a winding frame, in accordance with the invention, for constructing a filter element, provide significant advantages over the prior art, for fabricating a filter element in an efficient and effective manner without resorting to counter-productive machinations, such as the corrugated bearing surface of the center board or complex core constructions utilized in the prior art.

**[0036]** It is contemplated that, in practicing the invention, fluted filter media of conventional construction, as described, for example, in U.S. Patent No. 3,025,963 to Bauer, unconventional fluted filter media of the type described in commonly assigned U.S. Patent Applications No. 10/979,390 to Driml, et al., and 10/979,453 to Merritt, et al., for example, or any other appropriate type of fluted filter media, may be utilized, with the disclosure and teachings of the aforementioned patent to Bauer and applications to Driml and Merritt being incorporated herein in their entireties by reference.

**[0037]** As shown in FIGS. 2-4, the winding frame 108 defines a frame axis 128 extending substantially parallel to the longitudinal axis 102 of the filter element 100. The frame 108 further defines first and second oppositely facing axial ends 130, 132 of the

winding frame 108, disposed at opposite ends of the winding frame 108 along the frame axis 128. The winding frame 108 further defines a length "L", width "W" and thickness "T" of the winding frame 108, with the length L extending substantially along the frame axis 128 between the first and second axial ends 130, 132 of the frame 108, the width W extending substantially orthogonally to the frame axis 128, and the thickness T extending substantially orthogonally to both the frame axis 128 and the width W of the winding frame 108.

**[0038]** The winding frame 108, of the exemplary embodiment of the filter element 100, includes first and second longitudinally extending side rails 134, 136, joined in a transversely spaced relationship to one another and the frame axis 128 by a plurality of cross members 138-140, 143, 144, 146, 148, 150, extending transversely to the frame axis 128 across the width W of the winding frame 108. As shown in FIG. 2, several of the cross members 138, 139, 140, 142, 143, extend generally perpendicularly to the side rails 134, 136 and frame axis 128. Other cross members 144, 146, 148, 150, extend transversely between the first and second side rails 134, 136 in an angular relationship to the side rails 134, 136 and frame axis 128.

**[0039]** As will be appreciated, from an examination of FIG. 2, the arrangement of the side rails 134, 136 and cross-members 138, 139, 140, 142, 143, 144, 146, 148, 150, are joined together to form a truss-like structure defining a plurality of open areas 152 disposed between the side rails 134, 136 and extending through the thickness T of the frame 108. The truss-like structure of the frame 108 provides for a very efficient and effective use of the material, from which the frame 108 is fabricated, in a manner providing a structure which is significantly lighter in weight than the center boards or core constructions of prior filter elements, to thereby reduce manufacturing costs providing better utilization of scarce natural resources, and also providing a structure which is more amenable to recycling and incineration than the center boards and core constructions of prior filter elements.

**[0040]** As shown in FIGS. 3 and 5, the frame thickness T has a substantially oval cross section, having a maximum sectional thickness between the side rails 134, 136 and converging to a lesser sectional thickness at each side rail 134, 136. The cross section of the frame 108 defines a substantially smooth outer peripheral surface 154 having opposed central sections 156 of larger radius "R" disposed between the side rails 134, 136, joined by straight sections 158 to small radius "r" sections 160 forming outer longitudinally extending edges of the side rails 134, 136.

**[0041]** As shown in FIGS. 9 and 12, one of the edges 160 of the frame 108 forms the leading edge 116 of the frame 108, and the other edge 160 of the frame 108 forms a trailing edge 117 of the frame 108. When joining the media 110 to the frame 108 with the tape 118, the leading edges 114, 116 of the media 110 and frame 108 are positioned at a selected spaced distance "d", prior to joining the media 110 to the frame with the tape 118, with the particular spaced distance d being selected in such a manner that the leading edge 114 of the media 110 is brought into contact with the outer peripheral surface 154 of the frame 108 without the media 110 being wrapped around the leading edge 160 of the frame 108, as the frame 108 is rotated about a winding axis substantially coincident with the frame axis 128 and longitudinal axis 102 of the filter element 100. Specifically, as shown in FIG. 10, it is preferred that the spacing d between the leading edges 114, 116 of the media 110 and frame 108 be such that the tape 118 wraps around the edge 160 of the frame in a manner allowing the leading edge 114 of the media 110 to come into contact with the outer peripheral surface 154 of the frame 108 along the straight section 158 or the large radius curve section 154 of the frame 108. By virtue of this arrangement, the need for bending the media 110 around the leading edge 116 of the frame is eliminated, with the tape 118 providing a secure attachment of the media to the frame in such a manner that a relatively high winding tensile force  $F_T$  may be applied to the media 110 during the winding operation, in order to ensure that the media 110 is pulled into intimate contact with the winding frame 108 as the first layer of media 110 is applied, and into intimate contact with a previously wound layer of media 110 as the winding process continues.

**[0042]** As shown in FIG. 12, in the exemplary embodiment of the filter element described herein, the filter media 110 includes an undulating sheet 162 of porous filter material joined to a backing sheet 164. The spaces between the undulating sheet 162 and backing sheet 164 at the end of the length of filter media 110 adjacent the first end 104 of the filter element and leading edge 116 of the winding frame 108 are filled with a bead of adhesive/sealant 166, as indicated by dashed lines in FIG. 12, in the manner known in the art.

**[0043]** As shown in FIGS. 11-13, as the media 110 is wound onto the frame 108, a second bead of adhesive 126 is applied adjacent the second end 106 of the filter element 108 and 112 of the frame, in such a manner that flutes of the filter media 110 which are not sealed by the bead of adhesive 166 at the first end 104 of the filter are sealed by the second bead of adhesive 126 adjacent the second end of the filter element 100. As is well understood in the art, by virtue of this arrangement, adjacent flutes of the filter media 110 are blocked at opposite ends thereof by the first and second beads of adhesive sealant 166,

162 in such a manner that fluid entering one of the ends 104, 106 of the filter element must pass through the porous filter material of the undulating sheet 162, or the backing sheet 164 where the backing sheet is also made of porous filter material, into an adjacent flute in order to exit the filter element 100 at the opposite end 104, 106 thereof. In passing through the porous filter material in this manner, particulate matter is removed from the fluid and trapped within the filter media 110.

**[0044]** As shown in FIGS. 2, 12 and 13, one cross member 139 of the frame 108 is spaced inward from the second axial end 132, and is adapted for receiving the bead 126 of adhesive sealant during the first revolution of the frame 108, as the first layer of media 110 is being wound onto the frame 108. As indicated in FIG. 9, and in the rolled-out view of FIG. 13, the bead 126 of adhesive sealant is applied by an applicator 168.

**[0045]** As shown in FIGS. 11-14, in the exemplary embodiment 100, the applicator 168 is initially positioned at a distance from the second end of the frame 108 substantially equal to the distance at which the cross member 139 is spaced from the second end 132. The applicator 168 begins dispensing the bead 126 of adhesive/sealant onto the cross member 139, adjacent the trailing edge 117 of the winding frame 108, as shown in FIG. 13, at a first axial location 170, as indicated in FIG. 13. The applicator 168 then moves longitudinally across the frame 108 and along the media 110 a distance  $2W$ , which is substantially equal to twice the width  $W$  of the frame 108, while continuing to dispense the bead of adhesive/sealant 126. In this manner, the bead of adhesive/sealant 126 is initially applied across the cross member 139 of the frame 108, in such a manner that a double-thick bead of adhesive/sealant is applied along the upper side (as shown in FIGS. 11-14) of the cross member 139 of the frame 108, and a single bead of adhesive sealant is applied along the lower side (as oriented in FIGS. 11-14) of the cross member 139 of the frame 108, as the frame 108 is rotated about the frame axis 128 to begin winding the media 110 onto the frame 108.

**[0046]** As indicated in FIG. 13, after wrapping the media 110 at least once completely about the frame 108, the applicator 168 moves axially toward a second axial position 172 in such a manner that the bead of sealant 126 substantially traces a pattern, shown in the rolled-out view of FIG. 13, onto the media 110.

**[0047]** This approach to applying the bead of sealant 126 is utilized in recognition of the fact that it is difficult to control the flow of adhesive sealant 126 through the applicator 168 from the moment that the flow of adhesive sealant 126 is initiated. By initially applying the

bead of adhesive sealant 126 to the cross member 139, rather than attempting to apply it initially to the cross member 138 of the frame 108, the initial uncertainty in the flow rate of the adhesive sealant 126 through the applicator 168 need not be reckoned with further, in order to ensure that the adhesive sealant 126 is not squeezed out of the second end 104 of the filter element between layers of media 110 in a manner that might lead to plugging the open flutes at the second end 106 of the filter element 100. It is desirable, however, to have the second bead of adhesive sealant 126 be primarily located at a second axial position as near as possible to the second end 106 of the filter element 100 to maximize the length of the flutes in the filter element available for passage through the walls thereof of the fluid as it traverses the filter element from one end to the other thereof.

