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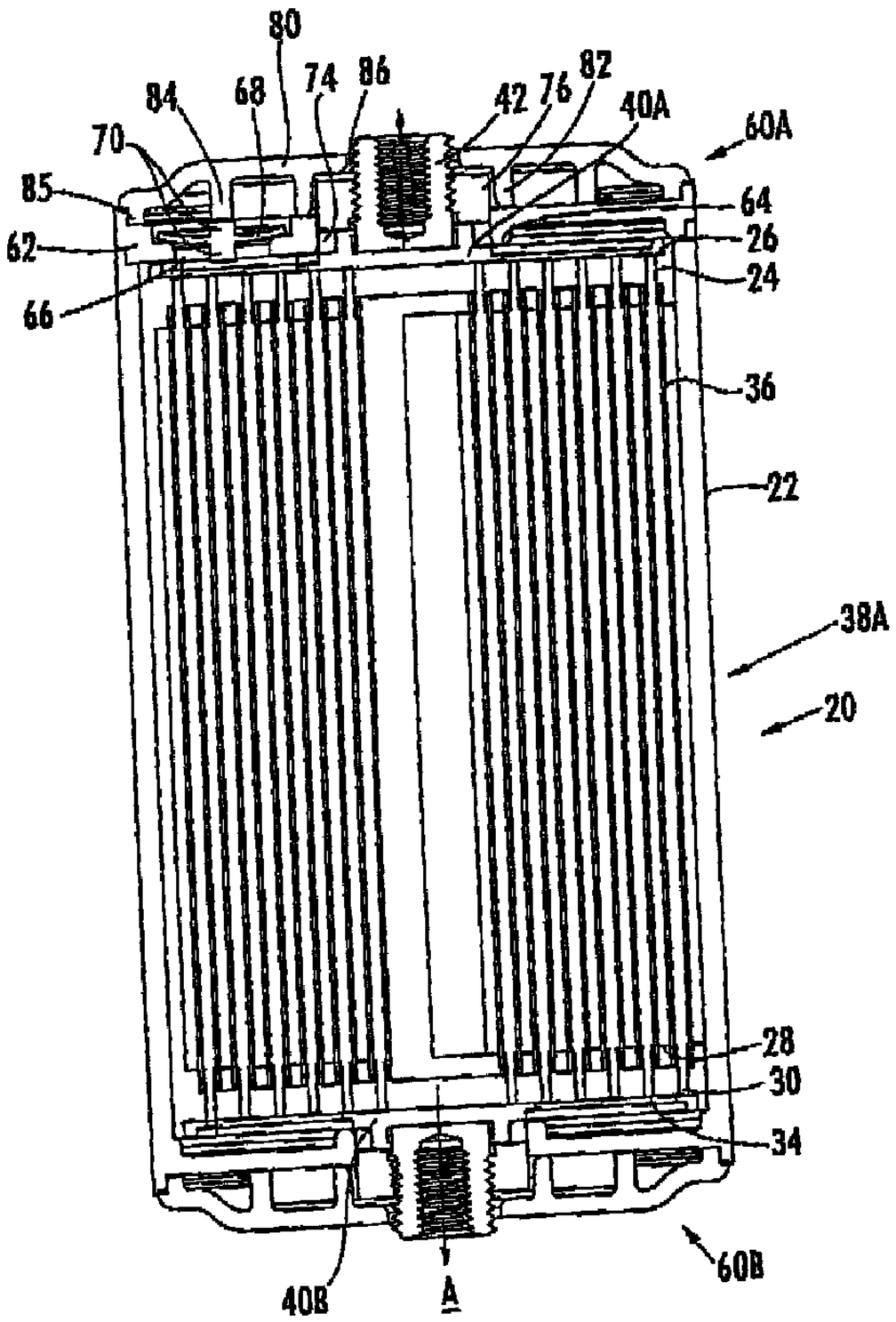


(57) Abrégé/Abstract:
A winding assembly for a battery includes a positive electrode plate, a negative electrode plate, a separator sheet, and a current collector. The positive and negative plates and the separator sheet are wound in overlying relationship such that the separator

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sheet is positioned between the positive and negative plates, an exposed top edge of the positive electrode plate is spaced longitudinally from an adjacent unexposed top edge of the negative plate, and an exposed bottom edge of the negative electrode plate is spaced longitudinally from an unexposed bottom edge of said positive electrode plate. The current collector is connected to one of the exposed edges of one of the positive and negative electrode plates, and, accordingly, is spaced apart from the adjacent unexposed bottom edge of the other (i.e., the non-attached) electrode plate. The current collector (40A) includes a terminal mounting portion (44) and a radially extending collecting web (43). The collecting web of the current collector includes a perimeter, at least one open-ended perimeter aperture (52) located at the perimeter and extending radially inwardly therefrom, and at least one closed-end internal aperture (54) positioned between the terminal portion and the perimeter. Also, the current collector may have recessed areas surrounding the apertures to facilitate joining of the current collector and the electrode plate.

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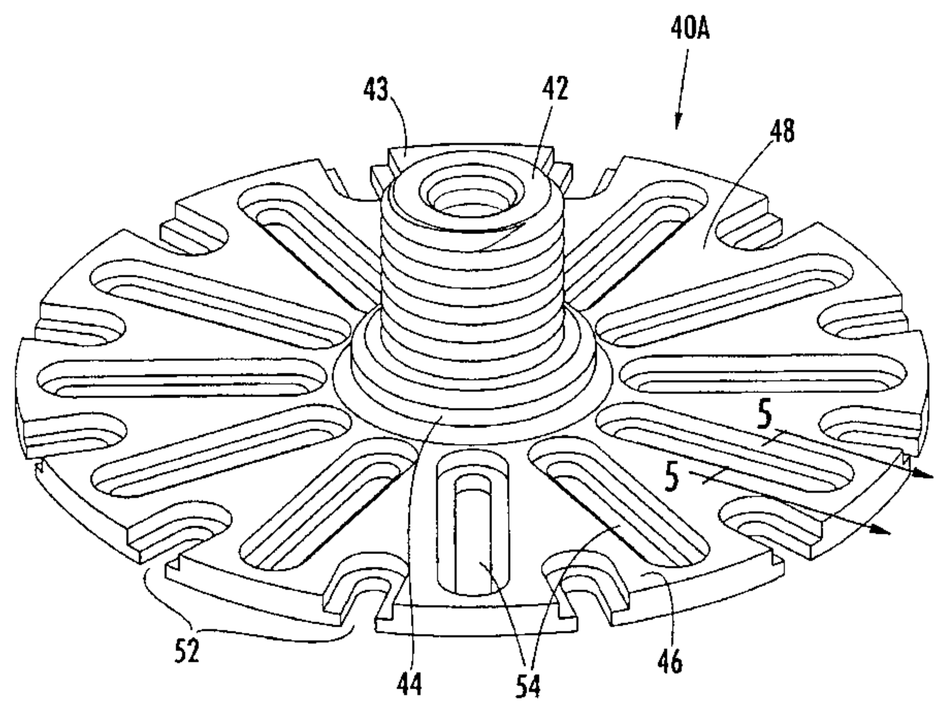


