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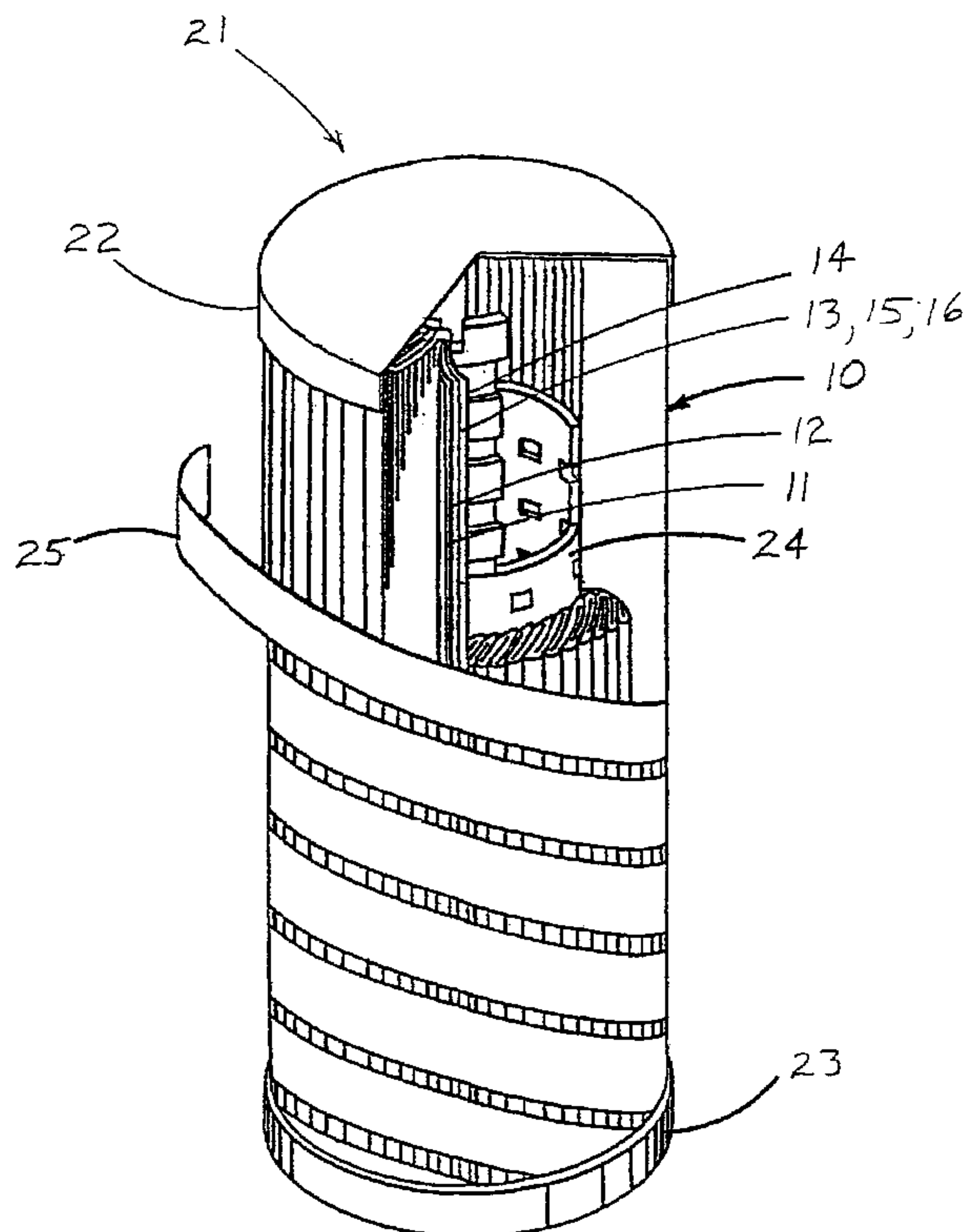
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A fluid treatment element for treating a fluid flowing through the pack comprises a first conductive layer and a second conductive layer electrically connected to the first conductive layer. The element further comprises a nonconductive porous treatment medium between the first and second conductive layers. The first and second conductive layers are positioned to offset electrical imbalances caused by fluid flowing through the nonconductive porous treatment medium. A fluid treatment pack for treating fluid flowing through the pack comprises a porous treatment medium and an electrical cage. The electrical cage surrounds the porous treatment medium and offsets electrical imbalances caused by fluid flowing through the porous fluid treatment medium.

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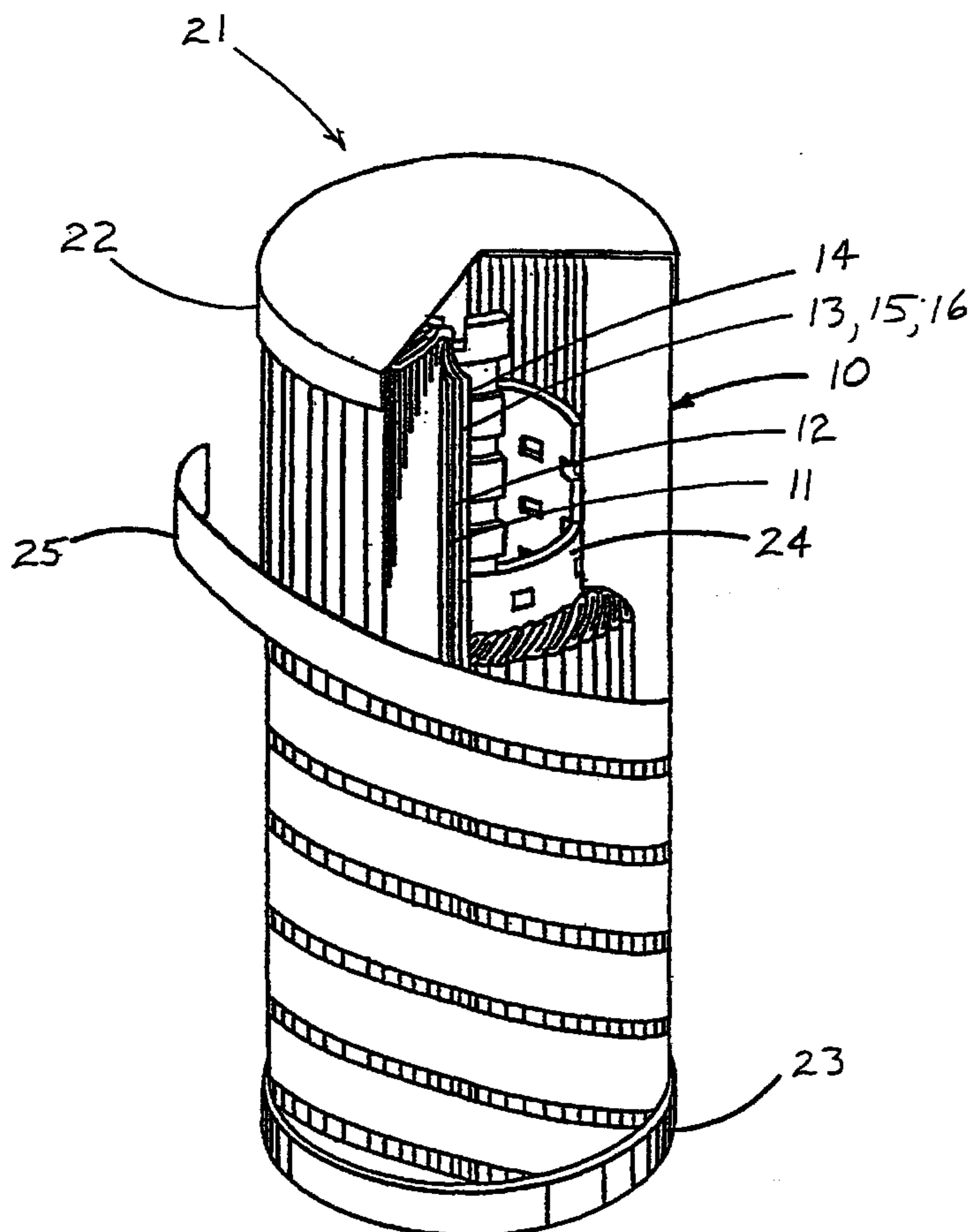
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(57) Abstract: A fluid treatment element for treating a fluid flowing through the pack comprises a first conductive layer and a second conductive layer electrically connected to the first conductive layer. The element further comprises a nonconductive porous treatment medium between the first and second conductive layers. The first and second conductive layers are positioned to offset electrical imbalances caused by fluid flowing through the nonconductive porous treatment medium. A fluid treatment pack for treating fluid flowing through the pack comprises a porous treatment medium and an electrical cage. The electrical cage surrounds the porous treatment medium and offsets electrical imbalances caused by fluid flowing through the porous fluid treatment medium.

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## CONDUCTIVE FILTER CARTRIDGE

Technical Field of the Invention

5           The present invention relates to fluid treatment packs, fluid treatment elements, and methods for treating fluids which inhibit electrical imbalance and/or electrical charge build up.

Background of the Invention

10           A wide variety of elements are used to treat fluids, i.e., gases, liquids, and mixtures of gases and liquids. Examples of fluid treatment elements include separation elements, such as filter elements and separator elements, coalescer elements, and mass transfer elements. They may be used in a wide variety of ways including to remove one or more substances, such as solids, liquids or chemical substances, e.g., a protein, from a  
15   gas or liquid; to concentrate or deplete one or more substances in a gas or liquid; to accrete one phase of a fluid, e.g., a liquid discontinuous phase, in another phase of the fluid, e.g., a continuous liquid or gas phase; or to transfer mass, such as a gaseous or chemical substance, between two fluid streams. In use, any of these elements may develop an electrical charge imbalance or buildup that can potentially damage the fluid  
20   treatment system.

          For example, filter elements, in addition to removing contaminants such as solids from fluids, may remove or add electrons to fluid passing through the filter elements, causing an imbalance in electrical charge or potential between the fluid, the filter element, and/or the surrounding housing, pipes, and fluid cavities. A gradual buildup of electrical  
25   charge may eventually lead to a discharge through a path of least resistance to, for example, the filter housing, the pipes, or any other conductive component such as a turbine-bearing cage. This discharge can degrade the fluid or harm the components experiencing a discharge arc. The service life of the fluid, the filter element, and the system containing the fluid is thus reduced.

30           Various techniques exist that purport to deal with the accumulation of charge and the resulting discharge in fluid treatment systems. One technique is to add conductive additives to the fluid. This technique can degrade fluid performance and also requires regular monitoring as the additive's effectiveness diminishes over time and use. Another technique is to provide some path to ground through the fluid treatment element.

However, many of these grounding techniques require that extraneous and expensive components be included to provide a conductive path to ground. This not only increases the cost of the fluid treatment elements, it can also reduce the performance of the fluid treatment element, e.g., increase the pressure drop through the fluid treatment element.

5 Further, these grounding technique often lead to complicated and expensive retrofitting of older systems to prevent the undesirable discharges.

### Summary of the Invention

The present invention effectively addresses the problems of electrical imbalances and charge accumulation in a variety of ways.

10

In accordance with one aspect of the invention, a fluid treatment element for treating a fluid flowing through the pack comprises a first conductive layer and a second conductive layer electrically connected to the first conductive layer. The element further comprises a nonconductive porous treatment medium between the first and second

15 conductive layers. The first and second conductive layers are positioned to offset electrical imbalances caused by fluid flowing through the nonconductive porous treatment medium.

In accordance with another aspect of the invention, a fluid treatment pack for treating fluid flowing through the pack comprises a porous treatment medium and an

20 electrical cage. The electrical cage surrounds the porous treatment medium and offsets electrical imbalances caused by fluid flowing through the porous fluid treatment medium.

In accordance with another aspect of the invention, a method for treating fluid comprises directing a fluid through a porous treatment medium; transferring an electrical charge from the fluid to the porous medium; and returning the electrical charge from the

25 porous fluid treatment medium to the fluid.

Embodiments of these aspects of the invention effectively inhibit electrical imbalance and charge buildup (1) by dissipating the charge to a neutral potential such as ground or (2) by collecting the charge in the fluid treatment medium and returning the charge to the fluid as the fluid flows through the conductive layers or by preventing the

30 charge from accumulating in the filter medium, where neither of the first nor second conductive layers is connected to a neutral potential such as ground. While not being bound by any particular theory of operation, it is believed that as the fluid passes through the porous treatment medium, in particular, as a conductive or nonconductive fluid passes

through a nonconductive porous treatment medium, electrical charge may be transferred between the porous medium and the fluid. The first and second conductive layers are preferably positioned in close proximity to the porous treatment medium to offset the electrical imbalance, e.g., to gather the electrical charge from the porous matrix and  
5 return the charge to the fluid thereby preventing charge buildup or to gather the electrical charge and dissipate the charge to a neutral potential, such as ground.

In accordance with another aspect of the invention, a fluid treatment element may be used in a fluid treatment assembly having a core or a cage such that the fluid treatment element is removably mountable to the core or the cage. The fluid treatment element  
10 comprises a fluid treatment pack which includes a pleated multi-layer composite having interior roots and exterior crests. The multi-layer composite further includes a porous treatment medium and at least one conductive layer electrically coupled to the porous medium. The fluid treatment element is coreless or cageless, and the conductive layer includes either an interior conductive surface at the roots of the fluid treatment pack or an  
15 exterior conductive surface at the crests of the fluid treatment pack. The pleats of the fluid treatment pack are dimensioned to provide an electrical connection between the roots and core or between the crests and the cage when the fluid treatment element is mounted to the fluid treatment assembly.

In accordance with another aspect of the invention, a method for treating a fluid  
20 comprises removably mounting a pleated fluid treatment element to a core or a cage, including electrically connecting the core and a conductive interior surface of a conductive layer at the roots of a pleated fluid treatment pack or electrically connecting the cage and a conductive exterior surface of a conductive layer at the crests of the pleated pack. The method further comprises directing a fluid through the fluid treatment  
25 pack, including directing the fluid through a porous treatment medium and the conductive layer. The conductive layer is electrically coupled to the porous medium, and the method further comprises transferring an electrical charge between the porous medium or the fluid and the conductive layer to the core or cage.

Embodiments of these aspects of the invention provide a highly effective  
30 connection between the fluid treatment element and a neutral potential such as ground. The surface area of contact between the interior surface of the conductive layer at the roots and the core or the exterior surface of the conductive layer at the crests and the cage is very large and, therefore, highly effective. In fact, the contact between the conductive



layer and the core and/or the cage may be the sole path to the neutral potential.

Consequently, no additional grounding connections, such as grounding straps, grounding springs or conductive O-ring seals, need be provided, simplifying both the construction of the fluid treatment element and any retrofitting of existing fluid treatment assemblies.

5           In accordance with another aspect of the invention, a fluid treatment element for treating a fluid flowing through the fluid treatment element comprises a porous treatment medium and an electrical contact. The porous medium includes a conductive substrate and a fibrous matrix supported by the conductive substrate. The electrical contact is electrically coupled to the conductive substrate and arranged to be connected to a neutral  
10   potential such as ground.

          In accordance with another aspect of the invention, a method for treating a fluid comprises directing a fluid through a fluid treatment element including a fibrous matrix supported by a conductive substrate and transferring electrical charge from the fibrous matrix or the fluid to an electrical contact on the fluid treatment element via the  
15   conductive substrate.