**[0048]** It will be understood, by those having skill in the art, that in other embodiments of the invention, in practicing the invention, the bead of adhesive/sealant 126 may be applied using alternate techniques and apparatuses, consistent with the configuration and desired results described herein. For example, as shown in FIG. 9, in alternate embodiments of the invention, the applicator 168 can alternatively be initially positioned above the tape 118, rather than above the cross member 139, at a distance from the second end of the frame 108 substantially equal to the distance at which the cross member 139 is spaced from the second end 132. The applicator 168 may then begin dispensing the bead 126 of adhesive/sealant onto the tape 118, as shown in FIG. 9, and continue dispensing the bead of adhesive/sealant 126 as the frame 108 is rotated about the frame axis 128. In this manner, the bead of adhesive sealant 126 is initially applied across the cross member 139 of the frame 108, as the cross member 139 is brought into contact with the bead of adhesive sealant 126 previously deposited onto the tape 118 and/or the surface of the media 110, as the frame 108 is rotated about the frame axis 128 to begin winding the media 110 onto the frame 108. The position of the applicator 168 may also be moved transversely and/or longitudinally, in a manner similar to that shown in FIG. 13, to move the location of the bead of adhesive/sealant 126 closer to the second end 106 of the filter element 100, as described above in relation to the exemplary embodiment 100.

**[0049]** As shown in FIG. 11, it is desirable to have the contour of the trailing edge 117 of the frame 108 be configured in such a manner, that as the media 110 is wrapped under winding tension  $F_T$  around the frame 108, the peaks 120 of two or more adjacent flutes of a first layer of the filter media 110 are tightly pulled against the outer peripheral surface 154 of the winding frame 108 in such a manner that the media 110 closely embraces and essentially grips the small radius section 160 at the trailing edge 117 of the frame 108. In this regard, it is desirable to have the particular configuration of the edge 160 of the winding

frame 108 coordinated with the pitch spacing of the peaks 120 of the media 110, in such a manner that the media 110 can be pulled down into intimate contact with the outer peripheral surface 154 of the frame 108 during application of the first winding layer.

**[0050]** It will be noted, by those having skill in the art, that, by virtue of the fact that the tape 118 at the leading edge 116 of the frame 108 is very thin in comparison to the thickness of the media 110, as the media 110 is further wrapped over the tape 118 at the leading edge 116 of the frame, the second layer of media 110 will lay very tightly and neatly against the outer surface of the first layer of media 110. It will be further noted, that by beginning the feed of adhesive sealant 126 onto the surface of the tape 118 in the distance *d* between the leading edges 114, 116 of the media and the frame 108, any excess amount of adhesive sealant 126 initially expressed by the applicator 168 will spread longitudinally along the side rail (134 or 136) forming the leading edge 116 of the frame 108 in a manner creating a smooth transition between the tape 118 and the leading edge 114 of the media 110 as it is wrapped onto, and pulled tight against, the outer peripheral surface 154 of the winding frame 108.

**[0051]** Those having skill in the art will recognize that, by virtue of the arrangement described above, the media 110 may be pulled along the smooth outer peripheral surface 154 of the winding frame 108 in a sliding motion leading to a significantly tighter fit between the media and the winding frame 108 than can typically be achieved in prior filter elements having other types of center boards and/or core constructions, and in particular a tighter fit than can be achieved by those center boards having varying areas including corrugated or other surface treatments to engage the flutes of the filter media being used to form the filter element. It will yet further be recognized, that the method of attachment of the leading edge 114 of the filter media to the leading edge 116 of the frame with the longitudinally oriented strip of tape 118, particularly in combination with the manner in which the media is caused to closely embrace and grip the trailing edge 117 of the frame 108 that the attachment between the filter media 110 and frame 108 that is achieved through practice of the present invention provides a substantially stronger attachment than is achieved in prior filter elements, such that a higher winding tensile force  $F_T$  may be utilized in forming a filter element, according to the invention, thereby further facilitating construction of a filter element 100, according to the invention.

**[0052]** As best shown in FIGS. 2, 3 and 6, the winding features 112, of the winding frame 108 of the exemplary embodiment of the filter element 100, extend substantially axially outward from cross members 138, 143 respectively forming the first and second

axial ends 130, 132 of the frame 108. The winding features 112 at the first and second axial ends 130, 132 of the frame 108 are essentially identical but face in opposite axial directions. Accordingly, the winding feature 112 at the second end of the frame 108 will be specifically described, but it is understood that the winding feature 112 at the first end 130 of the frame 108 is of substantially identical configuration. It will be noted, however, that in other embodiments of the invention, winding features at opposite ends of the frame need not be identical, that a winding feature may be provided at only an axial end of the frame.

**[0053]** The winding feature 112 at the second end 138 of the frame 108, as shown in FIGS. 2-4 and 6, is formed by a plurality of lugs which, in combination define a pair of guide surfaces 178, 180 extending substantially along the width  $W$  of the frame 108 in a manner allowing the guide surfaces 178, 180 to slide over corresponding driving surfaces 181, 182 of a pair of drivers 184 of a winding machine (not shown) for applying a driving torque through the drivers 184 to the frame 108 in a manner generating a winding moment to the guide surfaces 178, 180 directed substantially orthogonally to the frame axis 128 and the width  $W$  of the frame 108, as indicated by arrows  $M_w$  in FIGS. 3 and 12. By applying the winding moment  $M_w$  in this manner across the width  $W$  of the frame rather than substantially across the thickness of the frame as in prior art filters having a notched center board, a higher winding moment and resulting winding torque can be utilized for winding the media 110 onto the frame 108, which thereby causes a higher winding tensile force  $F_T$  to be utilizable to facilitate construction of the filter element 100. As shown in FIGS. 3 and 6, one of the lugs 176 of the winding feature 112 of the exemplary embodiment of the winding frame 108 is further configured to define a stop 186 for engaging the drivers 184, to thereby position the frame axis 128 substantially coincident with the drive axis 185 when the stop 186 is substantially abutting the driver 184.

**[0054]** As will be understood, by those having skill in the art, a driving feature 112, according to the invention, may take a variety of forms, within the scope of the invention, other than the one described above in relation to the exemplary embodiment of the filter element 100. For example, fewer or more lugs may be utilized for forming the winding feature, in the manner illustrated in FIGS. 7 and 8 which show two alternate embodiments. It will also be appreciated that a winding element, according to the invention, and methods for forming and/or utilizing a winding element according to the invention, may also be used in core structure other than the frame-like core 108 described herein with regard to the exemplary embodiment of the filter element 100.

[0055] The particular embodiment of the winding feature 112 selected for the exemplary embodiment shown in FIGS. 1-6 was selected because it provides the advantage of allowing the winding frame 108 to be formed in a two piece mold (not shown) having a parting plane 188 extending through the width W of the frame 108 to effectively divide the thickness T of the frame 108 in such a manner that the frame 108 has a parting line 190 coincident with the parting plane 188. In this manner, the embodiment shown in FIG. 6 is more readily moldable, utilizing only a two-piece mold, than the embodiment shown in FIGS. 7 and 8 which would require a mold having additional pieces to form the winding features as illustrated in FIGS. 7 and 8.

[0056] As shown in FIG. 14, it may be desirable, in some embodiments of the invention, to have the drivers 184 include notches 191 therein, corresponding to the particular configuration of the winding feature 112, in such a manner that the winding frame 108 need not be moved slidably as far in a lateral direction to engage the drivers 184 and position the frame 108 with respect to the drive axis 185. As further shown in FIG. 14, it may be desirable to provide some sort of rotatable guide 200 at each end of the filter element 100, perhaps as part of a winding mandrel assembly (not shown), in order to facilitate guidance of the media 110 onto the frame 108 during construction of the filter element 100.

[0057] In the exemplary embodiment of the filter element 100, it will be noted that the media 110 has a lateral width, in the direction of the longitudinal axis 102 of the filter element 100, which extends beyond the first and second ends 130, 132 of the frame 108, with the distal ends of the lugs 176 of the winding features 112 being disposed substantially flush with the lateral edges of the filter media 110 at the axial ends 104, 106 of the filter element. By virtue of this arrangement, the volume of active filter media 110 is maximized, for a given axial length of the filter element 100. With this arrangement, however, it is not possible to slide the completed filter element 100 off of the drivers 184 in a direction opposite to that in which the frame 108 was slidably installed onto the drivers 184 prior to winding the filter media 110 around the frame 108. It is contemplated therefore that, in accordance with a method for practicing the invention, subsequent to wrapping the media 110 about the frame 108, the filter element 100 is released from the drivers 184 by moving one or both of the drivers 184 axially along the drive axis 185 away from the filter element 100.

[0058] Referring now to FIG. 15, an alternative embodiment of the frame 108 from FIG. 12 is illustrated as frame 308. As used herein, when referring to frame 108 and frame

308, the term “frame” also includes, but is not limited to, a winding core, a winding board, a winding member, a winding structure, a core structure, a truss having open spaces therein, and other components suitable for winding a fluted filter media 110 to construct a filter element 100. Because frame 108 and frame 308 share common components and characteristics in many cases, like reference numerals have been employed to refer to like features in the figures featuring frame 308, namely FIGS. 15-19. Like frame 108 shown in FIG. 12, frame 308 depicted in FIG. 15 is also used to form a filter element 100 similar to that illustrated in FIG. 1. However, as will be more fully explained below, frame 308 also includes a plurality of relief notches 300 whereas frame 108 does not.