(57) Abstract: A winding assembly for a battery includes a positive electrode plate, a negative electrode plate, a separator sheet, and a current collector. The positive and negative plates and the separator sheet are wound in overlying relationship such that the separator sheet is positioned between the positive and negative plates, an exposed top edge of the positive electrode plate is spaced longitudinally from an adjacent unexposed top edge of the negative plate, and an exposed bottom edge of the negative electrode plate is spaced longitudinally from an unexposed bottom edge of said positive electrode plate. The current collector is connected to one of the exposed edges of one of the positive and negative electrode plates, and, accordingly, is spaced apart from the adjacent unexposed bottom edge of the other (i.e., the non-attached) electrode plate. The current collector (40A) includes a terminal mounting portion (44) and a radially extending collecting web (43). The collecting web of the current collector includes a perimeter, at least one open-ended perimeter aperture (52) located at the perimeter and extending radially inwardly therefrom, and at least one closed-end internal aperture (54) positioned between the terminal portion and the perimeter. Also, the current collector may have recessed areas surrounding the apertures to facilitate joining of the current collector and the electrode plate.

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# HIGH PERFORMANCE BATTERY AND CURRENT COLLECTOR THEREFOR

## FIELD OF THE INVENTION

The invention relates generally to batteries, and more particularly to high performance batteries.

## BACKGROUND OF THE INVENTION

A typical battery includes one or more electrochemical cells which are electrically connected within the battery and provide the source of electrical power for the battery. These cells generally comprise four basic components: a positive electrode (anode on charge and cathode on discharge) that receives electrons from an external circuit as the cell is discharged; a negative electrode (cathode on charge and anode on discharge) that donates electrons to the external circuit as the cell is discharged; an electrolyte (often in a solution or paste) which provides a mechanism for electrical charge to flow between the positive and negative electrodes; and one or more separators which electrically isolate the positive and negative electrodes. This configuration enables the cell to generate electric power because of the electrochemical relationship of these components. Once the current is generated, it is typically carried from the positive electrode through a current carrier to a terminal, from where it is conveyed to the external circuit and back into the battery through a terminal connected with the negative electrode plate (typically through another current carrier).

With any battery, performance can be defined by certain parameters. These can include, inter alia, the voltage, current, and capacity of the battery. Obviously, the battery for a particular application should be designed with these parameters in mind.

One set of performance parameters that can present difficulty in achieving are those of a rechargeable high performance battery, such as that used for powering "hybrid" electric vehicles (i.e., vehicles that rely on both a battery-driven

motor and an internal combustion engine for motive power), power tools and electric vehicles. Such batteries typically have low resistance so that current can be generated and provided to an external device very rapidly. Also, it is typically desirable that such a battery, particularly when used in conjunction with a hybrid vehicle, have a relatively low weight, and that it accept charge easily and rapidly.

In the cells of a high performance battery, the electrode plates, the electrolyte, and the separators should be selected such that the electrochemical relationship between these components can provide the desired current level in an acceptable discharge duration; of course, it would be desirable if such a battery were able to utilize currently available materials. Also, the cells should provide a current flow path from the electrode plates to and out of the cell terminal with relatively low resistance. Further, it would be desirable for the cells to have a configuration that facilitates manufacturing thereof.

## SUMMARY OF THE INVENTION

Some embodiments of the invention are directed to a low capacity, low resistance, high power cell. As a first aspect, the invention is directed to a winding assembly for a battery. The winding assembly includes a positive electrode plate, a negative electrode plate, a separator sheet, and a current collector. The positive and negative plates and the separator sheet are wound in overlying relationship such that the separator sheet is positioned between the positive and negative plates, an exposed top edge of the positive electrode plate is spaced longitudinally from an adjacent unexposed top edge of the negative plate, and an exposed bottom edge of the negative electrode plate is spaced longitudinally from an unexposed bottom edge of said positive electrode plate. The current collector is connected to one of the exposed edges of one of the positive and negative electrode plates, and, accordingly, is spaced apart from the adjacent unexposed bottom edge of the other (i.e., the non-attached) electrode plate. The current collector includes a terminal mounting portion and a radially extending collecting web. The collecting web of the current collector includes a perimeter, at least one open-ended perimeter aperture located at the perimeter and extending radially inwardly therefrom, and at least one closed-end internal aperture positioned between the terminal portion and the perimeter. In this configuration, the current collector can facilitate current flow from the electrode plate to which it is attached through a terminal and into an external circuit, thus providing a cell with the ability to

deliver high current quickly. Also, this configuration can simplify attachment of the current collector to an adjacent electrode plate by providing access for an attachment tool (such as a welding device) at both internal and perimeter locations on the current collector.

The winding assembly is particularly suitable for use with positive and negative electrode plates and current collectors formed of lead-containing materials. In one embodiment, the current collector includes multiple perimeter apertures, multiple internal apertures, or both (either or both of which can be spaced circumferentially equidistant from each other). Preferably, current collectors of the described configuration are attached at both ends of the winding assembly. Also, it is preferred that the winding be placed in a container and terminals added to the current collectors to form a cell for a battery.

As a second aspect, the invention is directed to a winding assembly for a cell which includes positive and negative electrode plates and a separator circumferentially wound as described above, as well as current collectors attached to the top edge of the positive electrode plate and to the bottom edge of the negative electrode plate. At least one of the current collectors is formed of a third material and includes a terminal mounting portion and a radially extending collecting web. The collecting web includes a collecting portion, at least one recessed area within the collecting portion, and an aperture positioned within the recessed area. In this configuration, the application of heat of a preselected temperature and duration can cause the recessed area and electrode plate edge to melt into a joint (due to similarity in thermal mass), while the collecting portion remains substantially unchanged in shape. As a result, attachment of the current collector to the adjacent electrode plate is facilitated.

As with the first aspect of the invention, the above-described winding assembly is particularly suitable for use with positive and negative electrode plates and current collectors formed of lead-containing materials. In one embodiment, the current collector includes multiple perimeter apertures, multiple internal apertures or both (either or both of which can be spaced circumferentially equidistant from each other). Preferably, current collectors of the described configuration are attached at both ends of the winding assembly. Also, it is preferred that the winding be placed in a container and terminals added to the current collectors to form a cell for a battery.

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As a third aspect, the invention is directed to a cover assembly for a battery cell. The cover assembly includes an internal cover including a vent and an external cover attached to the internal cover in overlying relationship. The external cover includes a downwardly-extending rib positioned directly above the vent. The cover assembly further includes a flexible diaphragm positioned in the vent that includes a projection extending upwardly to contact the rib of the external cover. In this configuration, the interaction between the rib and the projection maintains the diaphragm in place in the vent so that electrolyte does not leak from the cavity of the cell, yet allows venting of the battery cavity should the pressure therein become excessive.