          Embodiments of these aspects of the invention effectively inhibit electrical imbalance or charge buildup in the fibrous matrix. Because the fibrous matrix is supported by the conductive substrate, the conductive substrate is particularly well coupled electrically to the fibrous matrix, significantly enhancing the ability of the  
20   conductive substrate to transfer charges between the fibrous matrix and the electric contact and, hence, a neutral potential such as ground.

          In accordance with another aspect of the invention, a fluid treatment element for treating a fluid flowing through the fluid treatment element comprises one or more layers including at least one of a coalescing medium arranged to form droplets of a  
25   discontinuous phase of the fluid and a separator medium arranged to inhibit passage of the discontinuous phase and allow passage of the continuous phase of the fluid. At least one of the layers of the fluid treatment element is conductive. The fluid treatment element further comprises an electrical contact electrically coupled to the conductive layer and arranged to be connected to a neutral potential.

30           In accordance with another aspect of the invention a coalescer element comprises a coalescer medium having a graded nominal pore structure wherein an upstream region of the coalescer medium has a smaller nominal pore size than a downstream region of the coalescer medium. The coalescer medium is arranged to form droplets of a discontinuous

phase of a fluid. The coalescer element further comprises a conductive O-ring electrically coupled to the coalescer medium to enable electrical charge to be transferred from the coalescer medium to a neutral potential.

## 5 Description of the Drawings

Figure 1 is a partially cutaway oblique view of a fluid treatment element.

Figure 2 is a sectional view of a side seam of a pleated fluid treatment pack.

Figure 3 is a partially cutaway oblique view of another fluid treatment element.

Figure 4 is a partially cutaway oblique view of another fluid treatment element.

10 Figure 5 is a partially cutaway elevation view of another fluid treatment element.

Figure 6 is a partially cutaway elevation view of another fluid treatment element.

Figure 7 is an elevation view of a fluid treatment assembly.

Figure 8 is a partially cutaway elevation view of another fluid treatment element.

## 15 Detailed Description of Embodiments

One example of a fluid treatment element is a separation element, such as a filter element. Accordingly, in accordance with a first aspect of the invention, a fluid treatment pack such as a filter pack comprises first and second conductive layers and a porous fluid treatment medium such as a porous filter medium. The first and second conductive layers are preferably electrically connected to each other, and the filter medium is disposed between them. As a fluid, such as gas or a liquid or a mixture of gas and liquid, flows through the filter pack, one or more undesirable substances, e.g., particulate contaminants, may be removed from the fluid by the filter medium. In addition, an electrical charge may be transferred between the fluid and the filter medium, especially if the filter medium is nonconductive. The first and second conductive layers are preferably positioned in sufficient proximity to the filter medium to offset the electrical imbalance, for example, by dissipating the charge to a neutral potential, such as ground, or where the first and second conductive layers are isolated from the neutral potential, by collecting the charge in the fluid treatment medium and returning the charge to the fluid as the fluid flows through the conductive layers or by preventing the charge from accumulating in the filter medium. Thus, the conductive layers may be electrically connected to ground or alternatively, even if the filter pack is electrically isolated from the ambient environment, e.g., electrically isolated from a neutral potential such as ground, the first and/or second



conductive layers may offset all or a substantial portion of the electrical imbalance which may arise in the filter medium. The fluid treatment medium is thus substantially surrounded by an electrical cage which offsets the electrical imbalance.

As shown in Figure 1, one example of a fluid treatment pack, such as filter pack 10, embodying the present invention has a pleated, hollow, generally cylindrical configuration, and fluid preferably flows outside-in, or alternatively inside-out, through the filter pack 10. The pleats may extend generally radially and have a height substantially equal to  $(D-d)/2$ , where  $D$  and  $d$  are the outer and inner diameters, respectively, at the crests and roots of the pleats. Alternatively, the pleats may extend in a non-radial direction and have a height greater than  $(D-d)/2$ . For example, the pleats may lie in a laid-over state as disclosed in U.S. Patent 5,543,047, which is incorporated by reference in its entirety.

The filter pack 10 preferably comprises a pleated, multi-layer composite having a porous upstream drainage layer 11, a porous conductive cushioning layer 12, a permeable or semipermeable filter medium 13, preferably a nonconductive filter medium, and a porous conductive downstream drainage layer 14. The porous fluid treatment medium, e.g., the filter medium 13, may comprise a porous fluid treatment matrix such as a filter matrix 15, e.g., a fibrous, including filamentous, layer, and the fiber matrix 15 may be supported by a porous substrate 16. For example, the fiber matrix 15 may be dry-laid or wet-laid on a porous substrate 16 disposed immediately downstream of and in intimate contact, preferably intimate bonded contact, with the filter matrix 15. The conductive cushioning layer 12 and the conductive downstream drainage layer 14 may then comprise the first and second conductive layers in this embodiment with the nonconductive filter medium 13 disposed between them.

The upstream drainage layer 11 may be fashioned from a wide variety of materials having suitable drainage characteristics. For example, the edgewise flow resistance of the upstream drainage layer is preferably sufficiently low that fluid flowing through the filter pack is well distributed along the upstream surface of the filter medium from the crests to the roots of the pleats. The upstream drainage layer may be, for example, in the form of a mesh, e.g., a woven, knitted, extruded, or expanded mesh; a screen; a netting; or a woven or non-woven sheet. The upstream drainage layer may be formed of a nonconductive material, such as glass or ceramic fibers or a nonconductive polymer, or a conductive material, e.g., a conductive material such as a metal, carbon, or a conductive polymer, or

a nonconductive material that has been treated to render it conductive, such as a carbon or metal coated nonconductive glass or polymer. In the illustrated embodiment, the upstream drainage layer 11 preferably comprises a nonconductive extruded polyamide (e.g., nylon) mesh.

5           The conductive cushioning layer may be fashioned from any suitable material which resists abrasion between the upstream drainage layer 11 and the filter matrix 15. For example, the conductive cushioning layer 11 may be fashioned as a smooth and, preferably, thin and tough woven or non-woven sheet which is relatively porous compared to the filter medium 13, e.g., the filter matrix 15. The conductive cushioning  
10 layer 11 may be formed from a conductive material, such as a metal, carbon, or a conductive polymer, or from a nonconductive material, such as glass fiber or a nonconductive polymer, which is treated in any suitable manner to render the cushioning layer conductive. For example, a conductive additive, such as metal, carbon, or  
15 conductive polymeric particles or fibers, may be included with the nonconductive material or the nonconductive material may be coated with a conductive coating, such as a metal or carbon coating. In the illustrated embodiment, the conductive cushioning layer 12 preferably comprises a conductive nonwoven sheet, such as a carbon-coated polyester nonwoven sheet.

          The fibrous filter matrix 15 may be fashioned from a variety of fibrous, including  
20 filamentous, materials. For example, the filter matrix 15 may be fashioned from only nonconductive materials, such as glass fibers or nonconductive polymeric fibers, or from a mixture of nonconductive fibers and a conductive material, e.g., metal, carbon, or conductive polymer particles or fibers. The filter matrix 15 may have any of several fluid treating characteristics. For example, the filter matrix or the filter medium may have a  
25 removal rating in the range from about  $0.05\mu$  or less to about  $100\mu$  or more, preferably less than about  $25\mu$  or less than about  $5\mu$  or less than about  $1\mu$ . The filter matrix or the filter medium may have a uniform or graded pore structure, i.e., an upstream region having larger pores and a downstream region having finer pores, and/or may comprise a single layer or multiple sublayers, each having the same or different filtering  
30 characteristics. In the illustrated embodiment, the filter matrix 15 comprises a wet-laid, resin-bonded glass fiber layer.

          The porous substrate 16 may be fashioned from a variety of suitable materials. The filter matrix 15 preferably is laid on the substrate 16, e.g., dry-laid or wet-laid, and is



bonded to the substrate 16, e.g., chemically bonded, solvent bonded, thermally bonded, and/or mechanically bonded by mechanical entanglement of the fibers of the filter matrix and the substrate, forming a composite filter medium. The substrate 16 then supports the filter matrix 15 against the differential pressure across the filter matrix 15. The substrate  
5 16 may be, for example, a mesh, screen, netting, or woven or non-woven sheet that is sufficiently strong to support the filter matrix 15 within the filter pack 10. The porous substrate 16, like the upstream drainage layer, may be formed from a nonconductive material such as glass or ceramic fibers or a nonconductive polymer. In the illustrated embodiment, the substrate 16 preferably comprises a nonconductive nonwoven sheet,  
10 such as a polymeric, e.g., polyester, nonwoven sheet.

The conductive downstream drainage layer 14 functions as a drainage layer in a manner analogous to the upstream drainage layer 11, except the downstream drainage layer 14 drains filtrate from the downstream side of the substrate from the crests to the roots of the pleats and into the interior of the filter pack 10. Consequently, many of the  
15 characteristics of the upstream drainage layer are applicable to the downstream drainage layer. Further, the downstream drainage layer may function as a conductive layer. The downstream drainage layer may then comprise a conductive material, such as a metal, carbon, or a conductive polymer, or a nonconductive material, such as glass fiber or a nonconductive polymer, which is treated in any suitable manner to render the downstream  
20 drainage layer conductive. A conductive additive, such as metal, carbon, or conductive polymeric particles or fibers, including filaments, may be included with the nonconductive material or the nonconductive material may be coated with a conductive coating, such as a metal or carbon coating. In the illustrated embodiment, the downstream drainage layer 14 preferably comprises a carbon-coated polyamide (e.g.,  
25 nylon) extruded mesh.

The multi-layer composite may be pleated in any suitable manner and formed into a generally cylindrical filter pack 10, for example, by sealing a longitudinal side seam. The filter pack 10 may be incorporated into a filter element 21 in a variety of ways. For example, the ends of the filter pack 10 may be joined to opposite end caps 22, 23 in any  
30 suitable manner, such as melt bonding, adhesive bonding, or spin bonding. One of the end caps may be blind and the other may be open, or both end caps may be open. A cage (not shown) may be disposed around the exterior of the filter pack 10 and/or a core 24 may be disposed around the interior of the filter pack 10. Further, a wrap member 25



may be disposed around the exterior of the filter pack 10. USP 5,252,207, which is incorporated herein by reference in its entirety, discloses various examples of a wrap member and a wrapped filter element. The end caps, the core, the cage and the wrap member may be formed of either a conductive material, such as metal or a conductive polymer, or alternatively a nonconductive material, such as a nonconductive polymer.

The conductive layers, such as the conductive cushioning layer 12 and the conductive downstream drainage layer 14, may be electrically connected to each other in a variety of ways. For example, they may be electrically connected at the longitudinal side seam of the filter pack 10. In one embodiment, the edge(s) of at least one, or both, of the conductive layers, e.g., the conductive cushioning layer 12 and the conductive downstream drainage layer 14, extend beyond the edges of the other layers at the side seam and are brought into contact with the other conductive layer. For example, as shown in Figure 2, the edge of the conductive cushioning layer 12 at the side seam may extend beyond the edges of the other layers and may be folded back into the composite in contact with the conductive downstream drainage layer 14. A sealant 26 may then be applied to the side seam, joining and sealing the side seam with the conductive cushioning layer 12 in electrical contact with the conductive downstream drainage layer 14.

Alternatively or additionally, the first and second conductive layers may be electrically coupled to each other in any other suitable manner. For example, the side seam sealant may be a conductive sealant, such as a conductive resin or a nonconductive resin having a conductive additive. The conductive sealant may be applied to the edges of the multi-layer composite in a manner which allows the conductive sealant to electrically connect the first and second conductive layers, e.g., the conductive cushioning layer 12 and the conductive downstream drainage layer 14, at the side seam. For example, the edges of the layers of the composite may be coextensive, and the conductive sealant may penetrate the porous layers and, thereby, join and seal them as well as electrically connect the first and second conductive layers. Alternatively, the side seal may be formed by fusion bonding, e.g., sonic welding, the edges of the layers, e.g., without the addition of a separate sealant. Fusion bonding effectively melts the edges of the layers resulting in a molten mass which may penetrate any intervening layers and, thereby join and seal them as well as electrically connect the first and second conductive layers. Where one or more of the layers of the composite material are formed from a

conductive material, e.g., a conductive polymer, the melted edge of the conductive material serves as a sealant which can join and seal the layers of the composite as well as electrically connect the first and second conductive layers.

As another example, electrical connectors, such as conductive staples or  
5 conductive threads may be inserted into the edges of the composite material at the side seam. The conductive connectors may then mechanically join the layers of the multi-layer composite and electrically connect the first and second conductive layers at the side seam.

Further, the first and second conductive layers may be electrically connected  
10 through the intervening layers. For example, the filter matrix 15 may comprise conductive fibers including conductive filaments, or a mixture of conductive and nonconductive fibers and/or the substrate may comprise conductive material. The conductive cushioning layer 12 and the conductive downstream drainage layer 14 may then be electrically connected via the conductive fibers in the filter matrix 15 and the  
15 conductive substrate 16 across the entire area of the filter medium 13.

Alternatively or additionally, the first and second conductive layers may be electrically connected at the ends of the filter pack 10. For example, prior to bonding the end caps 22, 23 to the ends of the filter pack 10, the edges of one or both of the conductive layers at the ends of the filter pack 10 may be brought into contact with one  
20 another in a manner analogous to that previously described with respect to the edges at the side seam. Also, a conductive bonding agent, such as a conductive adhesive, may be used to bond the ends of the filter pack 10 to the end caps 22, 23, electrically connecting the edges of the conductive layers at the end caps 22, 23 in a manner analogous to that previously described with respect to the conductive sealant and the edges of the  
25 conductive layer at the side seam.

Further, the first and second conductive layers may be electrically coupled via a conductive end cap, e.g., a metal end cap or an end cap formed from a conductive polymer, including a nonconductive polymer having a conductive additive. For example, the edges of the conductive layers at the ends of the filter pack 10 may extend beyond the  
30 edges of the other layers of the composite and may be folded to lie flat against the end caps 22, 23. Also, the end caps 22, 23 may be joined to the ends of the filter pack 10, e.g., with a conductive adhesive. Or, the ends of the filter pack 10, with or without the edges of the conductive layers extending beyond the edges of the other layers, may be

inserted into a molten portion of each end cap comprising a conductive polymer. The molten conductive polymer may then wick into the ends of the fluid treatment pack 10 and, once solidified, join and seal the ends of the filter pack 10 to the end caps 22, 23 as well as electrically connect the first and second conductive layers. With the first and  
5 second conductive layers electrically connected to each other, the filter medium is substantially surrounded with an electrical cage.

While the embodiment illustrated in Figures 1 and 2 has been described with reference to a fluid treatment pack 10 comprising a conductive cushioning layer 12 as a first conductive layer, e.g., an upstream conductive layer; a conductive drainage layer 14  
10 as a second conductive layer, e.g., a downstream conductive layer; and a fibrous fluid treatment matrix 15 dry-laid or wet-laid on a porous substrate 16, the invention is not limited to this embodiment. For example, the upstream conductive layer may alternatively be a conductive upstream drainage layer or an additional conductive layer which does not function as either a drainage layer or a cushioning layer. Thus, the  
15 cushioning layer such as the conductive cushioning layer 12 may be eliminated entirely, and the fluid treatment pack may then comprise a conductive upstream drainage layer as the upstream conductive layer. Or the upstream conductive layer may be an additional layer which is conductive and which is positioned upstream of the fluid treatment medium with the upstream drainage layer or with both the upstream drainage layer and  
20 the upstream cushioning layer, either or both of which may be conductive or nonconductive.