**[0059]** Referring to FIG. 15, the relief notches 300 are generally formed in the side rails 134, 136 of the frame 308. As shown in both FIGS. 15 and 16, the relief notches 300 extend generally inwardly into the side rails 134, 136 from the radius section 160 (a.k.a., the distal portion of the side rails) of the frame 308. The relief notches 300 also extend entirely through the opposing faces 400, 402 of the frame 308. As such, the relief notches 300 define a peripheral surface 408 that, in general, opens outwardly away from the remainder of the frame and forms an indent or pocket in the side rails 134, 136 of the frame 308.

**[0060]** In the illustrated embodiment of FIG. 15, the relief notches 300 have a curved profile when viewed from one of the opposed faces 400, 402. In particular, each of the relief notches in FIG. 15 generally forms a semi-circle when the frame 308 is viewed from above or below. Despite what is depicted in the illustrated embodiment of FIG. 15, the relief notches 300 may be any shape suitable for receiving an amount of adhesive 126 therein, as will be more fully explained below. For example, the relief notches 300 in the frame may form a portion of a square, a rectangle, an ellipse, and the like. In addition, the relief notches 300 may have an irregular or non-symmetrical shape.

**[0061]** As shown in the illustrated embodiment of FIG. 15, the relief notches 300 are generally aligned with each other across the frame 308 and arranged in pairs. One pair of the relief notches 300 is disposed on an upper half 410 of the frame 308 (as oriented in FIG. 15) and separated by cross rail 139 while another pair of the relief notches is disposed on a lower half 412 of the frame 308 (as oriented in FIG. 15) and separated by cross rail 142. Each relief notch 300 on the upper half 410 of the frame 308 is equally spaced apart or offset from the axial end 132. Likewise, each relief notch 300 on the lower half 412 of the frame 308 is equally spaced apart or offset from the axial end 130. As such, the relief notches 300 on the side rail 134 are positioned along the length “L” of the frame 308 (for

reference, see “L” as is depicted in FIG. 2) the same as the relief notches 300 on the side rail 136.

**[0062]** Despite the particular location and orientation of the relief notches 300 in FIG. 15, the relief notches may be formed in the side rails 134, 136 at various positions along the length “L” of the winding frame 308. The relief notches 300 need not be provided on the winding frame 308 in pairs and, if desired, a single relief notch 300 or an odd number of relief notches 300 may be formed in the frame 308 if required by a particular application.

**[0063]** The relief notches 300 have a depth 404 that extends generally in a direction between the opposed side rails 134, 136. The depth 404 may vary as desired, but should be sufficient to permit adhesive 126 to be suitably directed into the relief notches 300. In the illustrated embodiment of FIG. 15, the depth 404 of the relief notches 300 is about one half of a thickness 406 of the winding core 308 measured between the pair of opposed faces 400, 402 adjacent the relief notches 300, as shown in FIG. 17. If needed for a particular application, the open areas 152 can be reduced in size and/or the cross members 139, 142 may be made thicker in order to permit enlargement of the relief notches 300. For example, the open areas of the frame 308 may be eliminated altogether such that the frame 308 is a solid winding board having one or more relief notches therein.

**[0064]** Referring now to FIGS. 16 and 18-19, to construct a filter element 100 similar to that shown in FIG. 1, the fluted filter media 110 is secured to the frame 308. In the illustrated embodiment of FIG. 16, the leading edge 114 of the fluted filter media 110 is secured to the leading edge 116 of the frame 308 using a length (a.k.a., a strip) of securing tape 118. Thereafter, the applicator 168 dispenses a suitable amount of adhesive 126 lengthwise along the securing tape 118 between the fluted filter media 110 and the frame 308. When the applicator 168 reaches the relief notch 300 on the upper half 410 of the frame 308 proximate the strip of securing tape 118, the applicator 168 directs a suitable amount of the adhesive 126 into a reservoir 414 formed by the relief notch 300, the fluted filter media 110, and the securing tape 118. As shown, the adhesive 118 is generally situated between the relief notch 300 and the fluted filter media 110 and on top of the securing tape 118.

**[0065]** After applicator 168 has applied adhesive into the reservoir 414, the applicator 168 applies adhesive 126 onto the fluted filter media 110 in a direction transverse to the securing tape 118 and in alignment with the relief notch 300 on the upper half 410 of the frame 308 proximate the securing tape 118. As shown in FIGS. 16 and 18, the further

amount of adhesive 126 is applied to the fluted filter media 110 in a direction generally transverse to the flutes and the strip of securing tape 118 until the location 172 is reached. In the illustrated embodiment of FIG. 18, the width of the line of adhesive 126 progressing over the fluted filter media is thinner than the adhesive situated or collected in the relief notch 300 and/or the reservoir 414.

**[0066]** After the adhesive 126 is applied in the manner noted above, the frame 308 is rotated about the drive axis 185 (a.k.a., the winding axis). The drive axis 185 is generally orthogonal to both a major axis 416 and a minor axis 418 passing through the frame 308. The major axis 416 has a greater span than the minor axis 418. In addition, the relief notch 300 intersects a plane parallel to the minor and winding axes 418, 185 and is offset from the winding axis 185 to an extent of the frame 308 (i.e., the end of the radius section 160) along the major axis.

**[0067]** When rotated, the frame 308 pivots generally about leading edge 116 and transitions from the position shown in FIG. 18 to the position of FIG. 19. When this occurs, the securing tape 118 is folded over the leading edge 116 of the frame 308. In addition, the notch 300 on the side rail 136 which is not secured by the strip of securing tape 118 generally falls over and aligns with the adhesive 126 extending across the fluted filter media. By continuing to wind the fluted filter media 110 around the frame 308 to form a filter element 100 as shown in FIG. 1, the relief notch 300 on the side rail 136 will eventually form an additional reservoir for the adhesive 126 in conjunction with the fluted filter media 110.

**[0068]** In the illustrated embodiment of FIGS. 16 and 18-19, the adhesive 126 is a foaming adhesive that has gas pockets formed substantially throughout. As such, the adhesive 126 expands after application. The adhesive 126 enlarges and grows atop the fluted filter media 110, within the relief notches 300, within the reservoir 414 (formed by the relief notch 300 on side rail 134, the tape 118, and the fluted filter media 110), and within the additional reservoir (formed by the relief notch 300 in the side rail 136 and the fluted filter media 110 when the frame 308 is wound half a revolution or turn). By expanding in these areas, particularly within the relief notches 300 and the reservoirs, the adhesive 126 prevents a leak path from forming through the filter element 100. The adhesive 126 generally does so by foaming and expanding into engagement with the peripheral face 408 of the frame 308, the convoluted sheet of the fluted filter media 110, and, in some cases, the securing tape 118. Because the adhesive 126 expands, adhesive

applied proximate and adjacent the reservoir 414 and the additional reservoir may be channeled therein as the adhesive 126 continues to foam and expand.

**[0069]** Because the frame 308 includes relief notches 300, the force ( $F_T$ ) used to wind the fluted filter media 110 (as shown in FIG. 10) about the frame 308 does not undesirably displace or squeeze the adhesive 126 from in between the leading edge 116 of the frame 308 and the convoluted sheet (a.k.a., inner wrap) of the fluted filter media 110 when the filter element 100 is being constructed. Indeed, because the fluted filter media 110, when wrapped about the frame 308 as shown in FIG. 10, engages the frame 308 along the leading edge 116 and lays over pocket formed by the relief notches 300, the adhesive 126 in the relief notches 300 is generally left intact when the filter element 100 is made.

**[0070]** All references, including publications, patent applications, and patents cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

**[0071]** The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) is to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

**[0072]** Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as

appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

WHAT IS CLAIMED IS:

1. A filter element comprising:  
a winding core having a pair of ends spaced apart from each other and extending laterally between a pair of opposed sides;  
a sheet of fluted filter media wound around the sides of the winding core;  
a relief notch formed in at least one of the sides of the winding core; and  
adhesive received at least partially in the relief notch, the adhesive securing the fluted filter media to the winding core.
2. The filter element of claim 1, wherein the winding core has a pair of opposed faces defined between the opposed ends and the opposed sides, wherein the relief notch extends entirely through both opposed faces and into the at least one of the sides of the winding core.
3. The filter element of claim 2, wherein the fluted filter media comprises a face sheet secured to a convoluted sheet, the convoluted sheet having peaks and valleys forming a plurality of inlet and outlet flutes, wherein the relief notch has a depth extending generally in a direction between the opposed sides that is about one half of a thickness of the winding core measured between the pair of opposed faces proximate the relief notch.
4. The filter element of claim 1, wherein the winding core has a pair of opposed faces defined between the opposed ends and the opposed sides, wherein the fluted filter media comprises a face sheet secured to a convoluted sheet, the convoluted sheet having peaks and valleys forming a plurality of inlet and outlet flutes, wherein a strip of the adhesive is laid across the convoluted sheet in alignment with the relief notch, wherein a thicker region of the adhesive is located in the relief notch relative to the strip of adhesive.
5. The filter element of claim 4, wherein the adhesive is an expanded foamed adhesive having gas pockets formed substantially throughout, the expanded foamed adhesive substantially filling the relief notch and expanded into sealing engagement with the convoluted sheet.
6. The filter element of claim 1, wherein the winding core has a pair of opposed faces defined between the opposed ends and the opposed sides, a winding axis running through the opposed ends with the fluted filter media being wound in a coiled configuration about the winding axis, the opposed sides being separated by major axis and the opposed

faces being separated by a minor axis transverse relative to the major axis, wherein the major axis has a greater span than the minor axis, wherein the relief notch intersects a plane parallel to the minor and winding axes and offset from the winding axis to an extent of the winding core along the major axis.