There is also provided a current collector for a winding assembly of a battery, said current collector comprising: a terminal mounting portion; and a collecting web connected to said terminal mounting portion, said collecting web having a collecting portion and including at least one recessed area within said collecting portion and an aperture positioned within said recessed area.

Another aspect of the invention provides a winding assembly for a battery, comprising: a positive electrode plate; a negative electrode plate; a separator sheet; said positive and negative plates and said separator sheet being wound in overlying relationship such that said separator sheet is positioned between said positive and negative plates, and such that an exposed top edge of said positive electrode plate is spaced longitudinally from an unexposed top edge of said negative plate, and such that an exposed bottom edge of said negative plate is spaced longitudinally from an unexposed bottom edge of said positive plate; a first current collector as defined above connected to said

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top edge of said positive electrode plate and being spaced apart from said top edge of said negative electrode plate; and a second current collector as defined above connected to said bottom edge of said negative electrode plate and being spaced apart from said bottom edge of said positive electrode plate.

In accordance with a further aspect of the invention, there is provided a cell for a battery, comprising: a hollow container; a winding assembly positioned within said container, said winding assembly comprising: a positive electrode plate; a negative electrode plate; a separator sheet; said positive and negative plates and said separator sheet being circumferentially wound in overlying relationship such that said separator sheet is positioned between said positive and negative electrode plates, an exposed top edge of said positive electrode plate is spaced longitudinally from a adjacent unexposed top edge of said negative electrode plate, and an exposed bottom edge of said positive electrode plate is spaced longitudinally from an adjacent unexposed bottom edge of said negative electrode plate; a first current collector as defined above connected to said top edge of said positive electrode plate and being spaced apart from said top edge of said negative electrode plate; a second current collector as defined above connected to said bottom edge of said negative electrode plate and being spaced apart from said bottom edge of said positive electrode plate; and first and second terminals mounted in, respectively, said terminal mounting portions of said first and second current collectors.

## BRIEF DESCRIPTION OF THE DRAWINGS

**Figure 1** is a front section view of a cell of an embodiment of the invention.

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**Figure 2** is an exploded perspective view of the cell of **Figure 1.**

**Figure 3** is an enlarged perspective view of the positive and negative electrode plates and the separator sheet of the cell of **Figure 1.**

**Figure 4** is a greatly enlarged perspective view of the current collector and terminal of the cell of **Figure 1.**

**Figure 5** is a section view of the current collector taken along lines **5-5** of **Figure 4.**

**Figure 6** is an enlarged section view of the top cover assembly including the diaphragm.

**Figure 7** is a top view of a battery containing multiple cells of the invention.

## DETAILED DESCRIPTION

Embodiments of the invention now will be described fully with reference to the accompanying drawings. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numerals refer to like components throughout. The dimensions of some components may be exaggerated for clarity.

Referring now to the figures, a cell, designated broadly at **20**, is illustrated in **Figure 1**. The cell **20** includes a cylindrical outer can **22**, positive and negative electrode plates **24, 30** spirally wound with a separator sheet **36** into a winding **38** (see **Figure 3**), top and bottom current collectors **40A, 40B** (which together with the winding **38** form a winding assembly **38A**), and top and bottom cover assemblies **60A, 60B**. These components are described in greater detail below.

The can **22** is, illustratively and preferably, cylindrical and is formed of an electrically insulative material, such as a polymeric material (examples include polycarbonate, acrylonitrile-butadiene-styrene, and blends and co-polymers thereof) or a polymer-lined metal (examples include aluminum and painted mild steel). Rather than being cylindrical, the can **22** can alternatively take other shapes, including those in which its cross-section is oval, elliptical, or some other non-circular shape, such as the shapes described in PCT Publication No. WO 00/08704 (the '8704 application). Irrespective of its shape, the can **22** or alternative container should be sized such that, when the winding **38** is positioned therein, the positive electrode **24**, negative electrode **30** and separator **36** are compressed, as such compression can increase contact between these components and thereby improve battery performance.

Turning now to **Figure 3**, in which the winding **38** is illustrated in isolation, the positive electrode **24** and negative electrode **30** are thin layers disposed in a circumferentially wound configuration about an axis **A** in which they are separated from direct contact with one another by the separator **36**. As used herein, the term "circumferentially wound" in reference to one or more layers means that the layer defines a path about a central axis in which, for a given angle relative to an imaginary baseline that extends normal to the axis, subsequent layers increase in distance from the axis. The term is intended to include non-circular spiral paths, such as those in which the path formed by a layer is generally elliptical, oblong or oval in shape, as well as spiral paths in which a circumferentially wound circular, elliptical or oval shape is flattened somewhat, such as by the application of pressure from opposite sides. Such shapes are described in the '8704 application referenced above.

The materials for the positive electrode **24** and negative electrode **30** should be selected such that they have the capacity to exhibit the desired electrochemical relationship for the generation of electric power. Similarly, the material for the separator **36** should be selected to enhance this electrochemical

relationship. Also, the materials for positive and negative electrodes **24, 30** and the separator **36** should have sufficient flexibility and toughness to be successfully circumferentially wound and further processed into the desired shape. Exemplary materials for the positive electrode **24** include lead-containing materials, such as lead oxides and lead sulphates. As used herein, "lead-containing material" means that the material contains at least 50 percent lead by weight; preferred lead-containing materials include at least 68 percent lead by weight. Exemplary materials for the negative electrode **30** include lead-containing materials such as lead oxide and lead sulphates. Exemplary materials for the separator **36** include glass microfibers and organic particularly polymeric materials. In one embodiment, the positive and negative electrodes are lead-containing materials, and the separator is a polymeric sheet reinforced with glass or other microfibers. These materials are discussed in detail in the '8704 application.

Referring still to **Figure 3**, the positive electrode **24** and negative electrode **30** are circumferentially wound such that the top edge **26** of the positive electrode **24** is longitudinally spaced along the axis A from the top edge **32** of the negative electrode plate **30**. Preferably, this spacing is between about 0.1 and 0.2 inches, with a spacing of 0.125 inches being more preferred. Similarly, the bottom edge **34** of the negative electrode plate **30** is longitudinally spaced along the axis A from the bottom edge **28** of the positive electrode **24**, with a similar spacing as described above for the top edges **26, 32** being preferred. In this configuration, the top edge **26** of the positive electrode **24** is available for electrical contact with the current collector **40A** without the negative electrode **30** being in electrical contact therewith; similarly, the negative electrode **30** can be in electrical contact with the current collector **40B** without the current collector **40B** being in electrical contact with the positive electrode **24**. Such a configuration is described in U.S. Patent Nos. 5,047,300; 5,045,086; and 5,368,961 to Juergens and 5,677,078 to Juergens et al.