Further, the downstream conductive layer may be a conductive downstream cushioning layer or the substrate may be conductive. The conductive substrate may be formed from a conductive material, such as metal, carbon or a conductive polymer or  
25 from a nonconductive material which is treated in any suitable manner to render the substrate conductive. For example, a conductive additive, such as metal, carbon or conductive polymeric particles or fibers, including filaments, may be included in the nonconductive material or the nonconductive material may be coated with a conductive coating such as metal or carbon coating.. Or, the downstream conductive layer may be an  
30 additional layer which is conductive and which does not function as either a drainage layer or a cushioning layer. The additional layer may be disposed downstream of the fluid treatment medium with either the downstream cushioning layer or the downstream



drainage layer or with both the downstream drainage layer and the downstream cushioning layer, either or both of which may be conductive or nonconductive.

Further, the fluid treatment medium need not comprise a fibrous matrix 12.

Rather, the fluid treatment medium may comprise any of a wide variety of porous  
5 separation media. For example, the fluid treatment medium may comprise a supported or unsupported porous membrane, including a permeable or semipermeable polymeric membrane, such as a polymeric membrane formed from a nonconductive polymer. Alternatively, the fluid treatment medium may comprise a screen or an open-celled foam formed from a conductive or nonconductive material.

10 The fluid treatment element may be placed in the housing (not shown) of a fluid treatment assembly such as a filter assembly. In one preferred embodiment, the first and second conductive layers are electrically connected to each other. Further, the fluid treatment element may include an electrical contact, and the first and second conductive  
15 layers may be electrically coupled to the electrical contact. The electrical contact may preferably comprise any conductive portion of the fluid treatment element which is electrically coupled to the conductive layers and is arranged to contact a neutral potential, e.g., ground. Preferably, the electrical contact may be coupled to the neutral potential through the housing or any other conductive portion of the fluid treatment assembly. For example, the electrical contact may be a conductive portion of a conductive end cap that  
20 is electrically coupled to the conductive layers of the fluid treatment element, e.g., directly or via a conductive bonding agent, and is also electrically coupled to a conductive portion of the housing. Alternatively or additionally, the electrical contact may be a portion of a conductive core that is electrically coupled to the first and second conductive layers and is electrically connected to a conductive portion of the housing, e.g., a stool, a  
25 spider, or a tie rod of the housing. Alternatively or additionally, the electrical contact may comprise one or more additional conductive components such as a conductive wire, strap, spring or seal, e.g., a conductive O-ring or gasket that is electrically coupled to the conductive layers, e.g., directly or via a conductive bonding agent and/or a conductive end cap, and to a conductive portion of the housing.

30 While not being bound by any particular theory of operation, it is believed that as the fluid passes through the filter medium, in particular as a nonconductive or conductive fluid passes through the nonconductive filter medium, electrical charge may be transferred between the filter medium and the fluid. The first and second conductive

layers comprising the conductive upstream cushioning layer and the conductive downstream drainage layer are positioned in sufficiently close proximity to the fluid treatment medium to offset any electrical imbalance. Additionally, by coupling the electrical contact to a neutral potential and by electrically connecting the conductive layers to each other and the electrical contact, any charge build-up in the filter medium or fluid may be substantially inhibited.

In another preferred embodiment the first and second conductive layers are electrically connected and are also preferably isolated, e.g., insulated, from a neutral potential, such as ground. The first and second conductive layers may be isolated in any suitable manner. For example, the end caps as well as the upstream drainage layer and the downstream drainage layer may be fashioned from a nonconductive material, preventing any electrical connection between the first and second conductive layers and the housing and, thereby to ground. As another example, if the fluid treatment element includes a cage and a core, the cage and the core as well as the end caps may be fashioned from a nonconductive material, again preventing any electrical connection between the first and second conductive layers and ground. In yet another example, if the exterior and interior of the fluid treatment element are spaced from the conductive portions of the housing, then only the end caps may be fashioned from a nonconductive material. For any of these examples, if the ends of the fluid treatment pack are electrically insulated from the end caps, e.g., by a nonconductive adhesive, then the end caps may also be fashioned from a conductive material.

In a preferred mode of operation, a fluid to be treated is directed through the housing of the fluid treatment assembly and through the fluid treatment element, e.g., outside-in through the filter element 21 in a dead-end mode of filtration. The fluid is distributed by the upstream drainage layer 11 along the upstream surface of the conductive cushioning layer 12 and, hence, to the upstream surface of the fluid treatment medium 13, e.g., the upstream surface of the filter matrix 15. The fluid then passes through the fluid treatment medium 13, e.g., through the filter matrix 15, depositing undesirable substances such as particulates on or within the filter matrix 15. The fluid then passes through the conductive substrate 16 and drains along the downstream drainage layer 14 through the perforated core 24 to the interior of the fluid treatment pack 10.

While not being bound by any particular theory of operation, it is believed that as the fluid passes through the fluid treatment medium 13, in particular, as a conductive or nonconductive fluid passes through a nonconductive medium, electrical charge may be transferred between the medium 13, e.g., the fluid treatment matrix 15, and the fluid. The first and second conductive layers 12, 14 are positioned in sufficiently close proximity to the fluid treatment matrix 15 to offset the electrical imbalance, e.g., to gather the electrical charge from the fluid treatment matrix 15 and return the charge to the fluid and/or to prevent the charge from accumulating in the fluid treatment matrix 15. For example, one or both of the first and second conductive layers may be immediately adjacent to and in face-to-face contact with the fluid treatment medium. This configuration is preferred because it enhances the electrical coupling between the fluid treatment medium and the conductive layer(s) over the entire surface area of the fluid treatment medium. Alternatively, one or more nonconductive layers may be interposed between the fluid treatment medium and each of the first and second conductive layers as long as the first and/or second conductive layers are sufficiently close to the fluid treatment medium to inhibit electrical imbalance and/or charge build-up through the intervening layer. Electrical imbalance and/or charge build-up in the fluid treatment medium and/or the fluid is thus substantially reduced. The porosity of both conductive layers or at least the downstream conductive layer is preferably arranged to provide sufficient contact between the fluid and the conductive layer to facilitate offsetting the electrical imbalance as the fluid flows through the conductive layers. For example, the nominal pore size one or both of the conductive layers may be less than about 500 $\mu$  or less than about 250 $\mu$  or less than about 100 $\mu$ . However, the pore size of each conductive layer is preferably large enough that no substantial pressure drop occurs as the fluid flows through the conductive layer. For example, the pressure drop through the downstream conductive layer is preferably no greater than about 5% or preferably no greater than about 1% of the pressure drop through the fluid treatment pack.

While the embodiment illustrated in Figures 1 and 2 has been described with reference to a generally cylindrical, pleated fluid treatment element, such as a filter element arranged for dead-end filtration, the invention is not limited to this embodiment. For example, the fluid treatment element may have a box-like configuration and/or the fluid treatment pack may include micro-pleats and macro-pleats. Several examples of a fluid treatment element having a box-like configuration and micro- and macro-pleats are



disclosed in USP 5,098,767, which is incorporated by reference in its entirety. As another example, the fluid treatment pack may be spirally-wound rather than pleated, and a fluid treatment element including pleated or spirally-wound pack may be arranged for cross flow separation, e.g., cross flow filtration. Several examples of a fluid treatment element including a pleated or spirally-wound fluid treatment pack being arranged for cross flow separation and/or mass transfer are disclosed in International Publication No. WO 00-13767, which is incorporated by reference in its entirety.

In accordance with a second aspect of the invention, a fluid treatment pack comprises a pleated multi-layer composite having interior roots and exterior crests. The multi-layer composite includes a porous fluid treatment medium and at least one conductive layer electrically coupled to the porous medium to transfer charge between porous medium and the conductive layer. The fluid treatment pack may be removably mountable to a conductive perforated core and the conductive layer may comprise the interior surface of the fluid treatment pack including the interior surface at the roots. Alternatively or additionally, the fluid treatment pack may be removably mountable to a conductive perforated cage and the conductive layer may comprise the exterior surface of the fluid treatment pack including the exterior surface at the crests. The pleats may be respectively dimensioned to enhance the electrical connection between the conductive layer and the core and/or the cage, e.g., by allowing the roots and/or the crests to press against the core and/or cage. As fluid flows through the fluid treatment pack, the fluid may be treated, e.g., undesirable substances, such as particulates, may be removed from the fluid. With the porous medium electrically coupled to the conductive layer and with the conductive layer electrically coupled to the core and/or cage, a substantial portion of any electrical charge in the porous fluid treatment medium and/or fluid may be dissipated via the conductive layer and the conductive core and/or cage to a neutral potential, such as ground.

In one preferred embodiment, a fluid treatment pack comprises a multi-layer composite removably mountable to a conductive perforated core. The multi-layer composite preferably includes a non-conductive upstream drainage layer, an upstream conductive cushioning layer, a non-conductive porous filter matrix bonded to a conductive substrate, and a conductive downstream drainage layer. The conductive layers are preferably electrically connected via a longitudinal side seam, for example by fusion bonding the conductive layers at the side seam. Further, the multi-layer composite

is preferably pleated and the pleats are dimensioned to allow the roots to press against the core and provide an electrical connection at the roots which comprises contact between the conductive downstream drainage layer and the core.

As shown in Figure 3, one example of a fluid treatment pack, e.g., a filter pack 40, embodying the present invention comprises a pleated, multi-layer composite having a hollow, generally cylindrical configuration. The multi-layer composite may comprise a porous upstream drainage layer 41, a porous conductive cushioning layer 42, a fluid treatment medium, such as a permeable or semipermeable filter medium 43, and a porous conductive downstream drainage layer 44, which includes the interior surface of the fluid treatment pack 40. The fluid treatment medium 43 may comprise a fluid treatment matrix 45, e.g., a fibrous, including filamentous, layer, and the fluid treatment matrix 45 may be dry-laid or wet-laid on and bonded to a porous conductive substrate 46. The porous conductive substrate 46 is preferably disposed immediately downstream of and in intimate bonded contact with the fluid treatment matrix 45, and the conductive downstream drainage layer 46, which may comprise the conductive layer in this embodiment of this second aspect of the invention, is disposed immediately downstream of and in face-to-face contact with the conductive substrate 46. Similarly, the conductive cushioning layer 42 is disposed immediately upstream of and in face-to-face contact with the fluid treatment matrix 45, and the conductive upstream drainage layer 41 is, which may also comprise the conductive layer in this embodiment of the invention, disposed immediately upstream of and in face-to-face contact with the conductive cushioning layer 42.

Many of the properties of the drainage layers, the cushioning layers, and the fluid treatment media may be similar to those previously described with the respect to the embodiment shown in Figure 1. However, the upstream and downstream drainage layers in the embodiment shown in Figure 3 are preferably fashioned from any of a variety of suitable conductive materials to provide a conductive interior surface of the fluid treatment pack, e.g., at the roots of the pleats, and a conductive exterior surface, e.g., at the crests of the pleats. For example, the conductive drainage layers may be fashioned from a conductive material, such as a metal, carbon, or a conductive polymer, or from a nonconductive material, such as glass fiber or a nonconductive polymer, which is treated in any suitable manner to render the downstream drainage layer conductive. A conductive additive, such as metal, carbon, or a conductive polymeric particles or fibers,

including filaments, may be included with the nonconductive material or the nonconductive material may be coated with a conductive coating, such as a metal or carbon coating. In the embodiment illustrated in Figure 3, the upstream and downstream drainage layers 41, 44 preferably comprise a conductive, carbon-coated polyamide (e.g., nylon) extruded mesh; the conductive cushioning layer 42 and the conductive substrate 46 preferably comprise a conductive carbon-coated polyester nonwoven sheet; and the fluid treatment matrix 45 preferably comprises a filter matrix of wet-laid, resin-bonded glass fibers.

The multi-layer composite may be pleated in any suitable manner and formed into the generally cylindrical fluid treatment pack, such as a filter pack 40, for example, by sealing a longitudinal side seam. The pleats may extend generally radially and have a height substantially equal to  $(D-d)/2$ , or the pleats may extend non-radially and have a height greater than  $(D-d)/2$ . The fluid treatment pack 40 may be incorporated in a fluid treatment element 51 in a variety of ways, as previously described with respect to the embodiment of Figure 1. For example, the ends of the fluid treatment pack 40 may be joined to opposite open or blind end caps 52, 53, and the end caps may be formed from a conductive material or a nonconductive material. A wrap member 54 may be disposed around the exterior of the fluid treatment pack 40. In the illustrated embodiment, the end caps 52, 53, the wrap member 54 and any adhesive bonding material or sealant are all preferably conductive.

In accordance with this second aspect of the invention, the fluid treatment element preferably does not include at least one of a core and a cage. Rather, the core and/or the cage may be mounted and electrically connected to the housing of a fluid treatment assembly, and the housing may, in turn, be electrically connected to a neutral potential such as ground. The fluid treatment element is preferably removably mounted to the core and/or the cage. In the illustrated embodiment, the fluid treatment element 51 may be removably mountable to a core, the core being attached to the housing of a fluid treatment assembly (not shown), which, in turn, is connected to ground. USP 5,476,585, which is incorporated by reference in its entirety, discloses various examples of coreless fluid treatment elements. However, in embodiments of this second aspect of the invention, the pleats are preferably dimensioned to contact the core.

The conductive layer, such as the conductive upstream drainage layer 41 and/or the conductive downstream drainage layer 44, and the fluid treatment medium, such as



the fibrous fluid treatment matrix 45, may be electrically coupled to each other in any suitable manner. For example, in the embodiment of Figure 3, the fibrous filter matrix 45, whether conductive or nonconductive, is in sufficiently close proximity to, preferably immediately adjacent to and in face-to-face contact with, the conductive cushioning layer 42 and the conductive substrate 46 to transfer electrical charge between them across the entire area of the filter medium. The conductive cushioning layer 42 and/or the conductive substrate 46, in turn, may each be electrically connected to the conductive upstream drainage layer 41 and/or the conductive downstream drainage layer 44, as well as the conductive cushioning layer 42 and the upstream drainage layer, in a variety of ways, as previously described with respect to the embodiment shown in Figure 1. For example, the conductive substrate 46 and the conductive downstream drainage layer 44 may be immediately adjacent one another and in intimate electrical contact with one another over the entire surface area of the conductive downstream drainage layer 44. Alternately, or additionally, the conductive layer, e.g., the conductive upstream and/or downstream drainage layer, may be electrically connected to one or more of the other conductive layers, including, for example, a conductive fluid treatment medium or fluid treatment matrix, a conductive substrate, a conductive cushioning layer, and/or a conductive drainage layer, at the side seam, at the ends of the fluid treatment pack, via conductive end caps, or via conductive intervening layers, all as previously described with respect to the previous embodiments.