7. The filter element of claim 1, wherein the adhesive received at least partially within the relief notch is secured to a peripheral surface of the relief notch, a convoluted sheet of the fluted filter media, and tape securing the winding core to an edge of the fluted filter media.

8. The filter element of claim 1, wherein a side opposing the at least one side includes an additional relief notch, the additional relief notch disposed between the pair of ends the same distance as the relief notch such that the relief notch and the additional relief notch are generally aligned with each other on the pair of opposing sides.

9. The filter element of claim 8, wherein the relief notch and the additional relief notch are separated by a lateral cross member of the winding core, the lateral cross member disposed generally transverse to the pair of opposed sides and supported by angular cross members oriented at an angle relative to the pair of opposites sides and the pair of opposed ends.

10. The filter element of claim 8, wherein each of the pair of opposed sides includes a further relief notch, each of the further relief notches disposed between the pair of opposed ends the same distance such that the further relief notches are generally aligned with each other on the pair of opposing sides and equally spaced apart from the relief notch and the additional relief notch, respectively.

11. The filter element of claim 10, wherein at least one of the pair of opposed ends includes a plurality of driving lugs oriented to permit driving of the winding core about the winding axis.

12. The filter element of claim 10, wherein the relief notch, the additional relief notch, and the further relief notches formed in the winding core each have a curved profile when the winding core is viewed from one of the opposed faces.

13. The filter element of claim 1, wherein the relief notch, the winding core, and tape securing the winding core to the fluted filter media collectively form an adhesive reservoir.

14. The filter element of claim 1, wherein the winding core includes a plurality of open areas defined by a plurality of cross members forming the winding core, several of the plurality of cross members oriented angularly relative to the opposed sides and the opposed ends and several other of the plurality of cross members oriented generally parallel to the opposed ends and transverse to the opposed sides.

15. The filter element of claim 14, wherein the winding core has a non-rectangular profile when viewed from each of the pair of opposed sides.

16. A method of forming a filter element comprising:  
securing a fluted filter media and a winding core to each other;  
directing adhesive into a reservoir disposed between the winding core and the fluted media, the reservoir being formed at least in part by a relief notch formed in the winding core;  
winding the fluted filter media about the winding core; and  
expanding the adhesive within the reservoir such that the adhesive engages both the winding core and the fluted filter media and prevents a leak path from forming through the filter element.

17. The method of claim 16, wherein the securing step is performed by taping the fluted filter media and the winding core to each other with a strip of tape, and wherein the method further comprises applying the adhesive lengthwise along the tape and between the winding core and the fluted filter media prior to the directing step.

18. The method of claim 17, wherein the method further comprises dispensing the adhesive onto a portion of the tape within the relief notch in the winding core, and collectively forming the reservoir with the fluted filter media, the relief notch, and the tape.

19. The method of claim 18, wherein the method further comprises dispensing the adhesive across the fluted filter media from and beyond the reservoir in a direction transverse to the strip of tape.

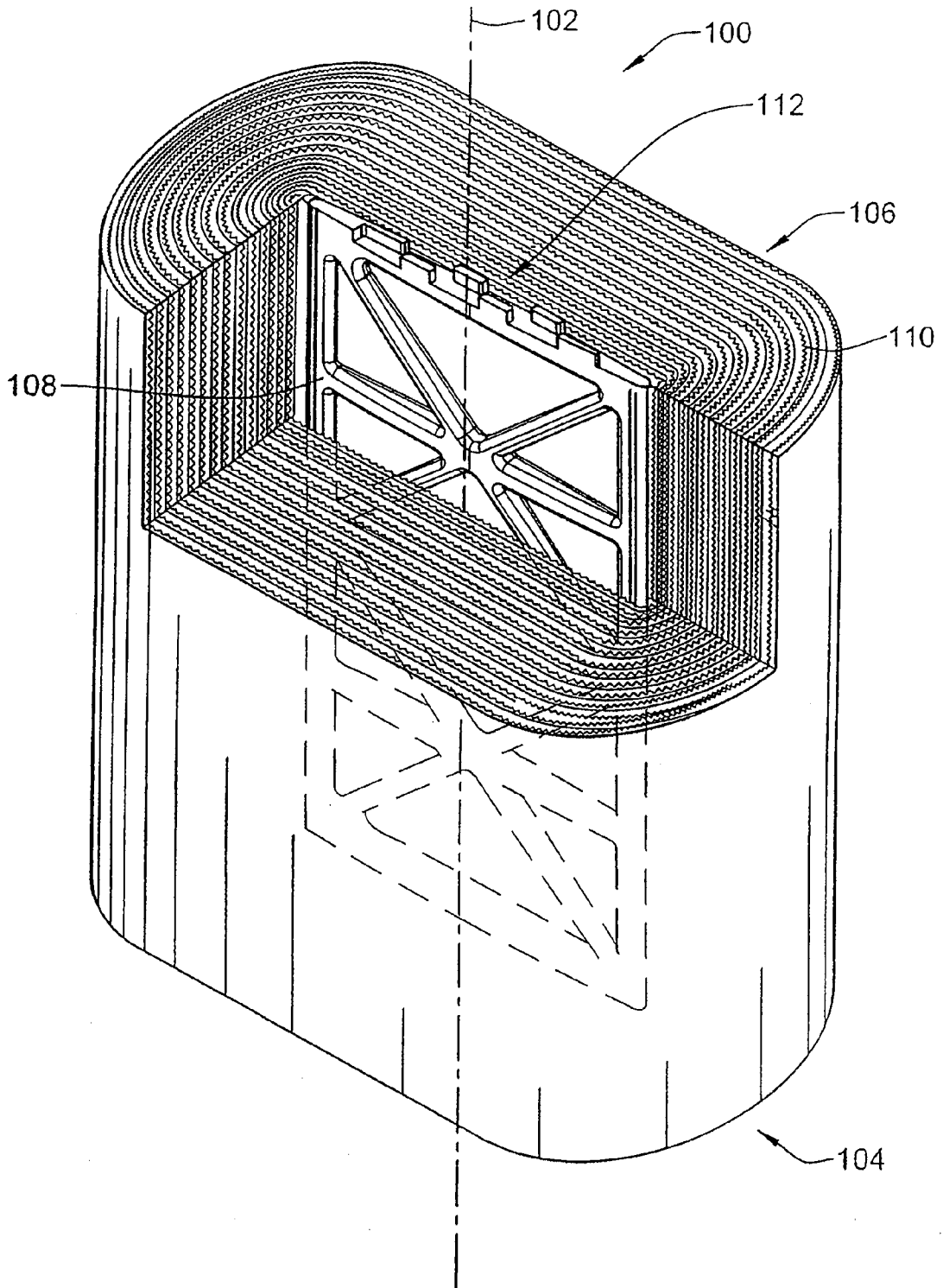
20. The method of claim 19, wherein the method further comprises winding the winding core such that the adhesive extending across the fluted filter is received within an additional reservoir formed by an opposing side of the winding core and the fluted filter media, the adhesive in the additional reservoir expanding such that the adhesive engages both the winding core and the fluted filter media and prevents a leak path from forming through the filter element.

21. A method of forming a filter element comprising:  
taping a winding core and a fluted filter media together using tape;  
applying adhesive between the winding core and the fluted filter media lengthwise along the tape;  
dispensing adhesive into a reservoir formed by a relief notch formed in the winding core, the fluted media, and the tape;  
dispensing adhesive across the fluted filter media in a direction transverse to flutes in the fluted filter media;  
winding the fluted filter media about the winding core; and  
foaming the adhesive within the reservoir until the adhesive engages the winding core, the fluted media, and the portion of the tape.

22. The method of claim 21, wherein the method further comprises channeling the adhesive into the reservoir during the foaming step.

23. The method of claim 21, wherein the method further comprises foaming the adhesive into an additional reservoir on an opposing side of the winding core as the reservoir until the adhesive engages the winding core and the fluted media.