Referring now to **Figure 4**, the current collector **40A** of the described embodiment has an essentially identical configuration to that of the current collector **40B** (with the current collector **40B** being oriented "upside-down" relative to the current collector **40A**); as such, only the current collector **40A** will be described

herein, with the understanding that the discussion thereof is equally applicable to the current collector **40B**.

The current collector **40A** includes a cylindrical terminal **42** and a collecting web **43** that includes a terminal mounting portion **44** and a collecting portion **46**. The lower end of the terminal **42** is embedded in the terminal mounting portion **44**, and the remainder of the terminal **42** extends upwardly therefrom. In this configuration, the terminal **42** and the collecting web **43** can be manufactured as a single unitary component by lowering the terminal **42** into the terminal mounting portion **44** during the molding of the collecting web **43**. Alternatively, the terminal **42** may be mounted in the terminal mounting portion **44** in other ways, such as being welded or soldered thereon. Illustratively, the terminal **42** includes both external and internal threads to facilitate the attachment of other components.

Preferably, the terminal **42** is formed of a high conductivity material, such as pure copper, brass or some other copper-containing alloy, and has a relatively high cross-sectional area to reduce resistance to electric current. For example, if the cell **20** is designed to deliver 200 amps of current, it is preferred that the terminal **42** have a cross-sectional area of at least about 0.08 $in^2$.

Referring still to **Figure 4**, the terminal mounting portion **44** is generally centrally located in the collecting web **43**. The terminal mounting portion **44** is somewhat thicker than the collecting portion **46** to enable the lower end of the terminal **42** to be embedded therein and to reduce electrical resistance.

The collecting portion **46** is illustratively generally circular, although the collecting portion **46** may take the ovoid, elliptical, and other shapes described in the '8704 application to match the shape of the winding **38**. The collecting portion **46** merges at its interior with the terminal mounting portion **44** and includes a generally flat upper surface **48** and a generally flat lower surface **50** (see **Figure 5**), portions of which are attached to the top edge **26** of the positive electrode **24**.

Open-ended perimeter slots **52** extend radially inwardly from the perimeter of the collecting portion **46**. Illustratively and preferably, these are spaced circumferentially equally about the perimeter of the collecting portion **46**. In addition, radially extending closed-ended internal slots **54** are included in the collecting portion **46**; these are also circumferentially equally spaced about the collecting portion **46** and, illustratively and preferably, are arranged in a circumferentially alternating

pattern such that one internal slot **54** resides between each pair of adjacent perimeter slots **52** and vice versa.

The perimeter and internal slots **52, 54** are included in the collecting portion **46** to provide direct access for a welding tool or some other joining device designed to interconnect the collecting portion **46** with the positive electrode top edge **26** at locations where the collecting portion **46** and top edge **26** meet. Preferably, the slots **52, 54** are between about 0.04 and 0.19 inches in width, but may be sized differently for different welding tools.

Of course, those skilled in this art will appreciate that other aperture patterns may also be employed in current collectors with the invention. For example, the slots **52, 54** as illustrated are substantially uniform in width; however, alternative configurations may include apertures of non-uniform width, such as apertures that flare or taper outwardly with increasing distance from the terminal mounting portion **44**. Also, all of the slots may be open-ended perimeter slots, or all of the slots may be closed-end internal slots as desired. The aperture pattern of the collecting portion **46** should permit the attachment of multiple points on the positive electrode top edge **26** to the collecting portion **46** and, preferably, should allow current to take a relatively direct path from the top edge **26** of the positive electrode **24** to the terminal mounting portion **44**.

The collecting web **43** can be formed as a contiguous unit from a high-conductivity material that is compatible for attachment to the top edge **26** of the positive electrode **24** and that can convey current from the positive electrode top edge **26** to the terminal **42**. For example, if the positive electrode **24** is formed of a lead-containing material, preferably the collecting web **43** is also formed of a lead-containing material, such as "pure" lead (i.e., a material that includes at least 99 percent lead).

Referring still to **Figure 4** and referring also to **Figure 5**, each of the perimeter slots **52** and internal slots **54** is surrounded by a recessed area **56** (an exemplary internal slot **54** and its accompanying recessed area **56** are illustrated in **Figure 5**). The recessed area **56** is defined by an upper surface **58** that is below and substantially parallel with the upper surface **48** of the collecting portion **46**. The thickness **t** of the recessed area **56** (i.e., measured between the upper surface **58** of the recessed area **56** and the lower surface **50** of the collecting portion **46**) is selected such that the recessed area **56** has a substantially similar thermal mass to that of the top

edge **26** of the positive electrode **24**. As such, when heat of a pre-selected temperature and duration is applied to the recessed area **56** and the top edge **26** of the positive electrode **24**, these areas will soften (and perhaps melt) and weld together to form a joint. However, the thickness **T** of the remainder of the collecting portion **46** (i.e., measured between the upper surface **48** and the lower surface **50** of the collecting portion **46**) is sufficient that its thermal mass enables it to resist melting during the application of heat sufficient to melt the recessed area **56** and top edge **26**. Thus, the collecting portion **46** becomes affixed to the positive electrode **24** without significant deformation of the non-recessed areas of the collecting portion **46**.

As an example, for a positive electrode **24** formed of a lead-containing material having a thickness of 1 mm and a collecting portion **46** formed of pure lead having a recessed area **56** with a thickness **t** of 0.8mm, the remainder of the collecting portion **46** can have a thickness **T** of at least 1.5mm and not experience a significant change in shape when heat is applied to the recessed area **56** and to the top edge **26** of the positive electrode **24** in the form of a welding torch at 621°F for a duration of a few milliseconds. As a result, the positive electrode **24** can be attached to the recessed area **56** without adversely affecting the shape (and, in turn, the performance) of the non-recessed area of the collecting portion **46**. Of course, other combinations of the thicknesses **t** and **T** of the collecting portion **46** and the thickness of the positive electrode **24** and the temperature and duration of applied may also be suitable for use with the invention.

As noted above in the illustrated embodiment, the current collector **40B** has an identical configuration to that of the current collector **40A**. As such, the foregoing discussion regarding the current collector **40A** is equally applicable to the current collector **40B** with the exception that the lower surface of the current collector **40B** is joined to the bottom edge **32** of the negative electrode **30**, with the result that the terminal **42** of the current collector **40B** extends downwardly. The current collectors may also take alternative configurations, such as one that lacks recesses (around the perimeter and internal slots or one having only internal slots. As other exemplary alternatives, the collector may lack a terminal mounting portion that does not vary in thickness from the collecting portion, or the collecting portion may be tapered such that it increases in thickness from perimeter to center.