While the embodiment illustrated in Figure 3 has been described with reference to a coreless fluid treatment pack such as a filter pack 40 comprising a fibrous filter matrix 45 dry-laid or wet-laid on a conductive substrate 46 and conductive upstream and/or downstream drainage layers 41, 44 as the conductive layer(s) electrically coupled to the fibrous matrix 45, the invention is not limited to this embodiment. For example, one or more conductive or non-conductive layers may be added to the fluid treatment pack. A conductive layer which functions neither as a cushioning layer nor a drainage layer may be added to the fluid treatment pack upstream or downstream of the fluid treatment medium. A conductive or nonconductive downstream cushioning layer may be disposed between the conductive substrate and the conductive downstream drainage layer, and the conductive downstream drainage layer may be connected to the conductive upstream cushioning layer at the side seam or at the ends of the fluid treatment pack and may be connected to the conductive substrate at the side seam, at the ends of the pack, or via

face-to-face contact through the intervening downstream cushioning layer. As another example, one or more of the layers may be fashioned from non-conductive material or may be eliminated entirely. The upstream cushioning layer or the substrate may be non-conductive or eliminated entirely, or both may be non-conductive or eliminated and the fluid treatment medium may be fashioned from a conductive material and electrically connected to the conductive downstream drainage layer, e.g., at the side seam or the ends of the pack. The conductive downstream drainage layer may be eliminated and the conductive substrate may comprise the conductive layer including the interior surface of the pack and electrically coupled to the fibrous matrix.

Further, the fluid treatment element may include a core, either conductive or nonconductive, but may be cageless, the cage being connected to the housing of the fluid treatment assembly and electrically connected via the housing to a neutral potential such as ground. The fluid treatment pack may then include a conductive layer, such as a conductive upstream drainage layer, having a conductive exterior surface which connects to the cage directly or indirectly through a conductive wrap member. The conductive layer, e.g., the conductive upstream drainage layer, may be electrically coupled to the porous fluid treatment medium or matrix in any suitable manner, e.g., by being immediately adjacent to and in face-to-face contact with the porous medium or matrix, via conductive intervening layers, such as a conductive upstream cushioning layer, or via a connection at the side seam or the ends of the fluid treatment pack to the cushioning layers, the porous medium or matrix, the substrate, or the downstream drainage layer.

Further, the porous fluid treatment medium need not comprise a fibrous matrix. Rather, the porous medium may comprise any of a wide variety of porous separation media. For example, the porous medium may comprise a supported or unsupported porous membrane, including a permeable or semipermeable polymeric membrane, such as a polymeric membrane formed from a nonconductive polymer. Alternatively, the porous medium may comprise a screen or an open-celled foam formed from a conductive or nonconductive material.

In a preferred mode of operation, a fluid treatment element such as a filter element 51 is mounted over a conductive perforated core of the housing of a fluid treatment assembly (not shown) through an open end cap. The pleats of the fluid treatment pack 40 are dimensioned to provide an electrical connection or contact between the interior surface of the conductive layer, e.g., the conductive downstream drainage layer 44, at the



roots of the pleats and the conductive core. Alternatively or additionally, the fluid treatment element may be mounted within a conductive cage and the pleats of the fluid treatment pack may be dimensioned to provide an electrical connection or contact between the exterior surface of the conductive layer, e.g., a conductive upstream drainage layer, at the crests of the pleats and the conductive cage, either directly or indirectly through a conductive wrap. A fluid to be treated, e.g., filtered, is directed through the housing of the fluid treatment assembly and preferably outside-in but alternatively inside-out through the fluid treatment element, e.g., through the filter element 51 in a dead-end mode of filtration. The fluid is distributed by the upstream drainage layer 41 along the upstream surface of the conductive cushioning layer 42 and, hence, to the upstream surface of the fluid treatment medium 43, e.g., the upstream surface of fibrous matrix 45. The fluid then passes through the fluid treatment medium 43, e.g., through the fibrous filter matrix 45, depositing undesirable substances such as particulates on or within the filter matrix 45. The fluid then passes through the conductive substrate 46 and drains along the conductive downstream drainage layer 44 and through the perforated core to the interior of the core, from which the fluid exits the housing.

While not being bound by any particular theory of operation, it is believed that as the fluid passes through the fluid treatment medium, in particular as a conductive or non-conductive fluid passes through a non-conductive fluid treatment medium, such as a non-conductive fluid treatment matrix 45, electrical charge may be transferred between the fluid treatment medium, e.g., the fibrous matrix 45, and the fluid. By providing electrical contact between the grounded core or cage and the interior or exterior surface of the conductive layer and by electrically coupling the conductive layer to the fluid treatment medium, the electrical imbalance is substantially offset and charge buildup in either the fluid treatment medium or the fluid is substantially inhibited. Once the fluid treatment element becomes sufficiently fouled, it may be removed from the core or cage and a cleaned or new fluid treatment element may be remounted to the core or cage.

In a preferred embodiment of this second aspect of the invention, the only electrical connection between the neutral potential such as ground and the fluid treatment pack is via the electrical contact between the interior surface of the conductive layer(s) and the core and/or the exterior surface of the conductive layer(s) and the cage. The surface area of the contact between the interior and/or exterior surface of the conductive layer(s) at the roots and/or crests of the pleats and the core and/or cage is very large and,



therefore, provides a highly effective electrical contact. The end caps may thus be formed from a non-conductive material such as a non-conductive polymeric material. No additional grounding connections, such as grounding straps, grounding springs, or conductive O-ring seals need be provided, simplifying both the construction of the fluid treatment element and the retrofitting of the existing fluid treatment assemblies with fluid treatment elements embodying this second aspect of the invention. Alternatively, the fluid treatment element may be electrically coupled to ground via any of these various other grounding connections in addition to the electrical connection between the conductive layer(s) at the roots and/or crests of the pleats and the core and/or cage.

While the embodiment illustrated in Figure 3 has been described with reference to a generally cylindrical, pleated fluid treatment element such as a pleated filter element arranged for dead-end filtration, the invention is not limited to this embodiment. Many of the alternatives suggested with respect to the embodiment shown in Figures 1 and 2 are applicable to the embodiment shown in Figure 3. For example, the fluid treatment element may include a pleated pack arranged for cross-flow separation or mass transfer.

In accordance with a third aspect of the invention, a fluid treatment element comprises a fluid treatment pack which includes a fibrous matrix supported by a conductive substrate. Preferably, the fibrous matrix is dry laid or wet laid on and bonded to the conductive substrate. The fluid treatment element further comprises an electrical contact which is electrically coupled to the conductive substrate. The electrical contact of the fluid treatment element is also arranged to be connected to a conductive portion of a fluid treatment assembly, e.g., the housing of the assembly, which, in turn, is connected to a neutral potential, such as ground. As the fluid flows through the fluid treatment assembly and, hence, through the fluid treatment element, the fluid is treated by the fibrous matrix. In addition, electrical charge may be transferred between the fluid and the fibrous matrix, especially if the fibrous matrix is nonconductive. Because the conductive substrate is bonded to the fibrous matrix, it is closely electrically coupled to the fibrous matrix. Consequently, a substantial portion of any charge imbalance which may arise in the fibrous matrix and/or the fluid can be substantially offset by the connection to the neutral potential via a conductive path including the conductive substrate and the electrical contact of the fluid treatment element and the conductive portion of the fluid treatment assembly.

As shown in Figure 4, one example of a fluid treatment element, e.g., a filter element 70, embodying the present invention comprises a fluid treatment pack, such as a filter pack 71, bonded to open and blind end caps 72, 73 at opposite ends of the filter pack 71. The pack 71 is supported by a core 74 and a cage 75 along the interior and exterior surfaces of the pack 71. The core 74 and the cage 75 are preferably permanently connected to the fluid treatment element 70, although the fluid treatment element may be coreless or cageless. In the illustrated embodiment, the end caps 72, 73, the core 74, the cage 75 and any adhesive bonding material or sealant are all preferably conductive.

The fluid treatment pack, e.g., the filter pack 71, may comprise a pleated, multi-layer composite having a hollow, generally cylindrical configuration. The multi-layer composite may be pleated in any suitable manner and formed into the generally cylindrical pack, for example, by sealing a longitudinal side seam. The pleats may extend generally radially and have a height substantially equal to  $(D-d)/2$ , or the pleats may extend nonradially and have a height greater than  $(D-d)/2$ .

The pleated multi-layer composite may comprise a porous conductive upstream drainage layer 80, a porous conductive upstream cushioning layer 81, fluid treatment medium, such as a filter medium 82, including a fibrous matrix, such as a fibrous filter matrix 83, dry-laid or wet-laid on and bonded to a porous conductive substrate 84, and a porous conductive downstream drainage layer. Many of the properties of the drainage layers and the cushioning layers may be similar to those previously described with respect to the embodiments shown in Figures 1-3.

However, the fluid treatment medium, e.g., the filter medium 82, may comprise a fibrous fluid treatment matrix 83 supported by the conductive substrate 84. Preferably the fibrous fluid treatment matrix 83 is laid on and bonded to the conductive substrate 84.

The fibrous matrix 83 may be fashioned from a variety of fibrous, including filamentous, materials and may be formed from only nonconductive materials, from conductive materials, or from a mixture of conductive and nonconductive materials. The conductive substrate 84 may be fashioned from a mesh, screen, netting, or woven or non-woven sheet and may be formed from a conductive material or a nonconductive material which is treated in any suitable manner to render the substrate conductive. The fibrous matrix 83 is preferably laid on the conductive substrate 84, e.g., dry-laid or wet-laid, and is bonded to the conductive substrate 84, e.g., chemically bonded, solvent bonded, thermally bonded, and/or mechanically bonded by mechanical entanglement of the fibers of the



fibrous matrix 83 and the substrate 84, thereby forming a composite fluid treatment medium 82. Many preferred composite media comprising a filter matrix and a conductive substrate are disclosed, for example, in United States Provisional Patent Application No. 60/166,990 of Joseph Adiletta, Leonard Bensch, Kenneth Williamson, and Ronald Hundley, entitled Porous Media For Dissipating Electrical Charge and the PCT application of Joseph Adiletta, Leonard Bensch, Kenneth Williamson, and Ronald Hundley, entitled Porous Media For Dissipating Electrical Charge filed concurrently with this application, which are incorporated by reference in their entirety. In the illustrated embodiment, the conductive substrate 84 preferably comprises a conductive non-woven sheet, such as a carbon coated polyester non-woven sheet, and the fibrous matrix 83 preferably comprises a wet-laid, resin-bonded glass fiber layer. The conductive substrate and the electrical contact may be electrically coupled in a wide variety of ways, including, any of the previously described electrical connections at the side seam, at the ends of the fluid treatment pack, or via intervening conductive layers.

The electrical contact preferably comprises any conductive portion of the fluid treatment element which is electrically coupled to the conductive layer and is arranged to contact a conductive portion of the fluid treatment assembly. For example, the electrical contact may be any conductive portion of the fluid treatment pack 71 (e.g., the interior surface or the exterior surface), the end caps 72, 73, the core 74, and the cage 75 which is electrically connected to the conductive substrate 84 and is arranged to contact a conductive portion of the fluid treatment assembly. In particular, the electrical contact 86 may preferably comprise a conductive portion of the open end cap 73 or the core 74 which may be mounted to and electrically contact a conductive fitting of the housing (not shown) which, in turn, is connected to a neutral potential such as ground.

While the embodiment illustrated in Figure 4 has been described with reference to a fluid treatment element, such as a filter element 70, which has a core 74 and a cage 75 and which includes several conductive components, the invention is not limited to this embodiment. For example, one or more conductive or nonconductive layers, such as a conductive or nonconductive downstream cushioning layer or a conductive layer which functions neither as a cushioning layer nor a drainage layer, may be added to the fluid treatment pack. As another example, one or more or all of the drainage layers, cushioning layers, and additional layers may be fashioned from a nonconductive material. The conductive substrate may, for example, then be connected to the electrical contact via a



conductive end cap. As still another example, one or more of the cushioning layers, the drainage layers, or the additional layers, such as the upstream cushioning layer or the downstream drainage layer may be eliminated entirely.

Further, the fluid treatment element may be cageless and/or coreless. The  
5 electrical contact may then comprise the exterior surface and/or the interior surface of the fluid treatment pack which contacts the cage and/or the core and is thereby electrically coupled to a neutral potential such as ground. Or the cage, the core, or both the cage and core may be fashioned from a nonconductive material. The electrical contact may then  
10 comprise a surface of a conductive end cap which is arranged to electrically contact a conductive portion of the housing. Or the end caps or the adhesive connecting the ends of the fluid treatment element to the end caps may be nonconductive. The electrical contact may then comprise a surface of a conductive cage or core which is electrically coupled to the conductive substrate in any suitable manner. The conductive cage or core may then  
15 be electrically connected to a conductive portion of the fluid treatment assembly in a wide variety of ways, e.g., via a conductive strap or wire or spring connecting the cage or the core to the housing.

In a preferred mode of operation, a fluid treatment element, such as a filter element 70, may be mounted to a fitting of the housing of a fluid treatment assembly, such as a filter assembly (not shown), at the open end cap 73. The surface of the end cap  
20 and/or the core which contacts the fitting may serve as the electrical contact which is coupled to a neutral potential such as ground through the housing. A fluid to be treated, e.g., filtered, is directed through the housing of the fluid treatment assembly and preferably outside-in, but alternatively inside-out, through the fluid treatment element, e.g., through a filter element 70 in a dead-end mode of filtration. The fluid passes  
25 through the perforated cage 75 and is distributed by the upstream drainage layer 80 along the upstream surface of the cushioning layer 81 and, hence, to the upstream surface of the fluid treatment medium 82 or the fibrous matrix 83. The fluid then passes through the fibrous matrix 83, where the fluid is treated, e.g., where undesirable substances such as particulates are deposited on or within the fibrous matrix 83. The fluid then passes  
30 through the conductive substrate 84, drains along the downstream layer 85, and passes the perforated core 74 to the interior of the core 74, from which the fluid exits the housing through the open end cap 73.

While not being bound to any particular theory of operation, it is believed that as the fluid passes the fibrous matrix 83, in particular as a conductive or nonconductive fluid passes through a nonconductive fibrous matrix, electrical charge may be transferred between the fibrous matrix and the fluid. By coupling the electrical contact 86 to the grounded fitting and by electrically connecting the conductive substrate 84 to the electrical contact 86, e.g., via a conductive connection between the conductive substrate 84 and the conductive end cap 73, any electrical imbalance may be substantially offset and any charge build up in either the fibrous matrix 83 or the fluid may be substantially inhibited. Because the fibrous matrix is laid on and bonded to the conductive substrate, the conductive substrate is particularly well coupled electrically to the fibrous matrix, significantly enhancing the ability of the conductive substrate to transfer charges between the fibrous matrix and the electrical contact and hence the neutral potential. Consequently, fluid treatment elements embodying this third aspect of the invention are very effective at inhibiting charge build up in the fibrous matrix and/or the fluid.

While the embodiment illustrated in Figure 4 has been described with reference to a generally cylindrical, fluid treatment element, such as a pleated filter element arranged for dead-end filtration, the invention is not limited to this embodiment. Many of the alternatives suggested with respect to the embodiments shown in Figures 1, 2, and 3 are applicable to this embodiment. For example, the fluid treatment element may include a pleated pack and/or may be arranged for cross flow separation or mass transfer, the fluid treatment element may include a fluid treatment pack which is spirally-wound rather than pleated, and/or the fluid treatment element may have a box-like configuration.

Another example of a fluid treatment element is a coalescer element which accretes one phase of a fluid, e.g., a liquid discontinuous phase, in another phase of the fluid, e.g., a liquid or gas continuous phase, allowing the discontinuous phase to be separated from the continuous phase. International Publications No. WO 98/14257 and No. WO 97/38781 and U.S. Patents No. 5,443,724 and No. 5,480,547 disclose a variety of coalescer elements and coalescer assemblies, as well separator elements and separator assemblies, and are incorporated herein by reference.