FIG. 1



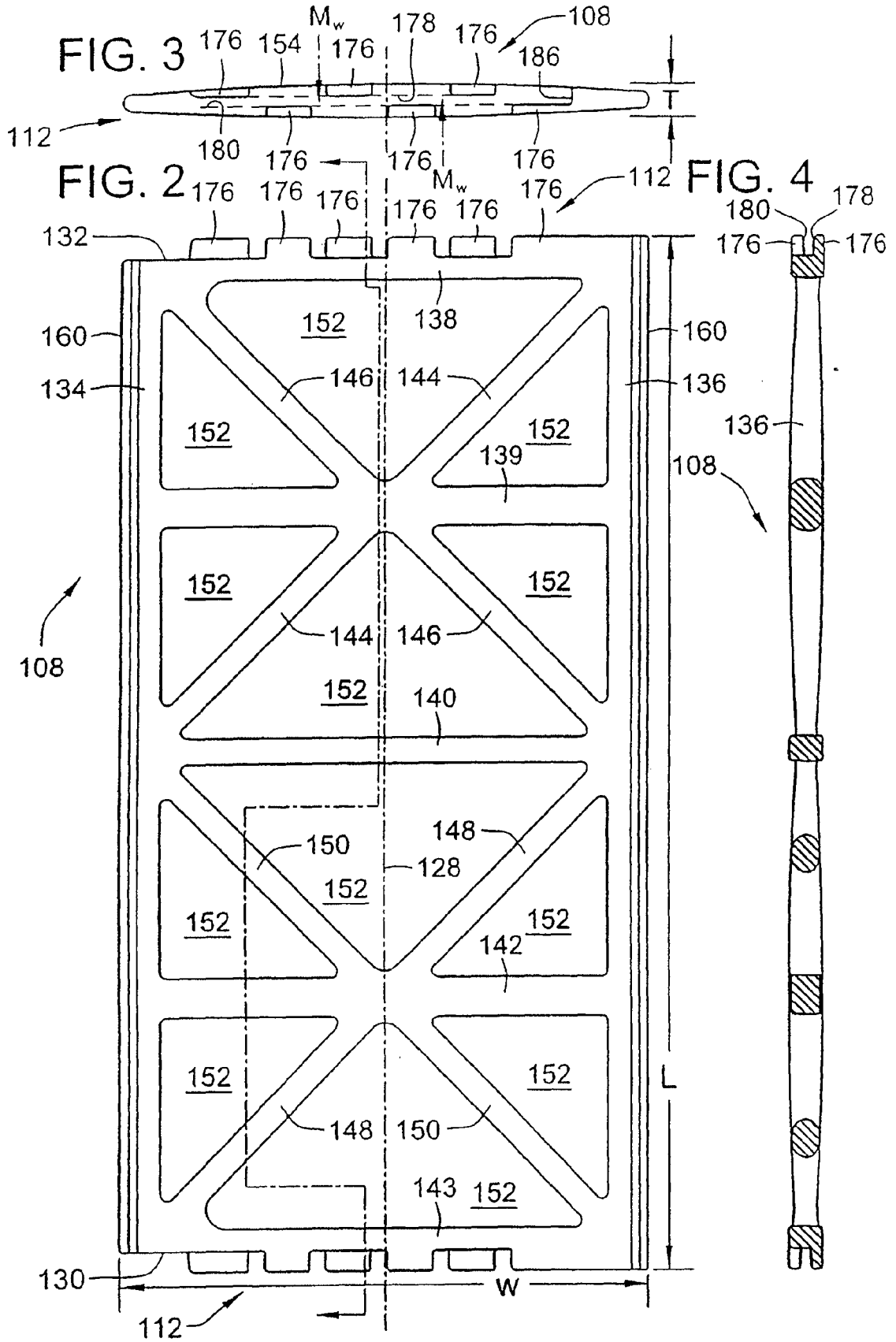
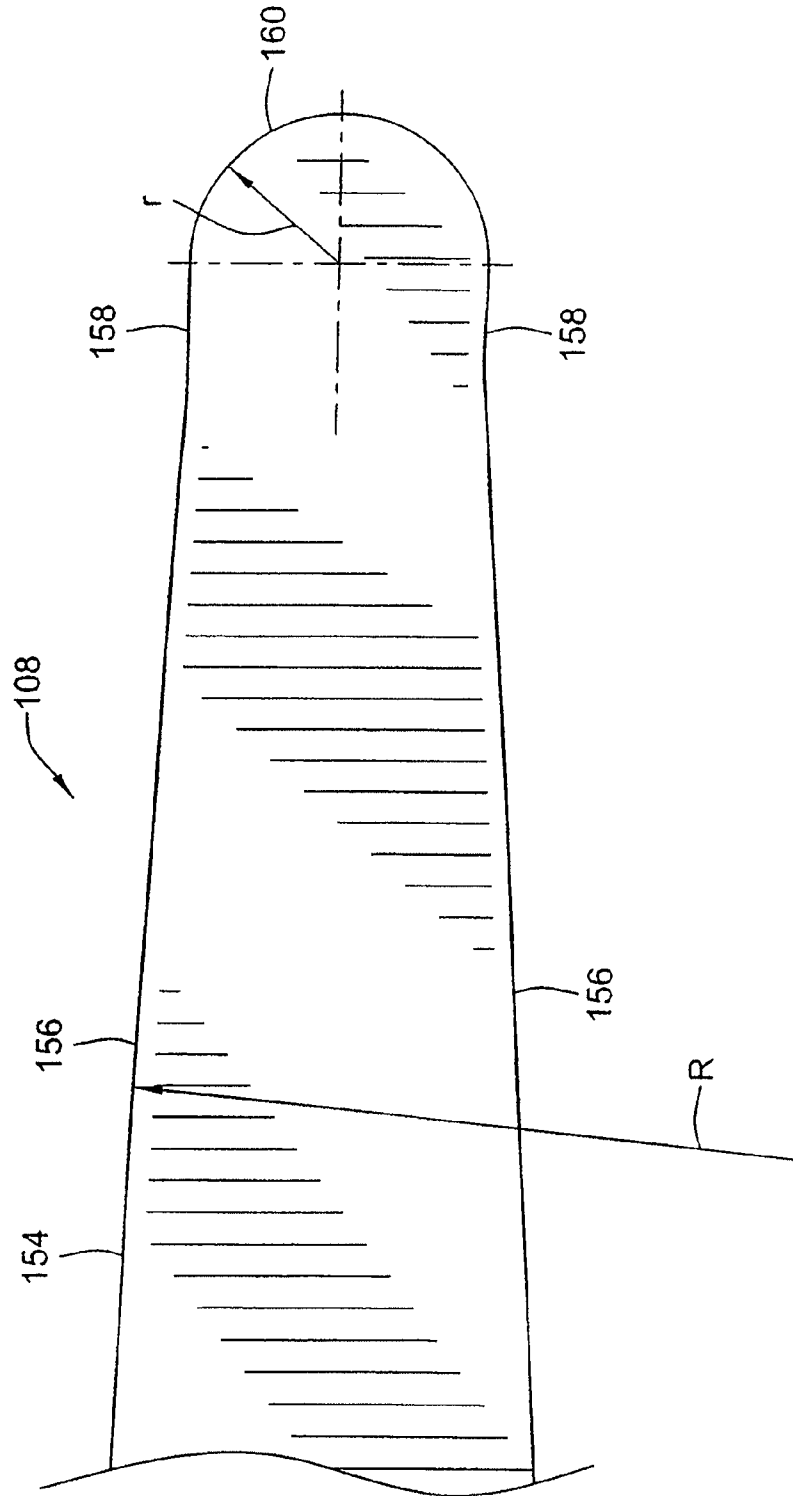