Referring back to **Figures 1** and **2**, the ends of the cell **20** are sealed by the top and bottom cover assemblies, **60A, 60B**. The cover assemblies **60A, 60B** are quite similar in configuration, so only the top cover assembly **60A** will be described herein, with the differences in the bottom cover assembly **60B** being noted.

The top cover assembly **60A** includes an internal cover **62** which is illustratively generally circular, although the shape of the internal cover **62** can also take other configurations; it preferably matches the shape of the winding **38** and current collector **40A**. The internal cover **62** includes a circular central rib **64** on its lower surface that extends downwardly to contact the upper surface **48** of the current collector **40A**. A central aperture **72** receives and encircles the terminal mounting portion **44** of the current collector **40A** and the terminal **42**.

The internal cover **62** is typically formed of a polymeric material or a polymer-lined metal. It is preferably formed of a material that can be easily attached to the top edge of the can **22** (such as with heat or ultrasonic welding or adhesive bonding).

A circular vent **66** (seen best in **Figure 6**) is eccentrically positioned on the internal cover **62** such that it resides above a small area of the collecting portion **46** of the current collector **40A**. A flexible diaphragm **68** having upwardly and downwardly extending posts **70** covers the vent **66** and can provide a gastight seal between the cavity of the cell **20** and the external environment. This seal retains electrolyte contained in the cell; however, in the event that the cell **20** generates substantial internal pressure (such as when the cell is in a high state of overcharge, which can cause inefficient oxygen recombination; the uncombined oxygen can cause the pressure inside the cell to rise significantly), the edges of the diaphragm **68** can flex upwardly away from the vent **66**, thereby allowing the internal pressure to be relieved. Exemplary materials for the diaphragm include EPDM and neoprene rubber.

An annular gasket **74** encircles the terminal mounting portion **44** of the current collector **40A** and fits within the central rib **64** of the internal cover **62**. Like the diaphragm **68**, the gasket **74** seals the terminal **42** and the external environment from the electrolyte present within the cell **20**. A nut **76** is threaded onto the external threads of the terminal **42** and compresses the gasket **74** against the radially inward section of the collecting web **43** to provide a gas-tight seal at that location. The gasket is typically formed of EPDM rubber.

The top cover assembly **60A** also includes an external cover **80** that rests atop the internal cover **62** and is welded or otherwise attached to the perimeter thereof. The external cover **80** includes a downwardly-extending, hexagonally-shaped central rib **82** within which the hexagonal nut **76** resides; the central rib **82** prevents the nut **76** from loosening once tightened. Also, the external cover **80** includes a downwardly-extending, circular intermediate rib **84** that is positioned to apply a downward force to the upwardly extending post **70** of the diaphragm **68** when the external cover **80** is in place. In this configuration, the intermediate rib **84** is able to maintain the diaphragm **68** in position to provide an external seal that prevents electrolyte leakage. An outer rib **85** extends downwardly from the perimeter portion of the external cover **80** to facilitate attachment of the external cover **80** to the internal cover **62**. The external cover **80** also includes an aperture **86** that receives the terminal **42**, which then extends above the external cover **80** to provide a contact component for a post or other connection component.

The external cover **80** is typically formed of a polymeric material or a polymer-lined metal. The material of the external cover **80** is preferably one that facilitates attachment of the external to the internal cover **62**. For example, if the internal cover **62** is formed of a polymeric material, and the internal and external covers **80** are to be joined by welding, the external cover **80** should also be formed of the same polymeric material or one that has physical properties that render it compatible with welding to the material of the internal cover **62.**

The bottom cover assembly **60B** includes an external cover **80** and gasket **74** that are identical to the external cover **80** and gasket **74** of the top cover assembly **60A**. The internal cover **62** associated with the bottom cover assembly lacks a vent **66**; thus, the diaphragm **68** is also omitted, although an identical internal cover **62** may also be employed. The materials described above for the internal and external covers **62, 80** and the diaphragm **68** of the top cover assembly **60A** should also be suitable for the bottom cover assembly **60B**.

The cell **20** is assembled by first circumferentially winding the positive and negative electrodes **24, 30** and the separator **36** into the winding **38** such that the top and bottom edges of the positive and negative electrodes **24, 30** are longitudinally spaced as described above. The top current collector **40A** is positioned in contact with the top edge **26** of the positive electrode **24** and is welded thereto by inserting a welding tool into the individual perimeter and internal slots **52, 54**. During welding,

the recessed areas **56** of the slots **52**, **54** tend to melt, as do areas of the top edge **26** of the positive electrode **24**, because their thermal masses are similar, but the remainder of the collecting portion **46** retains its shape. It is preferred to form welds between the top edge **26** and the collecting portion **46** over as much surface area as possible in order to facilitate current passage. Once the current collector **40A** has been attached, the procedure is repeated for the attachment of the current collector **40B** to the bottom edge **32** of the negative electrode **30** to complete the formation of the winding assembly **38A**. The winding assembly **38A** is then inserted into the can **22**. The gaskets **74** are slipped over the terminal mounting portions **44** of the current collectors **40A**, **40B**, and the nuts **76** are threaded onto the external threads of the terminals **42**. The internal covers **62** are then ultrasonically welded or otherwise attached to the upper and lower perimeters of the can **22**. Electrolyte solution is added to the positive and negative electrodes **24**, **30** through the vent **66**. The diaphragm **68** is positioned over the vent **66**, and the external covers **80** are ultrasonically welded to the internal covers **62**, with the central rib **82** of each cover fitting over the nut **76** and the medial rib **84** of the top external cover **80** pressing downwardly on the post **70** of the diaphragm **68** to maintain it in position. A terminal connector can then be threaded into the internal threads of the terminal **42** to provide a connection point for an external circuit.

Once completed, the cell **20** is configured to convey current efficiently from the winding **38** to the current collectors **40A**, **40B**, to the terminal **42** and out of the cell **20**. The configuration of the current collectors **40A, 40B** enables them to be attached expeditiously to many points along the edges of the electrodes **24, 30** through the access provided by the slots **52, 54** without substantial change in shape to the collecting portion **46**. The configuration of the slots **52, 54** enables current to travel in a direct, low resistance path to the terminal **42**. The terminal **42** itself, with proper sizing and material selection, can serve to enhance current flow. As such, the present configuration can enable the cell to provide desirable current flow properties to batteries, particularly those to be used in high performance applications like hybrid vehicles, electric vehicles, and portable power tools, although those skilled in this art will recognize that the cell **20** may be suitable for use in many other applications also.

Notably, the cover assemblies **60A, 60B** also facilitate manufacturing of the cell **20**, as they enable the manufacturer to attach a cover that includes a vent to the can **22**, and to do so rapidly. The presence of the intermediate rib **84** and the post

**70** allows the diaphragm **68** to remain in position without further retaining structure, and the configurations of the internal and external covers **62, 80** enable them to be attached quickly to one another and to the can **22**.