In accordance with another aspect of the invention, a fluid treatment element such as a coalescer element comprises first and second conductive layers and a porous fluid treatment medium such as a coalescer medium. The first and second conductive layers are preferably electrically connected to each other and the coalescer medium is disposed

between them. As a fluid flows through the coalescer element, in particular, the coalescer medium, a discontinuous phase of the fluid is accreted on the surfaces of the coalescer medium. In addition, an electrical charge may be transferred between the fluid and the coalescer medium, especially if the coalescer medium is non-conductive. The first and second conductive layers are positioned in sufficient proximity to the coalescer medium to offset any electrical imbalance, for example, by dissipating the charge and/or collecting the charge in the coalescer medium and returning the charge to the fluid as it flows through the conductive layers or by preventing the charge from accumulating in the coalescer medium. Thus, even if the coalescer element is electrically isolated from the ambient environment, e.g., electrically isolated from a common or neutral potential such as ground, the first and/or second conductive layers may offset all or a substantial portion of the electrical imbalance which may arise in the coalescer medium. The coalescer medium is thus substantively surrounded by an electrical cage which offsets, e.g., reduces, inhibits, or prevents, the electrical imbalance.

As shown in Figure 5, one example of a fluid treatment element such as a coalescer element 100 embodying the present invention has a hollow generally cylindrical configuration, and fluid flows outside-in or, preferably, inside-out through the coalescer element 100. The coalescer element 100 may include a perforated conductive core 101 and a coalescer medium 102 disposed around the core 101. The coalescer medium 102 preferably includes a packing material or coalescing matrix 103 having a smaller nominal pore size and a final classifier 104 having a larger nominal pore size downstream of the coalescing matrix 103. The coalescer medium 102 thus has a graded nominal pore structure where an upstream region has a smaller nominal pore size than the nominal pore size of a downstream region. In the illustrated embodiment, a fluid preferably flows inside-out through the coalescer element 100 and the coalescing matrix 103 is disposed co-axially between the core 101 and the final classifier 104. A conductive wrap structure 105 having openings, such as the wrap structure disclosed in International Publication No. WO 98/14257, is preferably disposed around the final classifier 104. Each of these components is preferably disposed between opposite end caps 110, 111, one or both of which may be an opened end cap. The conductive core 101 and the conductive wrap structure 105 may comprise the first and second conductive layers with the coalescer medium 102 including the coalescing matrix 103 disposed between them.



The core 101 may be fashioned from any suitably conductive material, such as a metal or a conductive polymer, or any non-conductive material that has been rendered conductive in any suitable manner and preferably has a perforated hollow configuration. For example, the core 101 preferably comprises a hollow, perforated, stainless steel tube, where fluid flows between the interior of the hollow tube and the exterior of the hollow tube via the perforations or holes. Alternatively, the core may have a solid configuration or a hollow configuration without holes and flow channels may be disposed along the outer surface of the core.

The coalescer matrix 103 may be fashioned from a wide variety of materials having suitable coalescing characteristics, including a fibrous mass, fibrous mats, woven or non-woven sheets or screens, or porous membranes. The coalescing matrix 103 may be a single layer structure or a multi-layer structure and may have a uniform pore structure or a graded pore structure where, for example, an upstream region adjacent to the core 101 has a larger pore size than a downstream region in order to more evenly distribute fluid flow from the core 101 into the coalescing matrix 103. A graded pore structure may also be effected with multiple layers where, for example, each layer has a uniform pore structure and an upstream layer has a larger pore size than a downstream layer. However, the nominal pore size of the coalescing matrix 103 is preferably in the range from about  $0.2\mu$  or less to about  $20\mu$  or more, e.g., from about  $0.2\mu$  to about  $5\mu$ . Further, while the coalescing matrix 103 may be pleated, it is preferably arranged in a non-pleated configuration, e.g., a hollow cylindrical configuration.

The coalescing matrix 103 may be formed from a material or may be surface modified in any suitable manner, e.g., coated with a material, which facilitates the formation of droplets of the discontinuous phase and the accretion of these small droplets into larger droplets as the discontinuous phase contacts the coalescing matrix 103. The desired physical and chemical characteristics, e.g., the critical surface energy, of the coalescing matrix 103 which promotes the formation and accretion of droplets of the discontinuous phase may vary in accordance with the nature of the discontinuous phase and/or the continuous phase. Thus, the coalescing matrix 103, as well as the final classifier 104, may comprise a metallic material, a polymeric material, a glass fiber material, or any other suitable material or mixture of materials and may be treated to modify its critical surface energy, e.g., by application of a suitable surface treatment, such

a silicone or fluoropolymer surface treatment available from 3M Company or from Pall Corporation.

5 A preferred embodiment of the coalescing matrix 103 comprises a matrix of non-conductive polymeric fibers, e.g., polyester fibers, blown onto the perforated metal core 101, as described in International Publication No. WO 96/03194. The polymeric fibers of the coalescing matrix 103 may be treated to modify the critical surface energy by application of a fluoropolymer surface treatment.

10 The final classifier 104 is disposed co-axially downstream of and, preferably, immediately adjacent to the coalescing matrix 103 and preferably has a nominal pore size no less than and preferably greater than that of the coalescing matrix 103. For example, the nominal pore size of the final classifier 104 is preferably in the range from about 50 $\mu$  to about 1000 $\mu$ , e.g., from about 50 $\mu$  to about 300 $\mu$ . The final classifier 104 may be fashioned from any suitable material or may be surface modified in any suitable manner, e.g., by application of a fluoropolymer surface treatment, which facilitates drainage of the  
15 droplets of the discontinuous phase away from the coalescing medium 103 and/or which further facilitates the formation and the accretion of droplets of the discontinuous phase. The final classifier 104 is also preferably formed as a cylindrical mass or sheet of polymeric fibers, e.g., polyester fibers. In a preferred embodiment, the final classifier 104 comprises a plurality of sheets of a fibrous polyester non-woven, e.g., about five sheets.  
20 The upstream sheet(s) have a smaller nominal pore size than the downstream sheet(s).

The conductive wrap structure 105 is disposed co-axially downstream of the final classifier 104, preferably immediately downstream. The wrap structure 105 preferably comprises a porous material having holes extending through the porous material. The holes are preferably arranged uniformly along the porous material and may have a  
25 dimension, such as a diameter, of about D, where D is any rational number in the range from about 20 thousandths of an inch or less to about 250 thousandths of an inch or more. The porous material may be treated to inhibit passage of the discontinuous phase but allow passage of the continuous phase. Accordingly, the droplets of the discontinuous phase may be constrained to flow primarily through the holes of the wrap structure 105  
30 while the continuous phase may pass through the pores of the porous material of the wrap structure 105.

The conductive wrap structure 105 may be formed from a conductive material, such as a metal, carbon, or a conductive polymer, or from a non-conductive material, such

as glass fiber or a non-conductive polymer, e.g., a non-conductive polymeric fiber, which is treated to render the wrap structure conductive. For example, the non-conductive material may be treated in any manner similar to those previously mentioned with respect to the filter elements, including providing a conductive additive such as metal, carbon, or  
5 conductive polymeric particles or fibers within a non-conductive material or coating the non-conductive material with a conductive coating such as a metal or carbon coating.

The ends of the wrap structure 105, the final classifier 104, the coalescing matrix 103, and the core 101 may be joined to opposite end caps 110, 111 in any suitable manner, such as melt bonding, adhesive bonding, spin bonding, welding, or brazing. One  
10 of the end caps may be blind and the other may be open or both end caps may be open.

The conductive layers such as the conductive wrap 105 and the conductive core 101 are preferably electrically connected to one another and may be electrically connected to each other in a variety of ways. For example, they may be electrically connected in many of the same ways that the conductive layers of the filter packs and the  
15 filter elements previously discussed are connected. For example, one of the conductive layers, e.g., the wrap structure 105, may physically contact the other conductive layer, e.g., the conductive core 101, at the ends of the conductive layers adjacent to the end caps. Alternatively or additionally, the first and second conductive layers may be electrically connected through the intervening layers. For example, the final classifier  
20 104 and the coalescing matrix 103 may include conductive fibers including conductive filaments which electrically connect one of the conductive layers to the other conductive layer across the entire area of the final classifier 104 and the coalescing matrix 103. Alternatively, or additionally, the first and second conductive layers may be electrically coupled via a conductive end cap, e.g., a metal end cap or a conductive polymeric end  
25 cap, and/or via a conductive adhesive at the end caps 110, 111. With the first and second conductive layers electrically connected to each other, the fluid treatment medium such as the coalescing medium 102 is substantively surrounded with an electrical cage.

While the embodiment illustrated in Figure 5 has been described with reference to a fluid treatment element comprising a conductive core 101, a fluid treatment medium  
30 such as a coalescing medium 102 including a coalescing matrix 103 and a final classifier 104, and a conductive wrap structure 105 arranged in a cylindrical configuration, the invention is not limited to this embodiment. For example, one or more of the layers, such as the final classifier, may be eliminated entirely and/or additional layers, such as a



drainage layer between the coalescing medium and the perforated core or a substrate on which the coalescing matrix is laid, may be added. Further, the core may be non-conductive or it may be electrically isolated from the second conductive layer, and the first conductive layer may comprise a conductive drainage layer or a conductive

5 substrate. Further, the wrap structure may be non-conductive or eliminated, and the second conductive layer may comprise a conductive final classifier, a conductive screen wrapped around the coalescing matrix or a conductive outer retainer such as a metal cage or a metal screen disposed around the exterior of the coalescer element. Additionally, the coalescer element may have a non-cylindrical geometry, e.g., a box-shaped configuration.

10 A fluid treatment element comprising the coalescer element 100 may be placed in a housing (not shown) of a fluid treatment assembly comprising a coalescer assembly or a combination coalescer and separator assembly. In one embodiment, the fluid treatment element includes an electrical contact, and the first and second conductive layers preferably are electrically connected to each other and are electrically coupled to the

15 electrical contact, which is arranged to be connected to a neutral potential, e.g., ground. The first and second conductive layers may be electrically coupled to the electrical contact and the electrical contact may be electrically coupled to the neutral potential in any suitable manner, for example, as previously discussed with respect to filter elements.

In another embodiment, the first and second layers may be electrically connected

20 to each other and isolated, e.g., insulated, from a common or neutral potential such as ground. The first and second conductive layers may be isolated in any suitable manner, for example, as previously discussed with respect to the filter elements.

In a preferred mode of operation, the fluid to be treated is directed through the housing of the fluid treatment assembly and through the fluid treatment element, e.g.,

25 inside out through coalescer element 100 in a dead-end mode of coalescence. The fluid is distributed by the perforated conductive core 101 along the upstream surface of the coalescing matrix 103. The fluid then passes through the fluid treatment medium, e.g., the coalescing matrix 103 and the final classifier 104, where droplets of the discontinuous phase are formed and accreted. The droplets of the discontinuous phase then pass

30 through the holes of the conductive wrap structure 105 while the continuous phase passes through the porous material of the wrap structure 105.

While not being bound by any particular theory of operation, it is believed that as the fluid passes through the fluid treatment element comprising the coalescing element

100, in particular, as a conductive or non-conductive fluid passes through a non-conductive coalescer medium 102, electrical charge may be transferred between the coalescer medium 102, e.g., the coalescing matrix 103 and/or the final classifier 104, and the fluid. The first and second conductive layers comprising the perforated conductive  
5 core 101 and the conductive wrap structure 105 are positioned in sufficiently close proximity to the fluid treatment medium, e.g., the coalescing medium 102, to offset any electrical imbalance, e.g., to gather the electrical charge from the coalescing matrix 103 and/or the final classifier 104 and dissipate the charge to ground or return the charge to the fluid and/or to prevent the charge from accumulating in the coalescing medium 102.  
10 For example, one or both of the first and second conductive layers may be immediately adjacent and in face-to-face contact with the fluid treatment medium, e.g., the coalescing medium 102. This configuration is preferred because it enhances the electrical coupling between the coalescing medium 102 and the conductive layer(s) over the entire surface of the fluid treatment medium. Alternatively, one or more non-conductive layers may be  
15 interposed between the fluid treatment medium and each of the first and second conductive layers of the coalescing element 100 as long as the first and/or second conductive layers are sufficiently close to the fluid treatment medium to inhibit any electrical imbalance and/or charge build-up through the intervening layer. The electrical imbalance and/or charge build-up in the fluid treatment medium such as the coalescing  
20 medium 102 is thus substantially reduced.

While the embodiment illustrated in Figure 5 has been described with reference to a generally cylindrical coalescer element 100 with a core 101 permanently attached to the element 100, the invention is not limited to this embodiment. For example, the conductive core may be permanently attached to and electrically connected to the  
25 housing, and the coalescer element may be removeably mounted to the conductive core. The conductive core may be electrically connected to the other conductive layer, e.g., the conductive wrap structure 105, in any suitable manner. For example, the other conductive layer may electrically contact one or more conductive end caps and the conductive end caps may physically contact the conductive core or may be electrically  
30 connected to the core via a conductive spring, wire, strap, or a conductive seal such as a conductive O-ring. Alternatively, the core may be non-conductive, and an inner conductive layer, such as a conductive drainage layer or substrate, may be disposed

adjacent to the coalescing medium and electrically coupled to the outer conductive layer, e.g., via conductive end caps.

In accordance with another aspect of the invention, a fluid treatment element comprises one or more layers including a coalescer medium arranged to form droplets of a discontinuous phase of a fluid flowing through the fluid treatment element. At least one of the layers of the fluid treatment element is conductive, and the fluid treatment element further comprises an electrical contact which is electrically coupled to the conductive layer of the fluid treatment element. The electrical contact is arranged to be connected to a conductive portion of a fluid treatment assembly, e.g., the housing of a coalescer assembly, which, in turn, is connected to a common or neutral potential such as ground. As the fluid flows through the fluid treatment assembly and, hence, through the fluid treatment element, the discontinuous phase of the fluid is coalesced by the coalescing medium. In addition, an electrical charge may be transferred between the fluid and the coalescing medium, especially if the coalescing medium is non-conductive. Because the fluid treatment element includes a conductive layer coupled to a neutral potential via an electrical contact, any charge imbalance and/or build-up which may arise in the coalescer medium and/or the fluid can be substantially offset, e.g., reduced or prevented, by the connection to the neutral potential.

As shown in Figure 6, one example of a fluid treatment element, e.g., a coalescer element 120, embodying the present invention comprises a perforated core 121, a coalescer medium 122, and a perforated wrap structure 125 disposed between opposite end caps 130, 131. The coalescer medium 122 preferably includes a packing material or coalescing matrix 123 and a final classifier 124. Each of the components of the coalescer element 120 may be similar to the components of the coalescer element 100 previously described.

However, in accordance with this aspect of the invention, one or more of the layers of the coalescer element 120 are conductive. For example, at least one of the core 121, the coalescing matrix 123, the final classifier 124, and the perforated wrap structure 125 are conductive and comprise the conductive layer of the fluid treatment. Any of these layers may be formed from a conductive material or may be rendered conductive in a manner similar to those previously described which respect to the filter packs and the filter elements. In a preferred embodiment, the coalescing matrix 123 is blown onto a conductive, perforated, stainless steel core 121 and the conductive core 121 comprises the



only conductive layer of the fluid treatment element. Alternatively, the coalescing matrix or the final classifier or the perforated wrap structure may each comprise the sole conductive layer, or any two, three or four of the core, the coalescing matrix, the final classifier, and the perforated wrap may comprise conductive layers. The conductive layer(s) is preferably in sufficiently close proximity to the coalescing medium 122, e.g., the coalescing matrix 123, to gather the electrical charge transferred between the fluid and the coalescing medium 122. Preferably, the conductive layer is in face-to-face contact with the coalescer medium 122 or matrix 123. While the coalescing medium itself may be conductive or may be rendered conductive, the coalescing medium is preferably fashioned in manner which enhances the physical and/or chemical characteristics, e.g., critical surface energy, that facilitate coalescence and, therefore, the coalescing medium may be non-conductive.