FIG. 5



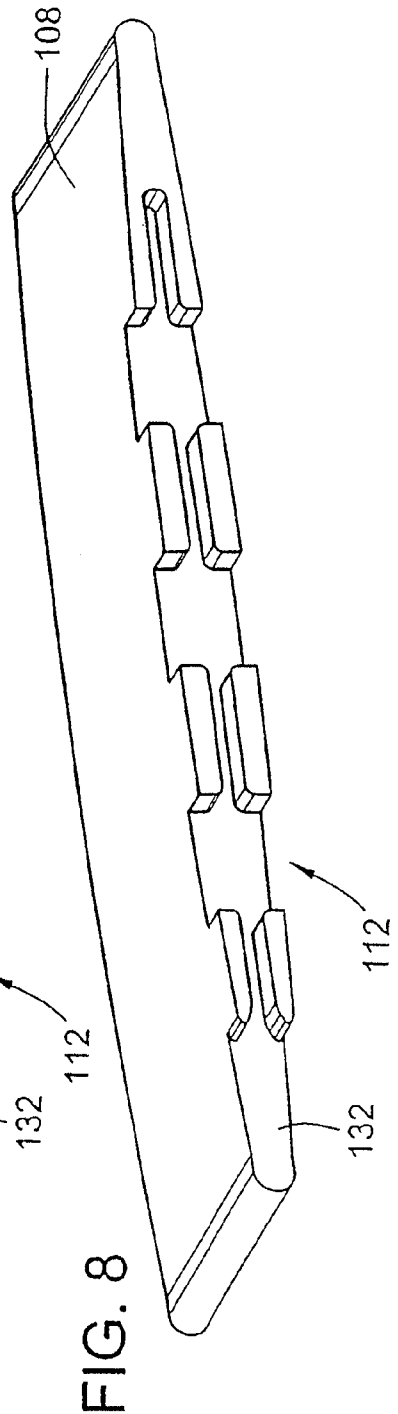
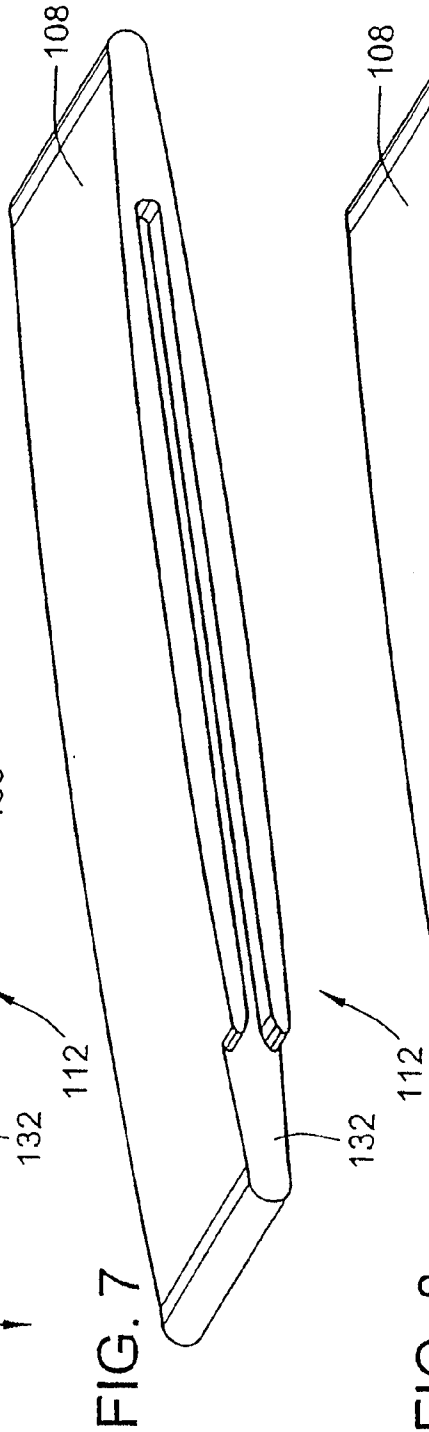
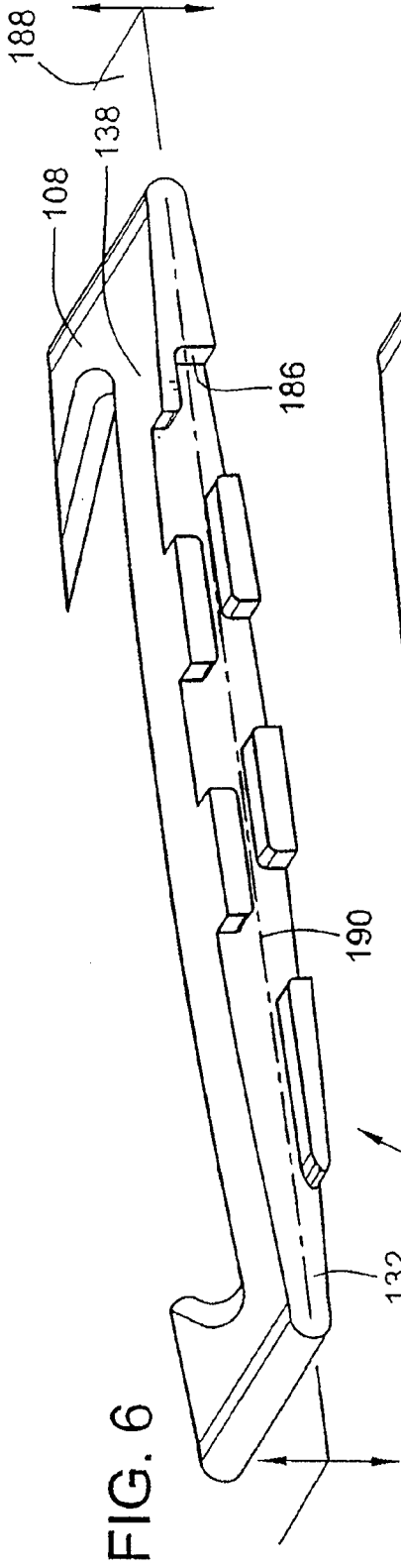