Those skilled in this art will recognize that the cell of the invention can be used either by itself or on conjunction with a plurality of cells to form a multicell battery (as is shown at **100** in **Figure 7**, which includes six interconnection cells **20**). If a plurality of cells is to be used, the terminals of the cells are typically electrically connected via wires, metal straps, or the like. The interconnected cells can then be placed in a single housing **101**.

The foregoing is illustrative of the invention and is not to be construed as limiting thereof. Although exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.

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CLAIMS:

1. A current collector for a winding assembly of a battery, said current collector comprising:

a terminal mounting portion; and

a collecting web connected to said terminal mounting portion, said collecting web having a collecting portion and including at least one recessed area within said collecting portion and an aperture positioned within said recessed area.

2. The current collector defined in Claim 1, further comprising a terminal mounted in and extending upwardly from said terminal mounting portion.

3. The current collector defined in Claim 2, wherein said terminal is formed of a copper-containing material.

4. The current collector defined in Claim 1, wherein said terminal mounting portion and said collecting web are integrally formed of a lead-containing material.

5. The current collector defined in Claim 1, wherein said at least one aperture is at least one radially-extending slot.

6. The current collector defined in Claim 5, wherein said at least one recessed area is a plurality of recessed areas, and said at least one slot is a plurality of radially-extending slots, each of said slots being positioned in a respective one of said recessed areas.

7. The current collector defined in Claim 1, wherein at least one of said plurality of slots has an open end located at a perimeter of said collecting portion.

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8. The current collector defined in Claim 1, wherein at least one of said plurality of slots has closed ends and is positioned between said terminal portion and a perimeter of said collecting portion.

9. The current collector defined in Claim 1, wherein said at least one open of said apertures having an open end comprises multiple apertures having an open end spaced generally circumferentially equidistant from one another.

10. The current collector defined in Claim 8, wherein said at least one aperture having closed ends comprises multiple apertures having closed ends spaced generally circumferentially equidistant from one another.

11. A winding assembly for a battery, comprising:

a positive electrode plate;

a negative electrode plate;

a separator sheet;

said positive and negative plates and said separator sheet being wound in overlying relationship such that said separator sheet is positioned between said positive and negative plates, and such that an exposed top edge of said positive electrode plate is spaced longitudinally from an unexposed top edge of said negative plate, and such that an exposed bottom edge of said negative plate is spaced longitudinally from an unexposed bottom edge of said positive plate;

a first current collector as defined in Claim 1 connected to said top edge of said positive electrode plate and being spaced apart from said top edge of said negative electrode plate; and

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a second current collector as defined in Claim 1 connected to said bottom edge of said negative electrode plate and being spaced apart from said bottom edge of said positive electrode plate.

12. The winding assembly defined in Claim 11, wherein said positive electrode plate has a first thickness and is formed of a first material, said negative electrode plate has a second thickness and is formed of a second material, said collecting web is formed of a third material and has a third thickness, said recessed area has a fourth thickness, and said first, second, third and fourth thicknesses and said first, second and third materials are selected such that said recessed area and said electrode plate top edge adjacent thereto melt upon application thereto of heat of a preselected temperature and duration, and said collecting portion does not melt upon the application of heat of said preselected temperature and duration.

13. The winding assembly defined in Claim 11, wherein said collecting portion has a perimeter that is substantially circular.

14. The winding assembly defined in Claim 11, wherein said collecting portion includes a lower surface, said recessed area includes an upper surface, and said upper and lower surfaces are substantially parallel.

15. The winding assembly defined in Claim 11, wherein said at least one aperture is at least one radially-extending slot.

16. The winding assembly defined in Claim 15, wherein said at least one recessed area is a plurality of recessed areas, and said at least one slot is a plurality of

radially-extending slots, each of said slots being positioned in a respective one of said recessed areas.

17. The winding assembly defined in Claim 16, wherein at least one of said plurality of slots has an open end located at the perimeter of said collecting portion.

18. The winding assembly defined in Claim 16, wherein at least one of said plurality of slots has closed ends and is positioned between said terminal portion and the perimeter of said collecting portion.

19. The winding assembly defined in Claim 11, further comprising a terminal extending upwardly from said terminal mounting portion.

20. The winding assembly defined in Claim 19, wherein said terminal is formed of brass.

21. A cell for a battery, comprising:

a hollow container;

a winding assembly positioned within said container, said winding assembly comprising:

a positive electrode plate;

a negative electrode plate;

a separator sheet;

said positive and negative plates and said separator sheet being circumferentially wound in overlying relationship such that said separator sheet is positioned between said positive and negative electrode plates, an exposed top edge of said positive electrode plate is spaced longitudinally from a adjacent unexposed top edge of said

negative electrode plate, and an exposed bottom edge of said positive electrode plate is spaced longitudinally from an adjacent unexposed bottom edge of said negative electrode plate;

a first current collector as defined in Claim 1 connected to said top edge of said positive electrode plate and being spaced apart from said top edge of said negative electrode plate;

a second current collector as defined in Claim 1 connected to said bottom edge of said negative electrode plate and being spaced apart from said bottom edge of said positive electrode plate; and

first and second terminals mounted in, respectively, said terminal mounting portions of said first and second current collectors.

22. The cell defined in Claim 21, wherein said positive electrode plate has a first thickness and is formed of a first material, said negative electrode plate has a second thickness and is formed of a second material, said collecting portion is formed of a third material and has a third thickness, said recessed area has a fourth thickness, and said first, second, third and fourth thicknesses and said first, second and third materials are selected such that said recessed area and said electrode plate top edge adjacent thereto melt upon application thereto of heat of a preselected temperature and duration, and said collecting portion does not melt upon the application of heat of said preselected temperature and duration.

23. The cell defined in Claim 22, further comprising top and bottom cover assemblies attached to top and bottom portions of said container, each of said top and bottom

cover assemblies including an internal cover and an external cover adjacent said internal cover, wherein each internal cover is positioned adjacent a respective one of said first and second current collectors.

24. The cell defined in Claim 23, wherein one of said internal covers includes a venting aperture.

25. The cell defined in Claim 24, further comprising a diaphragm valve within said venting aperture, wherein said diaphragm valve includes a projection extending toward said external cover, and wherein said adjacent external cover includes a rib that extends toward said internal cover and contacts said projection.