The electrical contact, which may be similar to the electrical contacts previously described for the filter elements, preferably comprises any conductive portion of the fluid treatment element, e.g., the coalescer element 120, which is electrically coupled to the conductive layer(s) and is arranged to contact a conductive portion of the fluid treatment assembly, e.g., the housing of a coalescer assembly. For example, the electrical contact may be a portion of the conductive core that is electrically connected to a conductive portion of the housing, e.g., a stool, a spider, or a tie rod of the housing. Alternatively or additionally, the electrical contact may be a conductive portion of a conductive end cap that is electrically coupled to the conductive layer(s) of the coalescer element, e.g., directly or via a conductive bonding agent, and to a conductive portion of the housing. Alternatively or additionally, the electrical contact may comprise one or more additional conductive components such as a conductive wire, strap, spring or seal, e.g., a conductive O-ring or gasket, that is electrically coupled to the coalescer medium via the conductive layer of the coalescer element, e.g., directly or via a conductive bonding agent and/or a conductive end cap, and to a conductive portion of the housing. Alternatively or additionally, the coalescer medium may be pleated and electrical contact may comprise a conductive portion at the roots or crests of the pleated coalescer medium or substrate that is electrically connected to the housing, e.g., to a conductive core or a conductive cage permanently connected to the housing.

As shown in Figure 7, one example of a fluid treatment assembly, e.g., a coalescer assembly 140 includes a housing 141 having an inlet 142, an outlet 143 and a tube sheet

144 including a plurality of stools 145. A coalescer element 120 is mounted to a hub on each stool 145, for example, by a tie rod 146 and a spider 147. The coalescer element 120 includes a conductive core 121 electrically connected to opposite conductive end caps 130, 131. A portion of the upper end cap 130 serves as the electrical contact  
5 electrically coupling the coalescer medium 122 via the conductive core 121 to the tie rod 146 and, hence, to ground. In addition, a conductive O-ring 148 mounted to the lower end cap 131 serves as the electrical contact electrically coupling the coalescer medium 122 via the conductive core 121 to the stool 145 and, hence, to ground.

In a preferred mode of operation, the fluid to be treated is directed through the  
10 housing of the fluid treatment assembly and through the fluid treatment element, e.g., inside out through the coalescer element 120 in a dead-end mode of coalescence. The fluid is distributed by the perforated conductive core 121 along the upstream surface of the fluid treatment medium, e.g., the coalescer medium 122. The fluid then passes through the coalescer medium 122, e.g., the coalescing matrix 123 and the final classifier  
15 124, where droplets of the discontinuous phase are formed and accreted. The droplets of the discontinuous phase then pass through the holes of the wrap structure 125 while the continuous phase passes through the porous material of the wrap structure 125.

While not being bound by any particular theory of operation, it is believed that as the fluid passes through the fluid treatment element comprising the coalescing element  
20 120, in particular, as a conductive or non-conductive fluid passes through a non-conductive coalescing medium 122, electrical charge may be transferred between the coalescer medium 122, e.g., the coalescing matrix 123 and/or the final classifier 124, and fluid. By coupling the electrical contact to the coalescer medium 122 via the conductive layer of the coalescer element 120, e.g., the conductive core 121, and to the grounded  
25 housing, any charge imbalance and any charge build-up in either the coalescer medium 122 or the fluid may be substantially reduced or prevented entirely.

While the embodiment illustrated in Figure 6 has been described with reference to a generally cylindrical coalescer element 120 having a core 121 permanently mounted to the coalescer element 120, a coalescer matrix 123, a final classifier 124, and a perforated  
30 wrap structure 125, the invention is not limited to this embodiment. For example, the core may be permanently attached to a housing and the coalescer may be removably mounted to the core. Further, one or more layers, such as the final classifier or the perforated wrap structure, may be eliminated entirely and/or other conductive or non-

conductive layers may be added, including a drainage layer between the coalescing medium and the perforated core, a substrate on which the coalescing matrix is laid, a screen wrapped around the downstream surface of the coalescing matrix, or an outer retainer, e.g., a cage or a screen disposed around the exterior of the coalescer element.

5 Additionally, the coalescer element may have a non-cylindrical geometry, e.g., a box-shaped configuration.

As shown in Figure 8, another example of a fluid treatment element includes a coalescer element 150 disposed adjacent to and preferably downstream of a filter element 151. The coalescer element 150 and the filter element 151 may be fixably mounted  
10 adjacent to one another between opposite end caps 152, 153 or may be removeably mounted as disclosed, for example, in International Publication No. WO 96/33789 and U.S. Application No. 60/145,213, both of which are incorporated by reference. Both the coalescer element 150 and the filter element 151 may include any of the previously described mechanisms for dissipating, transferring, and/or preventing the accumulation of  
15 electrical charge in the fluid treatment medium.

Another example of a fluid treatment element is a separator element which resists or prevents the passage of one phase of a fluid, e.g., a liquid discontinuous phase, but allows the passage of another phase, e.g., a liquid or gas continuous phase, through the separator element. In accordance with another aspect of the invention, a fluid treatment  
20 element such as a separator element comprises first and second conductive layers and a porous fluid treatment medium such as a separator medium. The first and second conductive layers are preferably electrically connected to each other and the separator medium is disposed between them. The fluid is directed toward the separator element and the separator medium resists or prevents passage of the discontinuous phase but  
25 allows passage of the continuous phase through the separator element. In addition, an electrical charge may be transferred between the fluid and the separator medium, especially if the separator medium is non-conductive. The first and second conductive layers are positioned in sufficiently close proximity to the separator medium to offset any electrical imbalance, for example, by dissipating the charge and/or collecting the charge  
30 in the separator medium and returning the charge to the fluid as it flows through the conductive layers or by preventing the charge from accumulating in the separator medium. Thus, even if the separator element is electrically isolated from the ambient environment, e.g., electrically isolated from a common or neutral potential such as



ground, the first and/or second conductive layers may offset all or a substantial portion of the electrical imbalance which may arise in the separator medium. The separator medium is thus substantially surrounded by an electrical cage which offsets, e.g., reduces, inhibits or prevents, the electrical imbalance.

5           One example of a fluid treatment element such as a separator element embodying the present invention has a hollow, generally cylindrical configuration and fluid flows inside-out or, preferably, outside-in through the separator element. The separator element preferably comprises a perforated conductive core and an outer conductive mesh. A separator medium such as a single layer of a material which is liquiphobic with respect to  
10 the discontinuous phase and liquiphilic with respect to the continuous phase is disposed between the perforated core and the outer mesh. The outer mesh and the perforated core are preferably electrically connected at the ends of the separator element, e.g., via direct physical contact or via conductive end caps or bonding agents.

          While not being bound by any particular theory of operation, it is believed that as  
15 the continuous phase of a fluid passes through the fluid treatment element comprising the separator element, in particular, as a conductive or non-conductive fluid passes through a non-conductive separator medium, an electrical charge may be transferred between the separator medium and the fluid. The first and second conductive layers comprising the perforated conductive core and the conductive outer sleeve are positioned in sufficiently  
20 close proximity to the fluid treatment medium, e.g., the separator medium, to offset any electrical imbalance, e.g., to gather the electrical charge from the separator medium and return the charge to the fluid and/or to prevent the charge from accumulating in the separator medium.

          In accordance with another aspect of the invention, a fluid treatment element  
25 comprises one or more layers including a separator medium arranged to inhibit or prevent the passage of a discontinuous phase while allowing the passage of a continuous phase of a fluid. At least one of the layers of the fluid treatment element is conductive, and the fluid treatment element further comprises an electrical contact which is electrically coupled to the separator medium via the conductive layer of the fluid treatment element.  
30 The electrical contact is arranged to be connected to a conductive portion of the fluid treatment assembly, e.g., the housing of a separator assembly, which, in turn, is connected to a common or neutral potential such as ground. As the continuous phase flows through the fluid treatment assembly, and, hence, through the separator medium, an electrical

charge may be transferred between the fluid and the separator medium, especially if the separator medium is non-conductive. Because the fluid treatment element includes a separator medium coupled to a neutral potential via the conductive layer and the electrical contact, any charge imbalance and/or build-up which may arise in the separator medium and/or the fluid can be substantially offset by the connection to the neutral potential.

One example of a fluid treatment element, e.g., a separator element embodying the present invention comprises a conductive perforated core and a single layer of a separator medium disposed around the core and preferably in intimate contact with the core. The separator medium may be conductive or non-conductive. The ends of the conductive core and the separator medium may be disposed between opposite end caps. The electrical contact, which may be similar to the electrical contacts previously described with respect to the coalescer elements and the filter elements, may be a portion of the conductive core that is electrically connected to a conductive portion of the housing; the electrical contact may be a conductive portion of a conductive end cap that is electrically coupled between the conductive core and the conductive portion of the housing; and/or the electrical contact may be an additional conductive component such as a conductive wire, strap, spring or seal, e.g., a conductive O-ring or gasket, that is electrically coupled between the conductive core and a conductive portion of the housing. As the continuous phase of the fluid flows through the separator medium, any electrical charge imbalance and/or build-up in the separator medium is coupled to ground via the conductive core and the electrical contact.

The conductive components of the present invention, including but not limited to the conductive drainage layers, cushioning layers, fluid treatment media, substrates and/or wrap members, as well as the conductive end caps, cage, core, seals, sealant and/or end cap bonding composition, preferably have high electrical conductivity or low electrical resistivity. For example, the conductive components preferably have a surface resistivity on the order of about  $10^{10}$  ohms/square or less, preferably on the order of about  $10^6$  ohms/square or less, more preferably on the order of about  $10^4$  ohms/square or less, e.g., from about  $1 \times 10^3$  ohms/square or less to about  $7 \times 10^3$  ohms/square or more. Alternatively or additionally, the conductive components preferably have a resistivity on the order of about  $10^{12}$  ohm-centimeters or less, most preferably  $10^{10}$  ohm-centimeters or less. The resistivity including the surface resistivity can be determined by methods known to those skilled in the art, e.g., by ASTM Method D257 and/or D4496.

The various aspects of the invention have been described with respect to many embodiments. However, the invention is not limited to these embodiments. For example, one or more of the features of any of these embodiments may be combined with one or more of the features of the other embodiments without departing from the scope of the invention. Further, one or more of the features of any of these embodiments may be modified or omitted without departing from the scope of the invention. Accordingly, the various aspects of the invention include all modifications encompassed within the spirit and scope of the invention as defined by the following claims.



## Claims

1. A fluid treatment element for treating fluid flowing through the element, the fluid treatment element comprising:
  - a first conductive layer;
  - 5 a second conductive layer electrically coupled to the first conductive layer; and
  - a nonconductive porous fluid treatment medium disposed between the first and second conductive layers, wherein the first and second layers are positioned to offset electrical imbalances caused by fluid flowing through the porous fluid treatment medium.
- 10 2. The fluid treatment element according to claim 1 further comprising an electrical contact electrically coupled to the first and second conductive layers and arranged to be connectable to a neutral potential.
- 15 3. The fluid treatment element according to claim 2 wherein the electrical contact comprises a conductive end cap.
4. The fluid treatment element according to any of the preceding claims wherein the first and second conductive layers are electrically connected to each other via a conductive side seam.
- 20 5. The fluid treatment element according to claim 1 wherein the first and second conductive layers are isolated from a neutral potential.
- 25 6. A fluid treatment pack for removing one or more substances from fluid flowing through the pack, the fluid treatment pack comprising:
  - a fluid treatment medium; and
  - an electrical cage surrounding the porous fluid treatment medium, wherein the electrical cage offsets electrical imbalances caused by fluid flowing through the porous fluid treatment medium.
- 30 7. The fluid treatment pack of claim 6 further comprising an electrical contact electrically coupled to the electrical cage and arranged to be connected to a neutral potential.

8. The fluid treatment pack of claim 6 wherein the electrical cage is isolated from a neutral potential.

5 9. A method for treating a fluid comprising:  
directing a fluid through a porous fluid treatment medium;  
transferring an electrical charge from the fluid to the porous treatment medium;  
and  
returning the electrical charge from the porous fluid treatment medium to the  
10 fluid.

10. A fluid treatment element for use in a fluid treatment assembly having a core or a cage attached to the fluid treatment assembly such that the fluid treatment element is removably mountable to the cage or the core of the fluid treatment assembly,  
15 the fluid treatment element comprising:

a fluid treatment pack including a pleated multi-layer composite having interior roots and exterior crests wherein the multi-layer composite includes a fluid treatment medium and at least one conductive layer electrically coupled to the fluid treatment medium, wherein the fluid treatment medium is coreless or cageless and the conductive  
20 layer includes one of an interior conductive surface at the roots of the fluid treatment pack and an exterior conductive surface at the crests of the fluid treatment pack, the pleats being dimensioned to provide an electrical connection between the roots and the core or the crests and the cage when the fluid treatment element is mounted to the fluid treatment assembly.

25

11. The fluid treatment element of claim 10 wherein the at least one conductive layer is positioned downstream of the fluid treatment medium.

12. A method for treating a fluid comprising:  
30 removably mounting a pleated fluid treatment element to a core or a cage,  
including electrically connecting the core and a conductive interior surface of a conductive layer at the roots of a pleated fluid treatment pack or electrically connecting

the cage and a conductive exterior surface of a conductive layer at the crests of the pleated fluid treatment pack;

directing a fluid through the fluid treatment pack, including directing the fluid through a porous fluid treatment medium and the conductive layer, the conductive layer  
5 being electrically coupled to the fluid treatment medium; and

transferring an electrical charge between the fluid treatment medium or the fluid and the conductive layer.

13. A fluid treatment element for treating a fluid flowing through the fluid  
10 treatment element, the fluid treatment element comprising:

a fluid treatment medium including a conductive substrate and a fibrous fluid treatment matrix supported by the conductive substrate; and

an electrical contact electrically coupled to the conductive substrate and arranged to be connected to a neutral potential.

15

14. A method for treating a fluid comprising:

directing a fluid through a fluid treatment element including directing the fluid through a fluid treatment medium including a fibrous fluid treatment matrix supported by a conductive substrate; and

20 transferring an electrical charge from the fibrous fluid treatment matrix or the fluid to an electrical contact on the fluid treatment element via the conductive substrate.

15. The fluid treatment element or method of any preceding claim wherein the fluid treatment medium comprises a filter medium, a coalescer medium, or a separator  
25 medium.

16. A fluid treatment element for treating a fluid flowing through the fluid treatment element, the fluid treatment element comprising;

one or more layers including at least one of a coalescing medium arranged to form  
30 droplets of a discontinuous phase of the fluid and a separator medium arranged to inhibit passage of the discontinuous phase and allow passage of the continuous phase of the fluid, at least one of the layers of the fluid treatment element being conductive; and



an electrical contact electrically coupled to the conductive layer and arranged to be connected to a neutral potential.

17. The fluid treatment element of claim 16 herein the electrical contact  
5 comprises a conductive O-ring electrically coupled to a conductive end cap.