FIG. 9

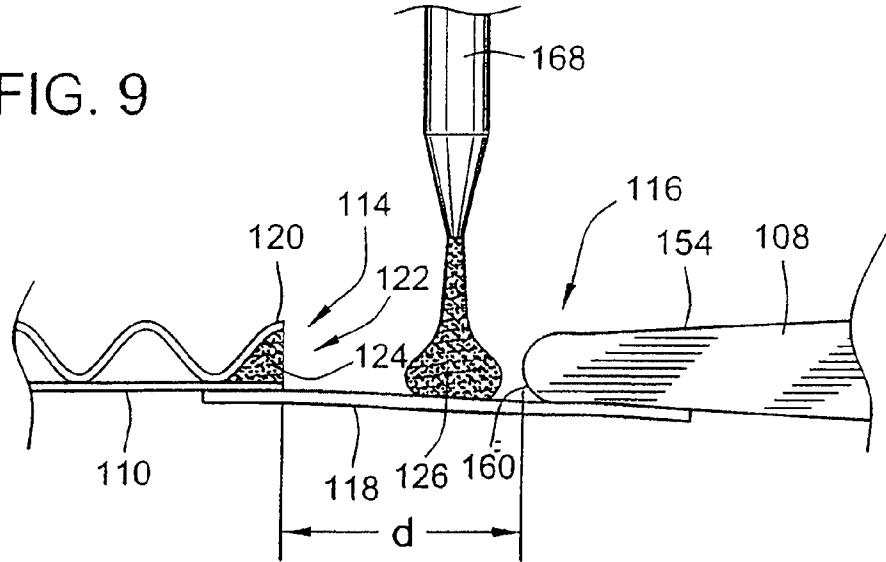


FIG. 10

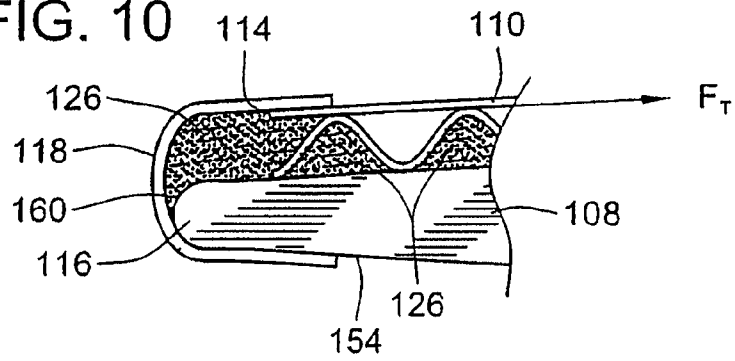


FIG. 11

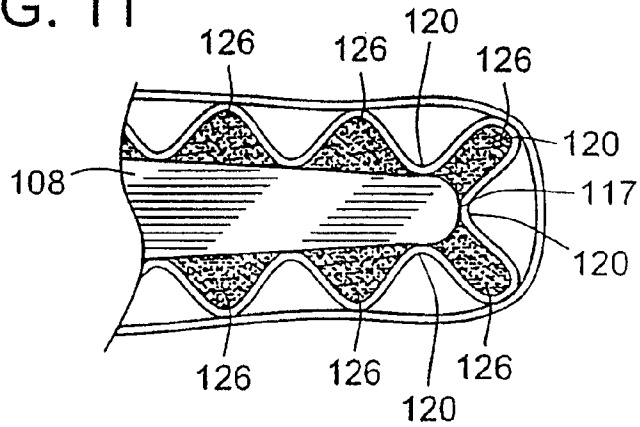




FIG. 13

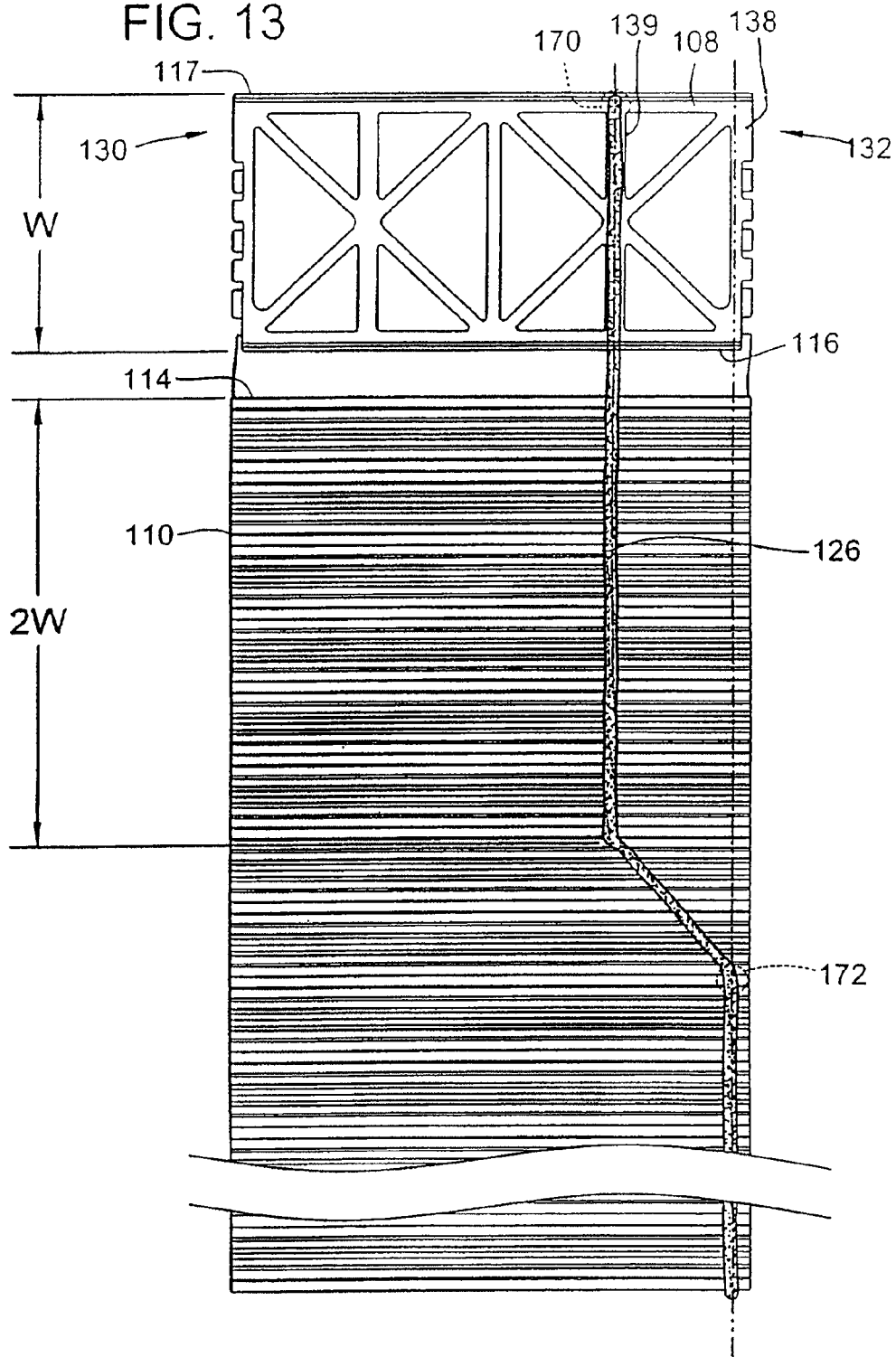
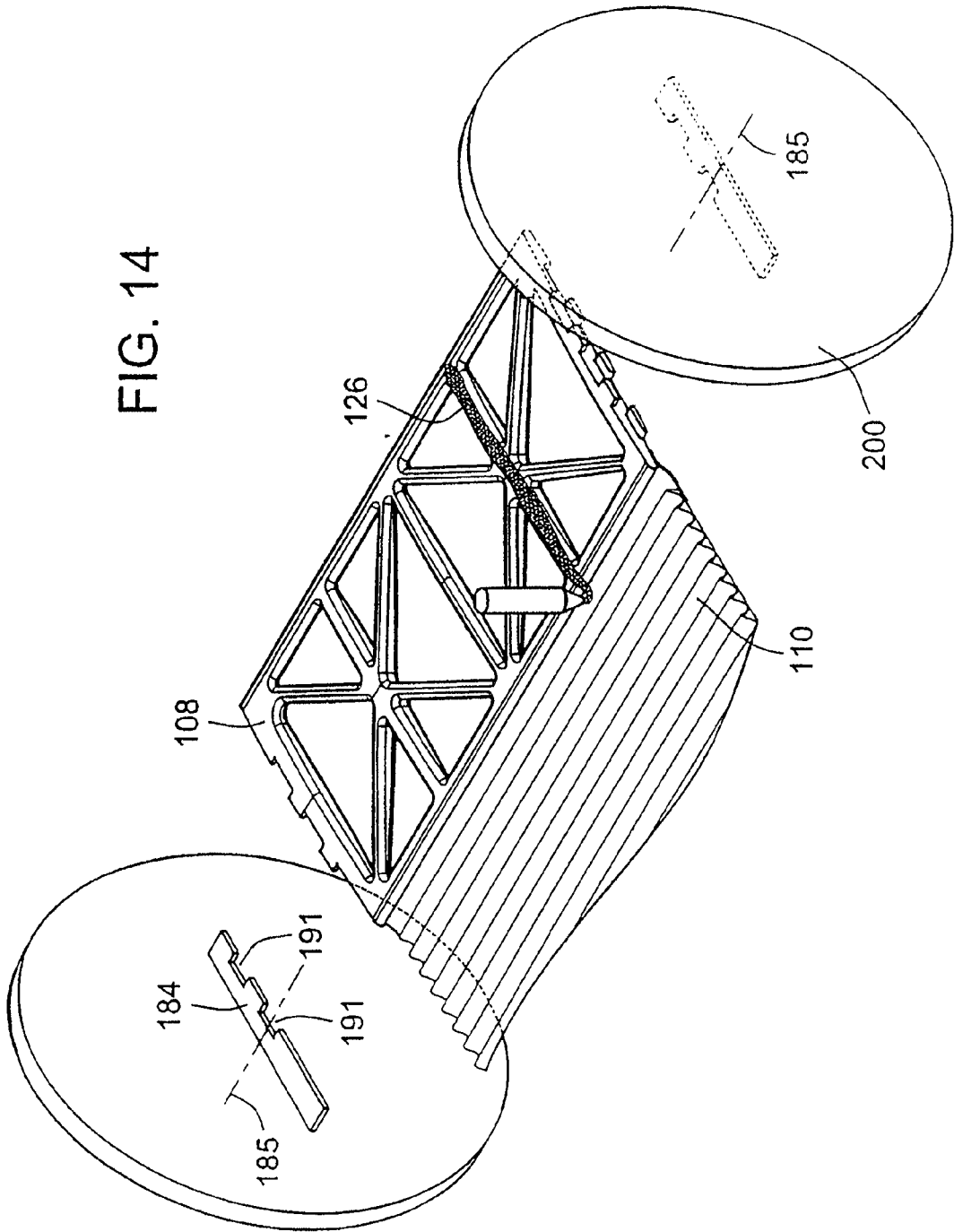