SMART & BIGGAR

OTTAWA, CANADA

PATENT AGENTS

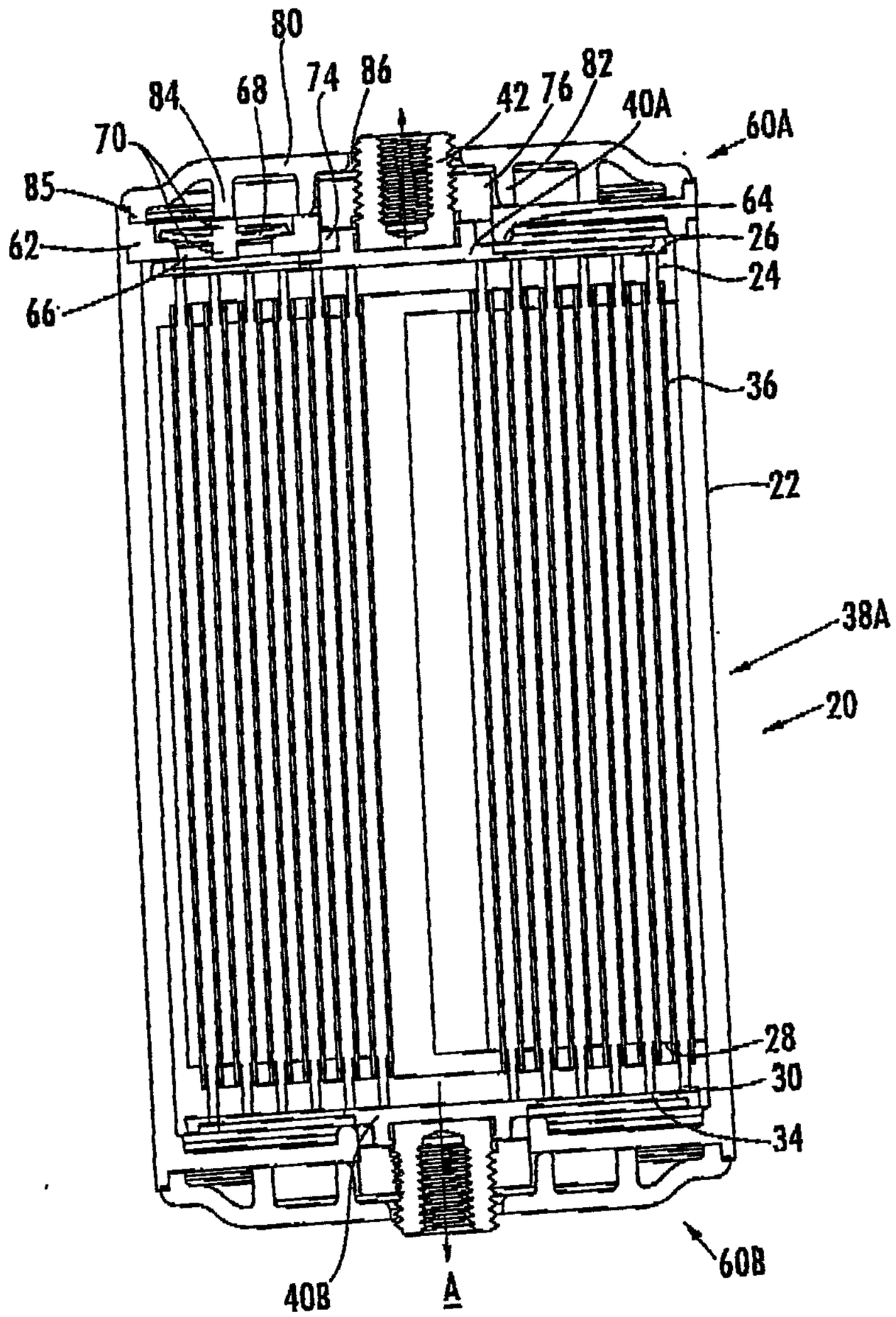
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FIG. 1.

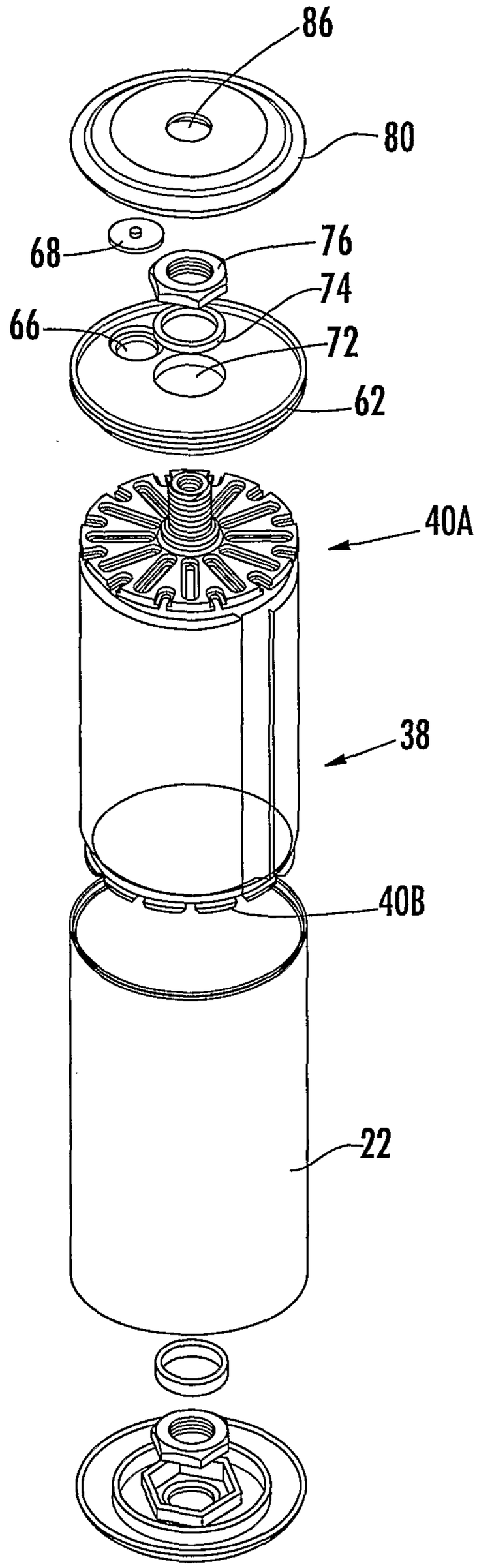



FIG. 2.