18. A coalescer element comprising:

a coalescer medium having a graded nominal pore structure wherein an upstream  
region of the coalescer medium has a smaller nominal pore size than a downstream region  
10 of the coalescer medium, the coalescer medium being arranged to form droplets of a  
discontinuous phase of a fluid; and

a conductive O-ring electrically coupled to the coalescer medium to enable  
electrical charge in the coalescer to dissipate to a neutral potential.

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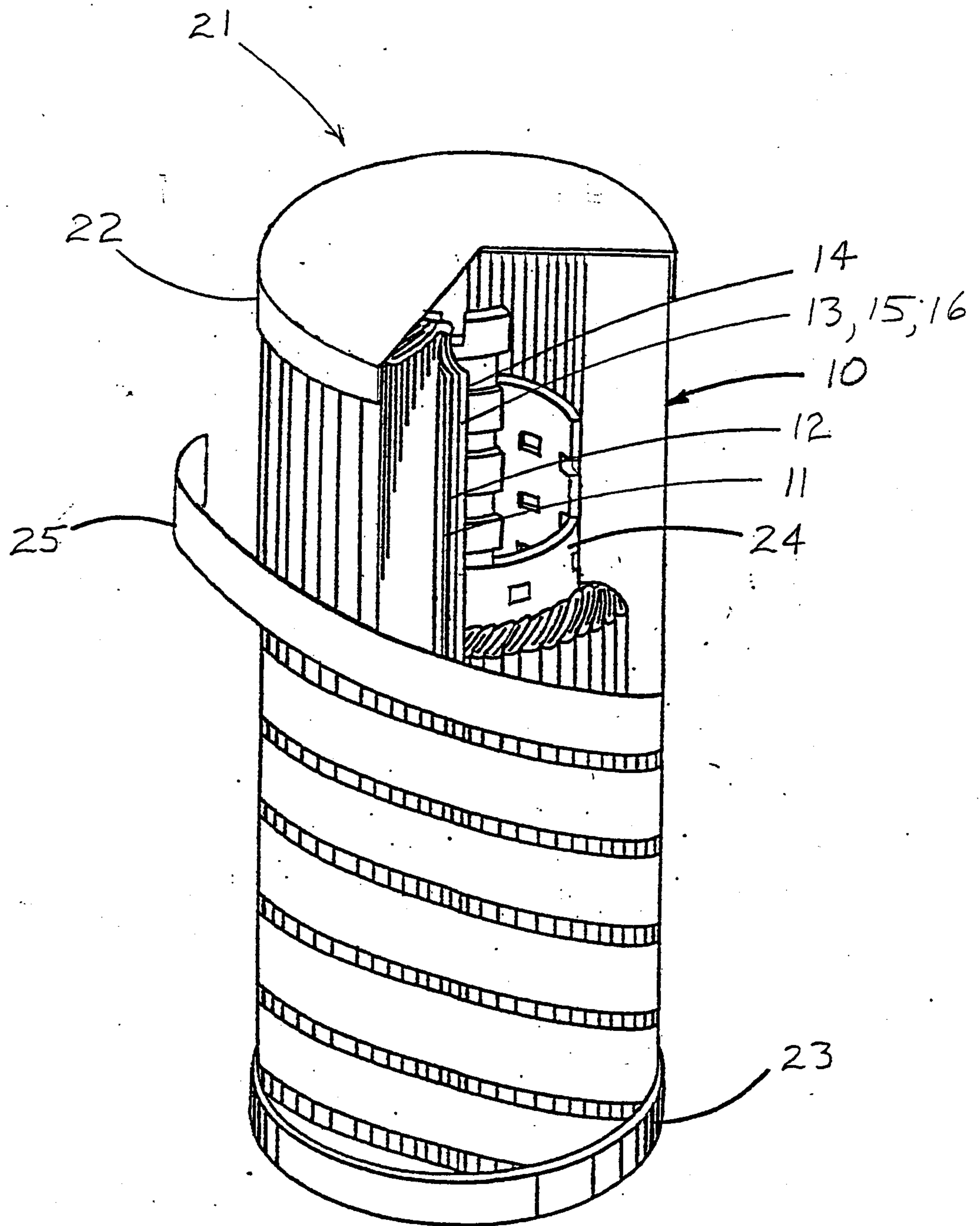


FIG. 1

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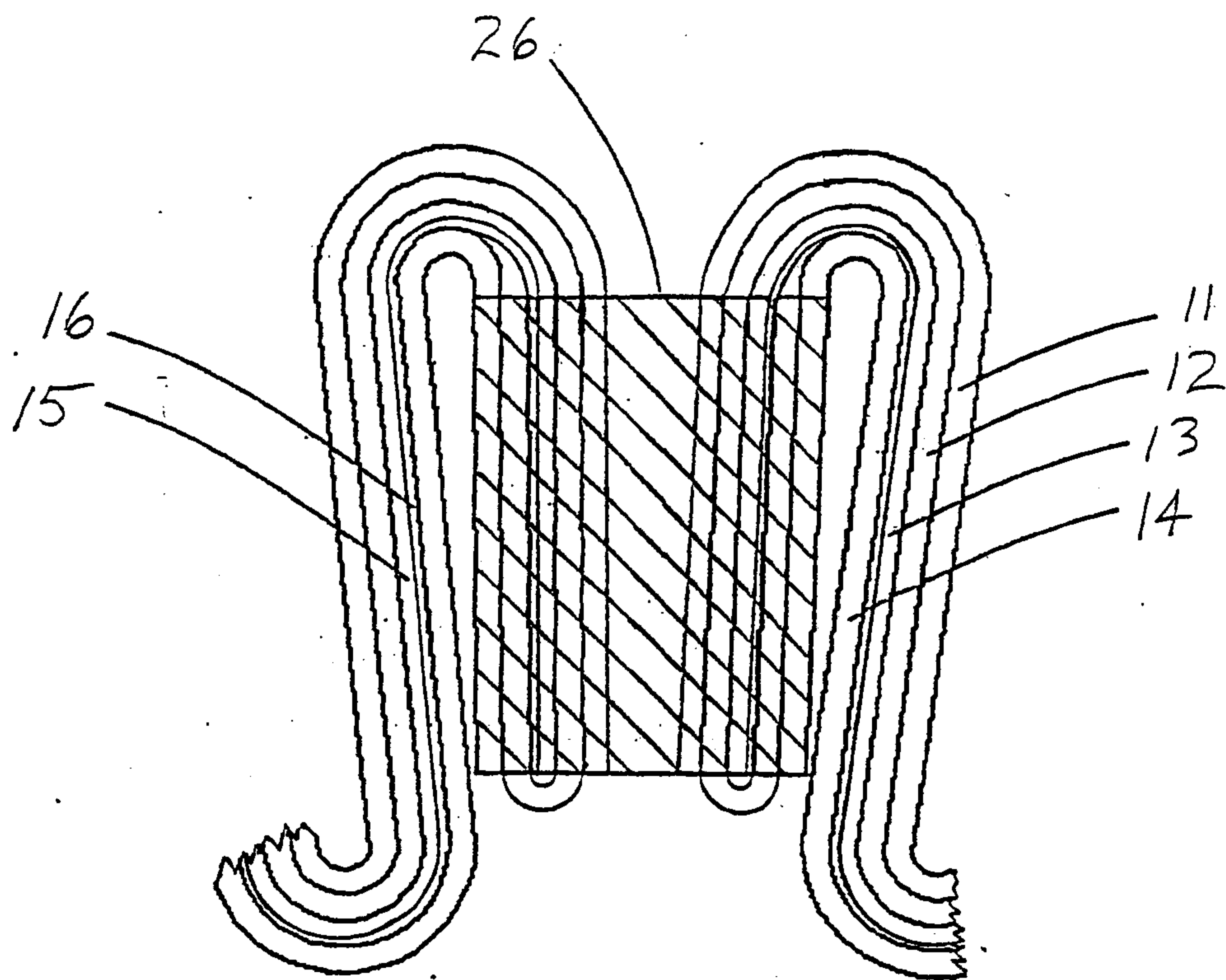


FIG. 2



3/8

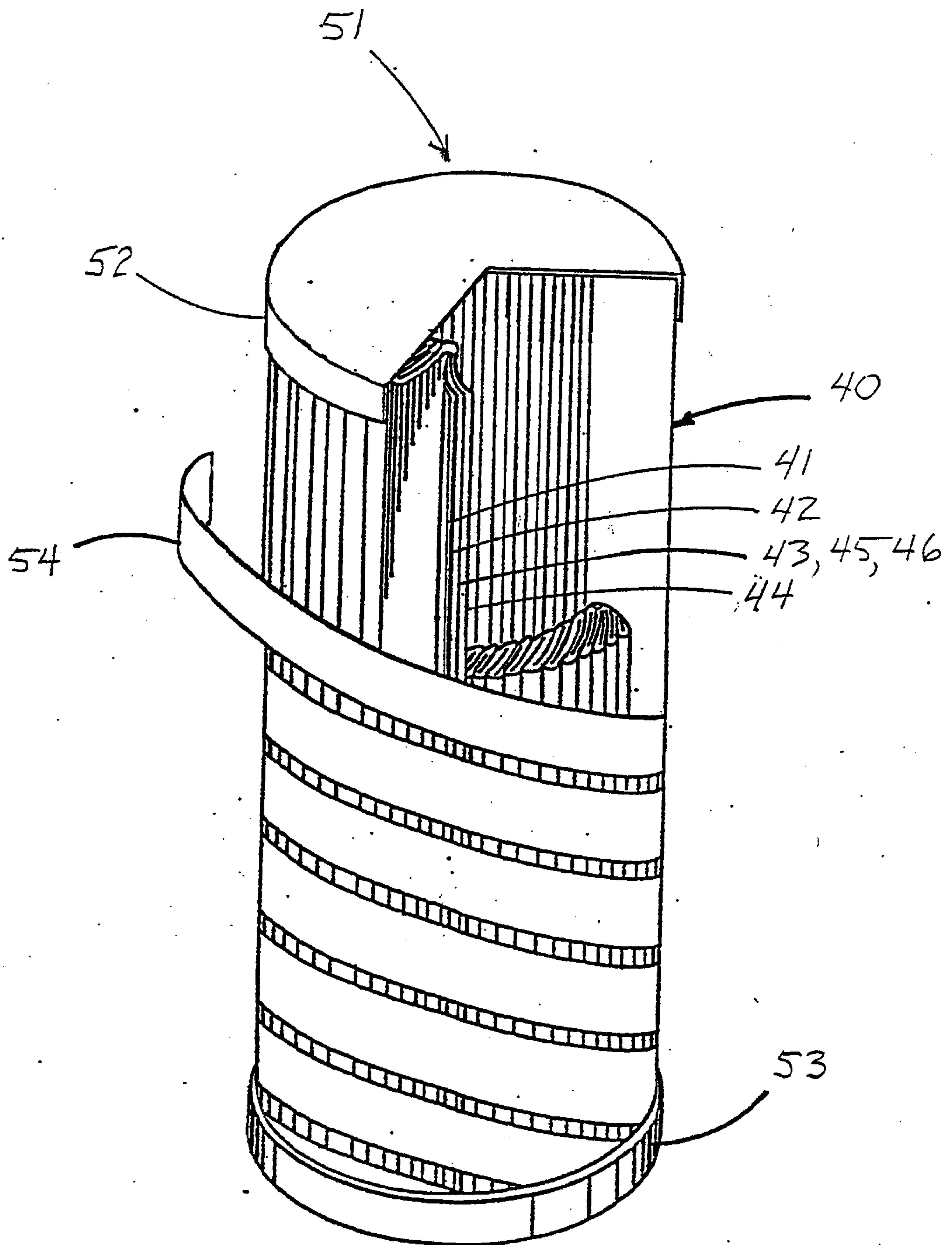
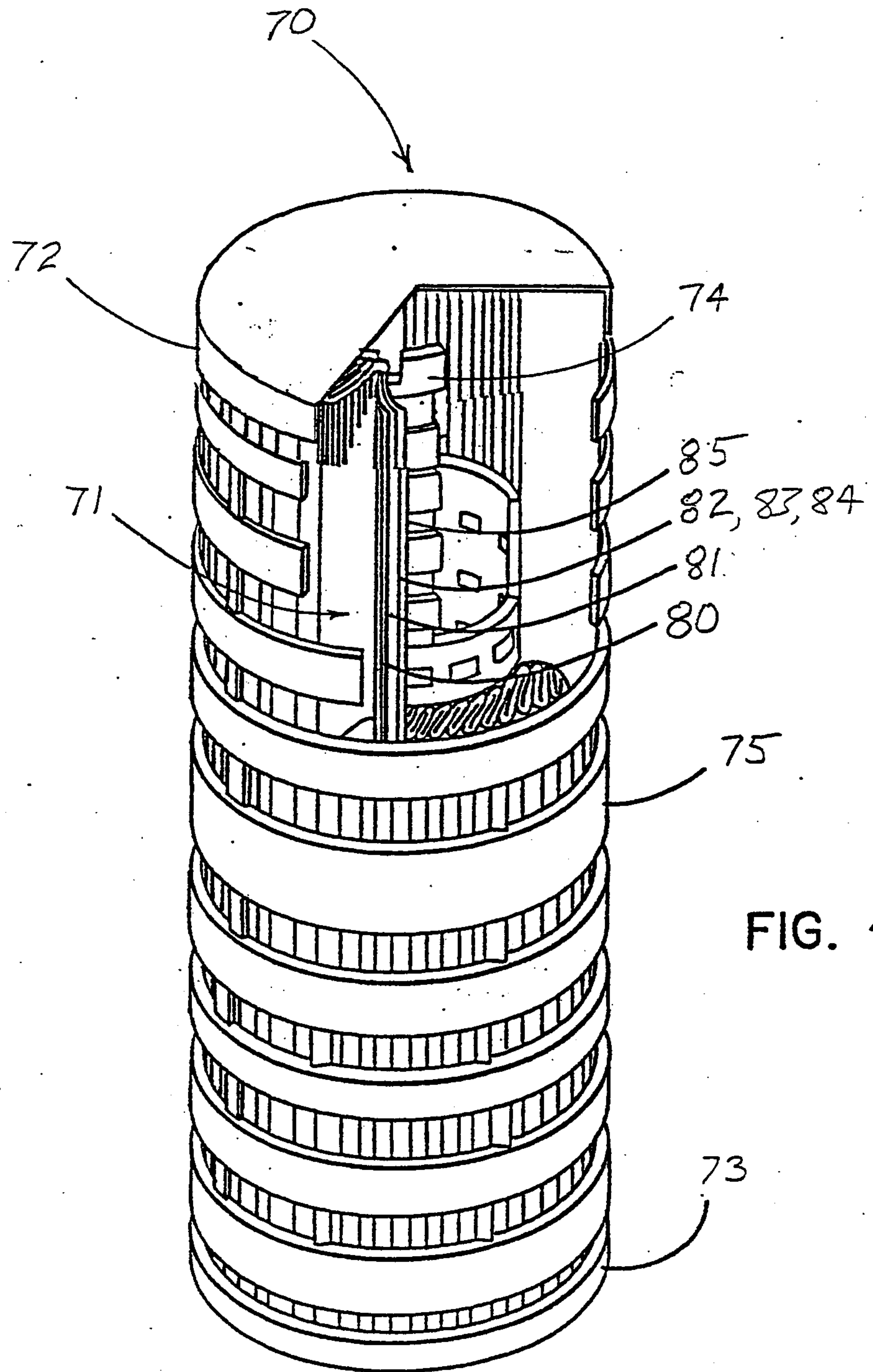