FIG. 14



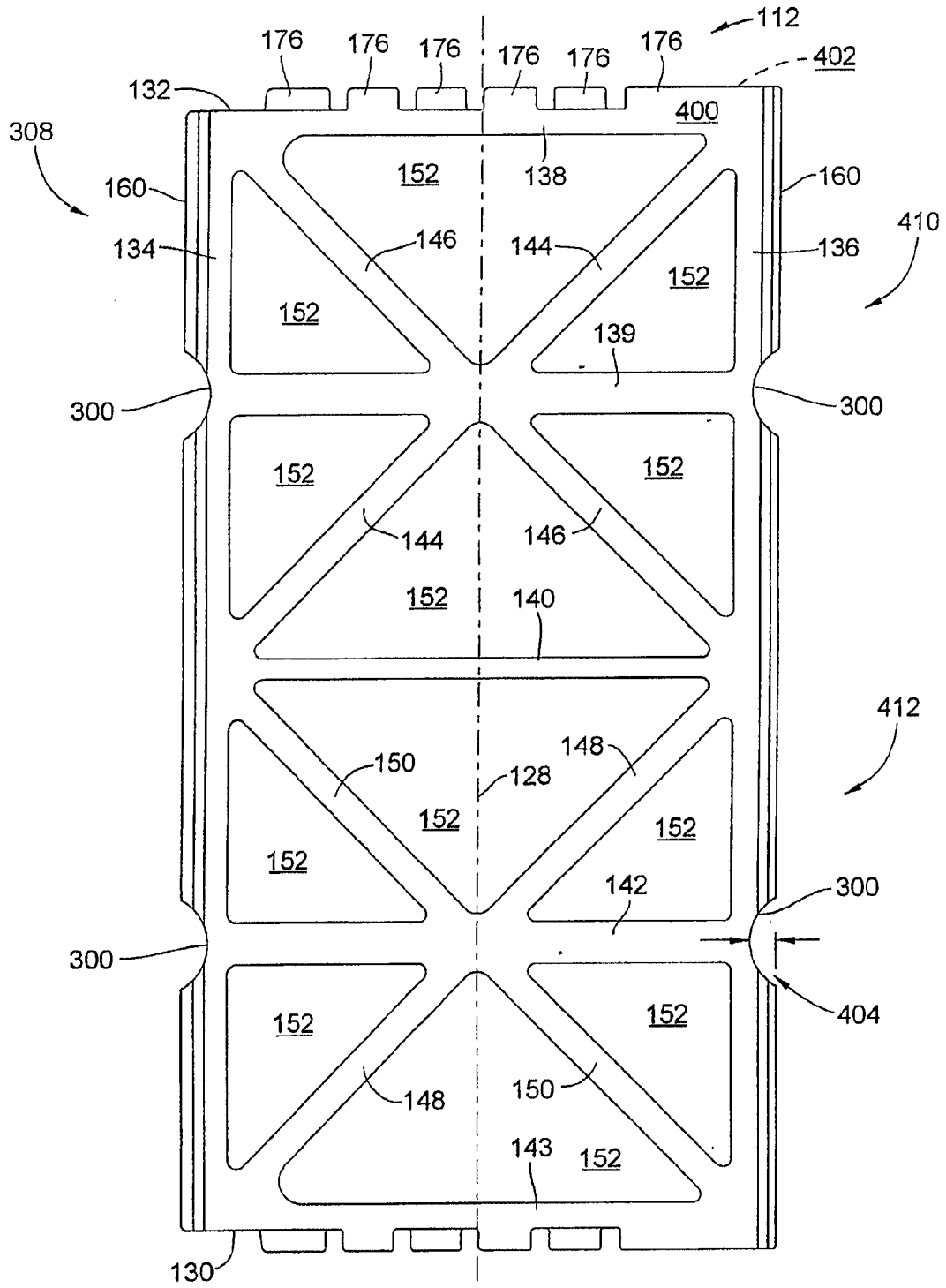


FIG. 15



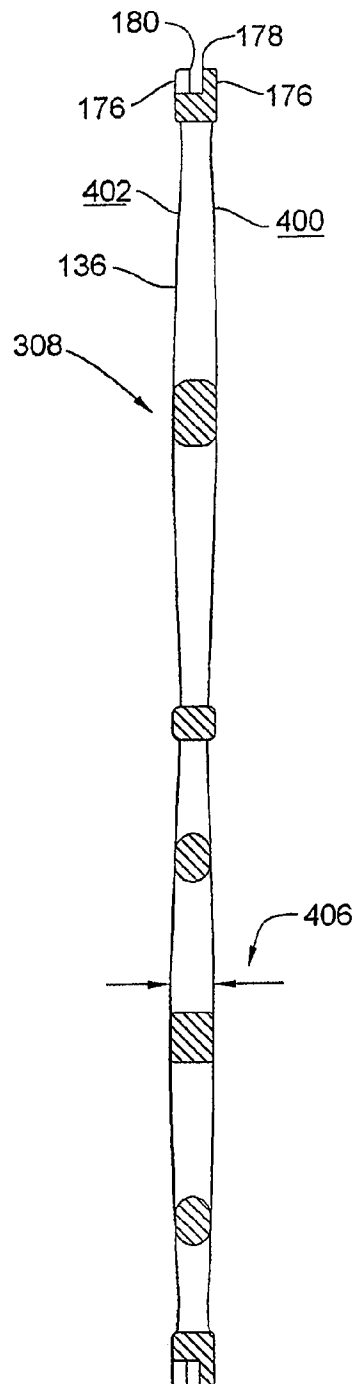


FIG. 17

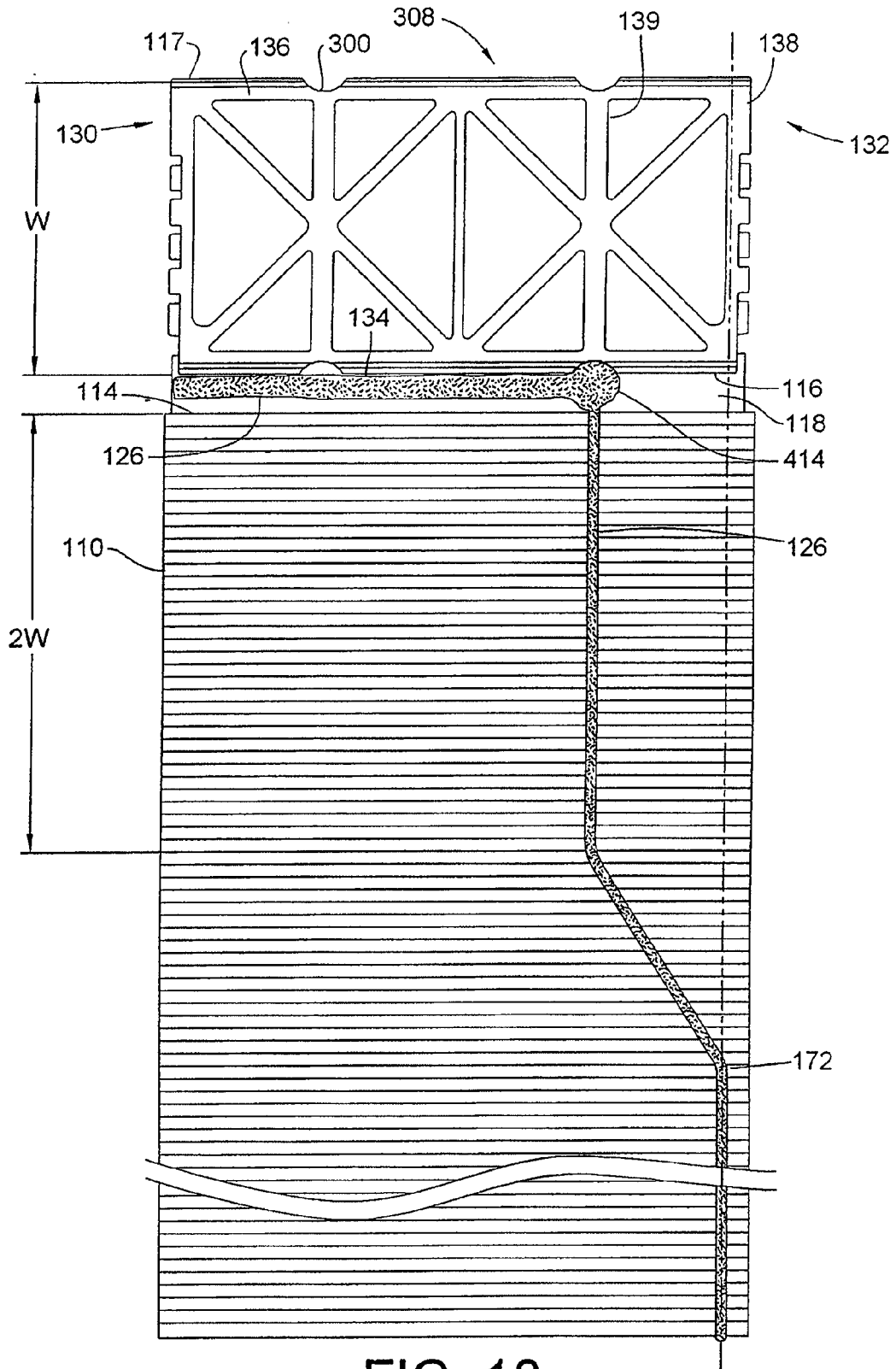


FIG. 18

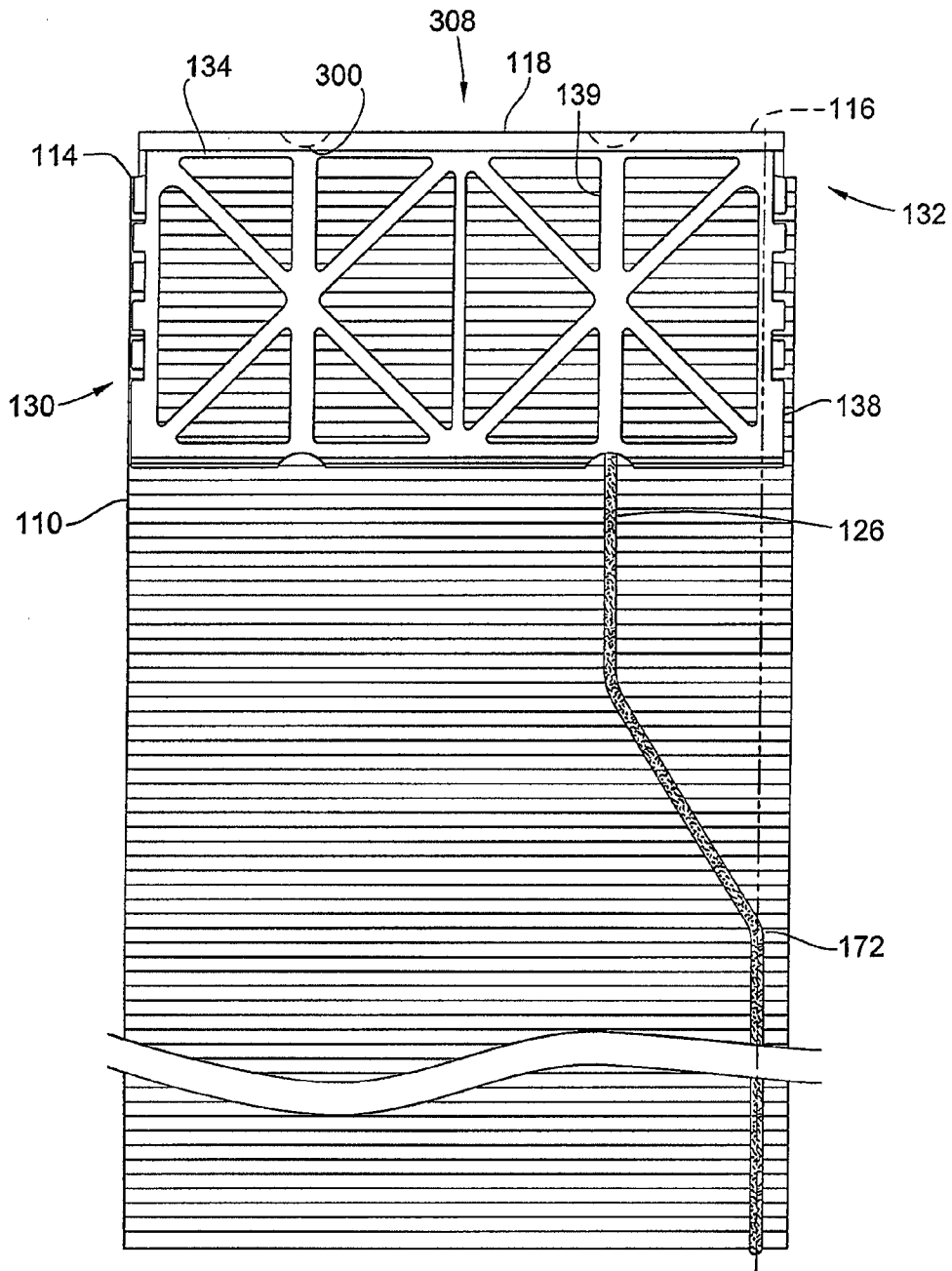


FIG. 19