FIG. 3



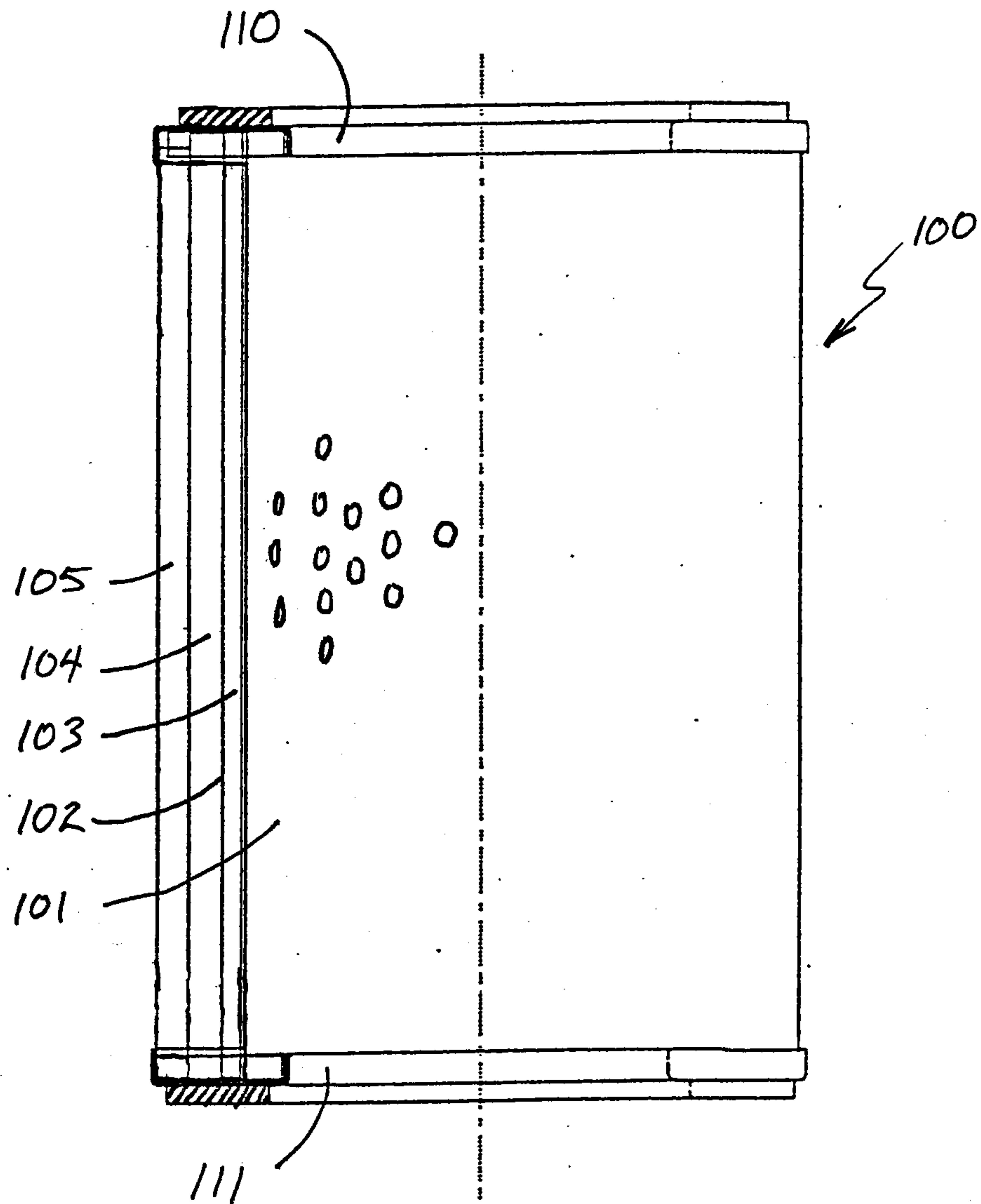


FIGURE 5



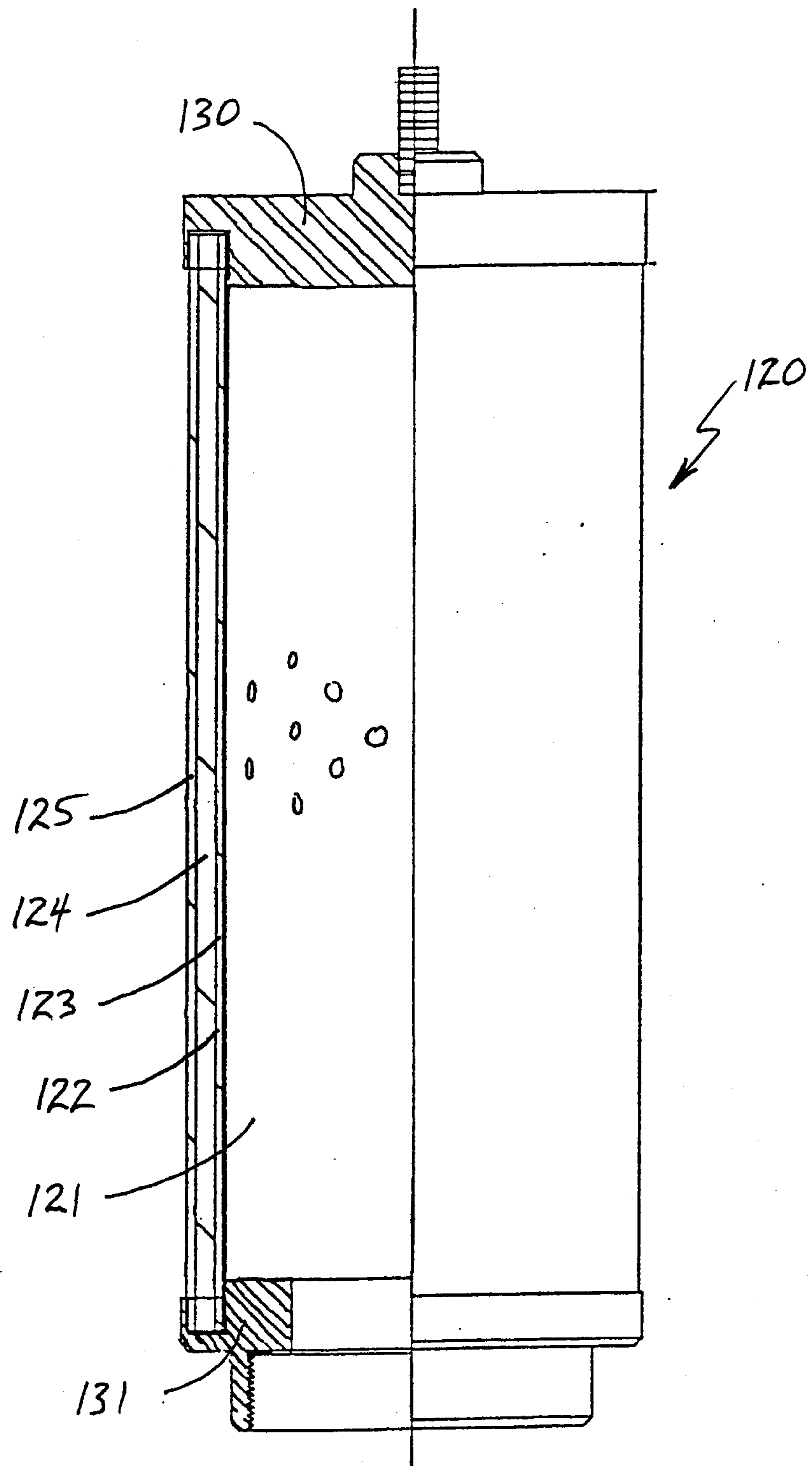


FIGURE 6

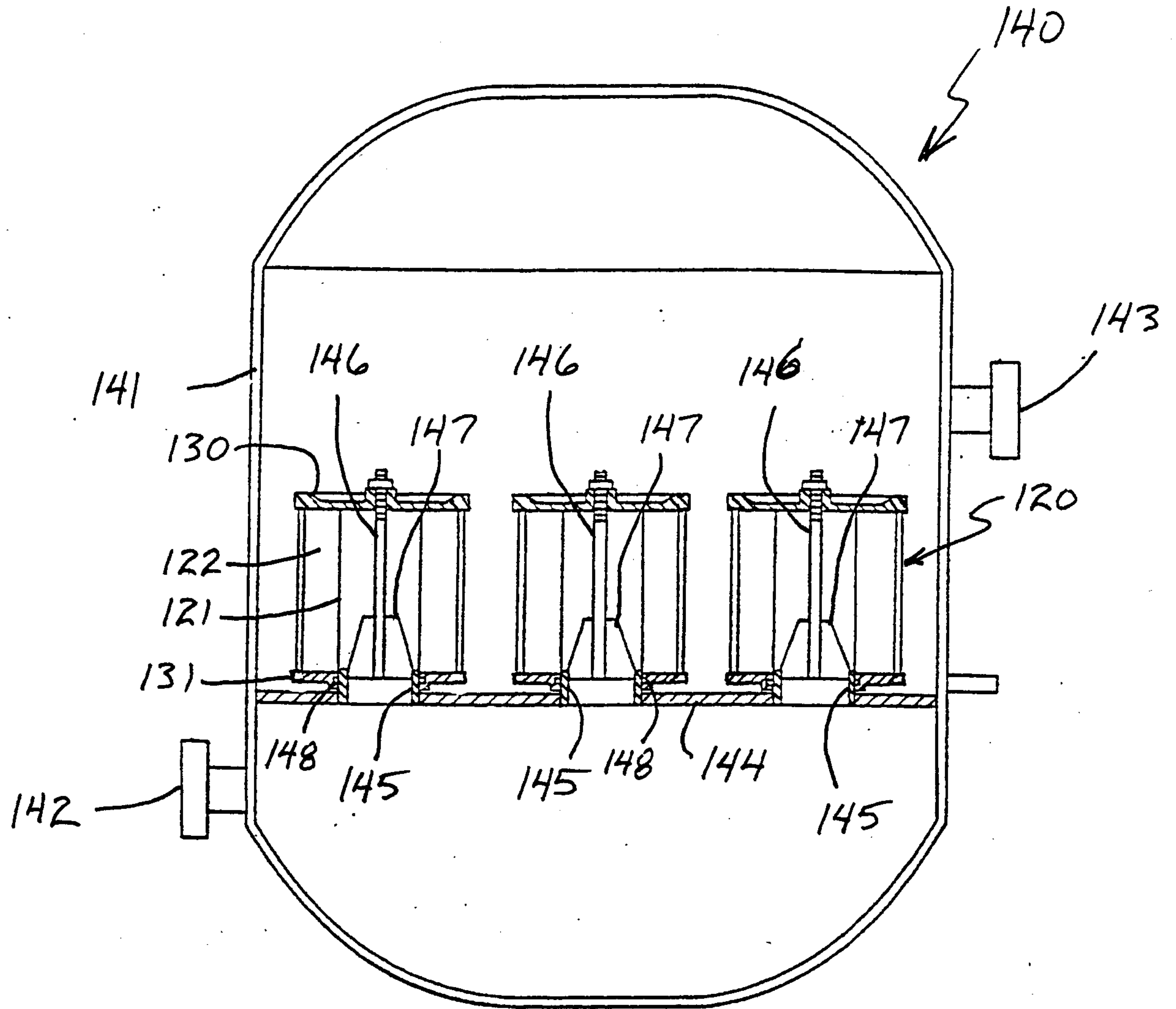


FIGURE 7

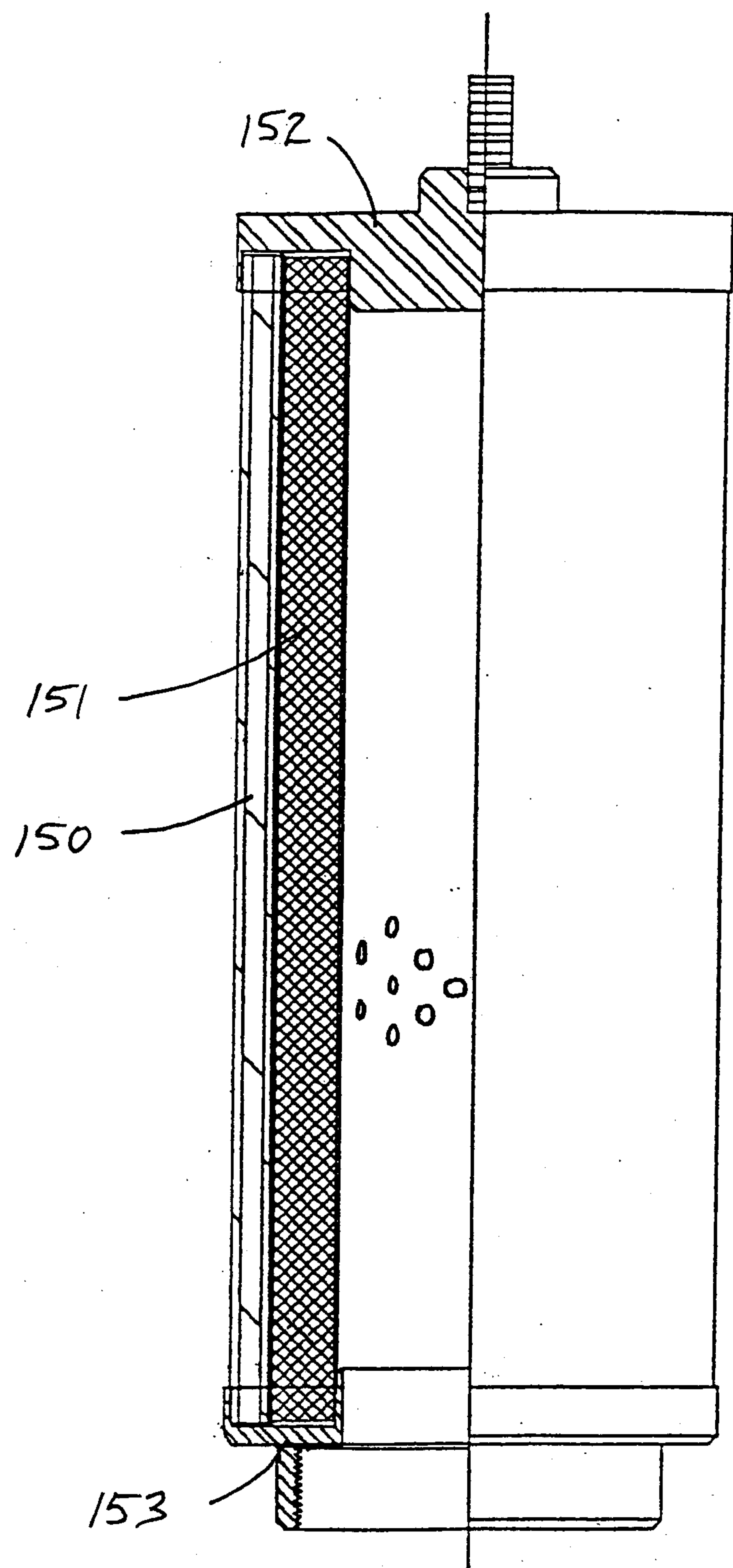


FIGURE 8