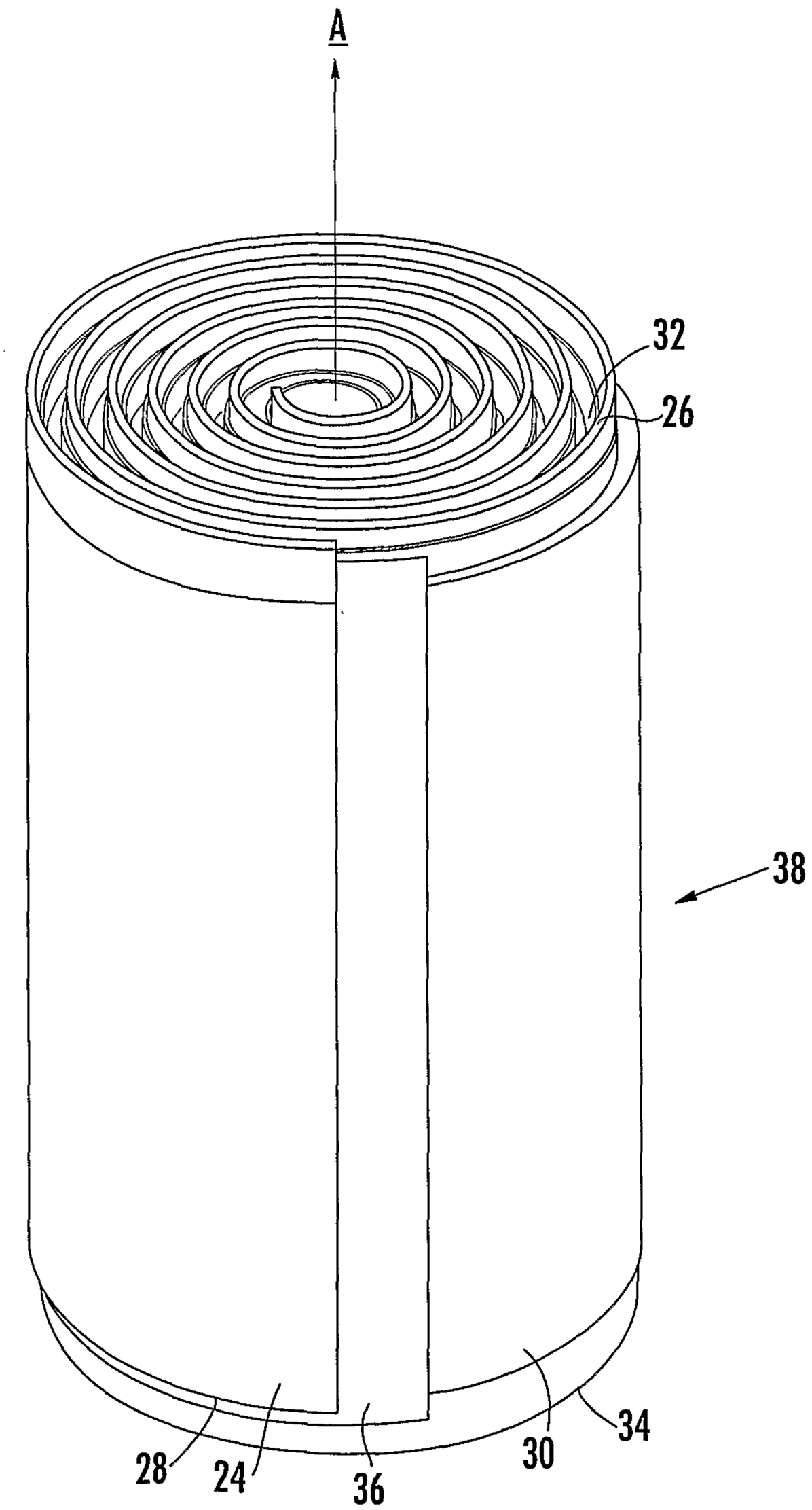



FIG. 3.

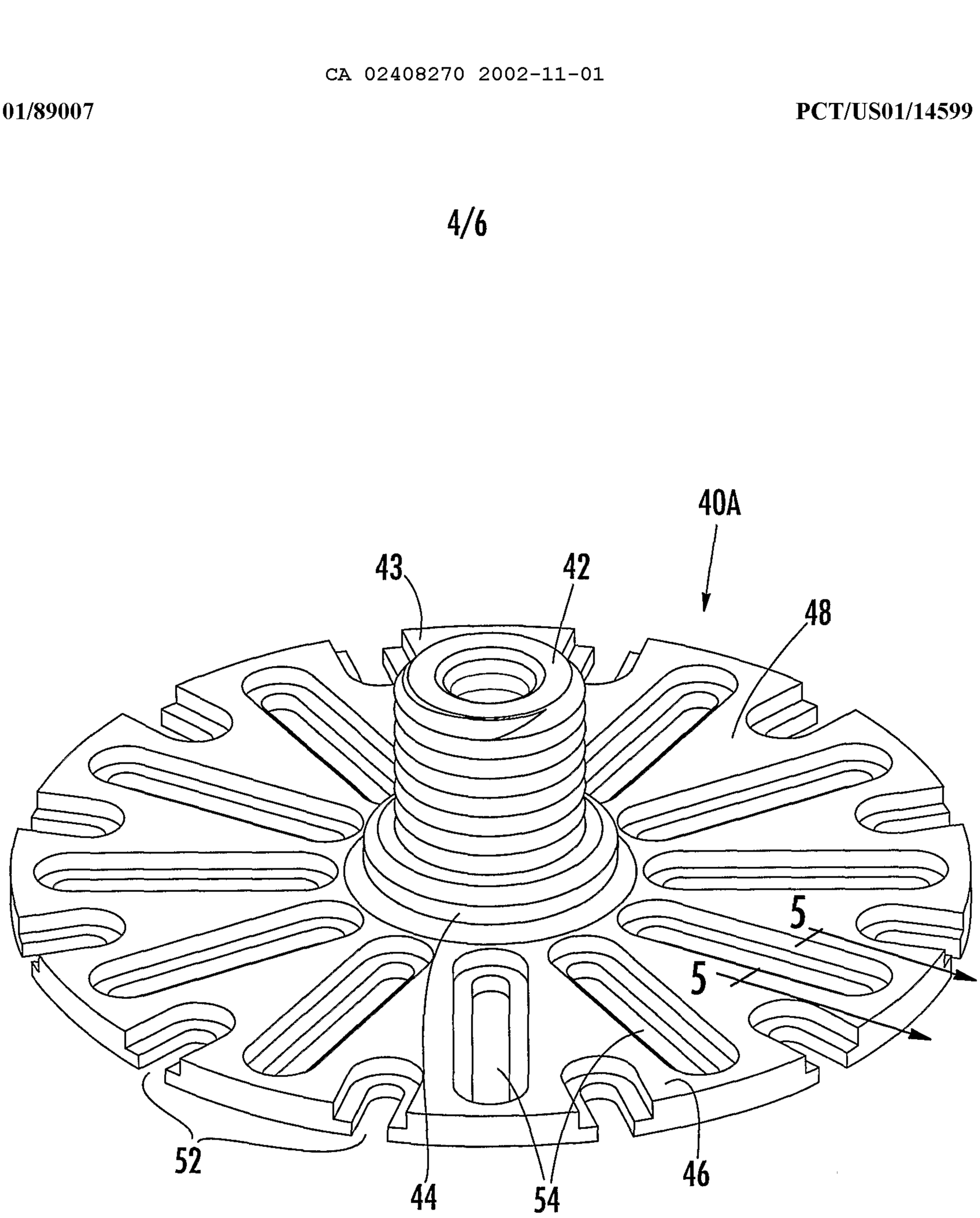



FIG. 4.

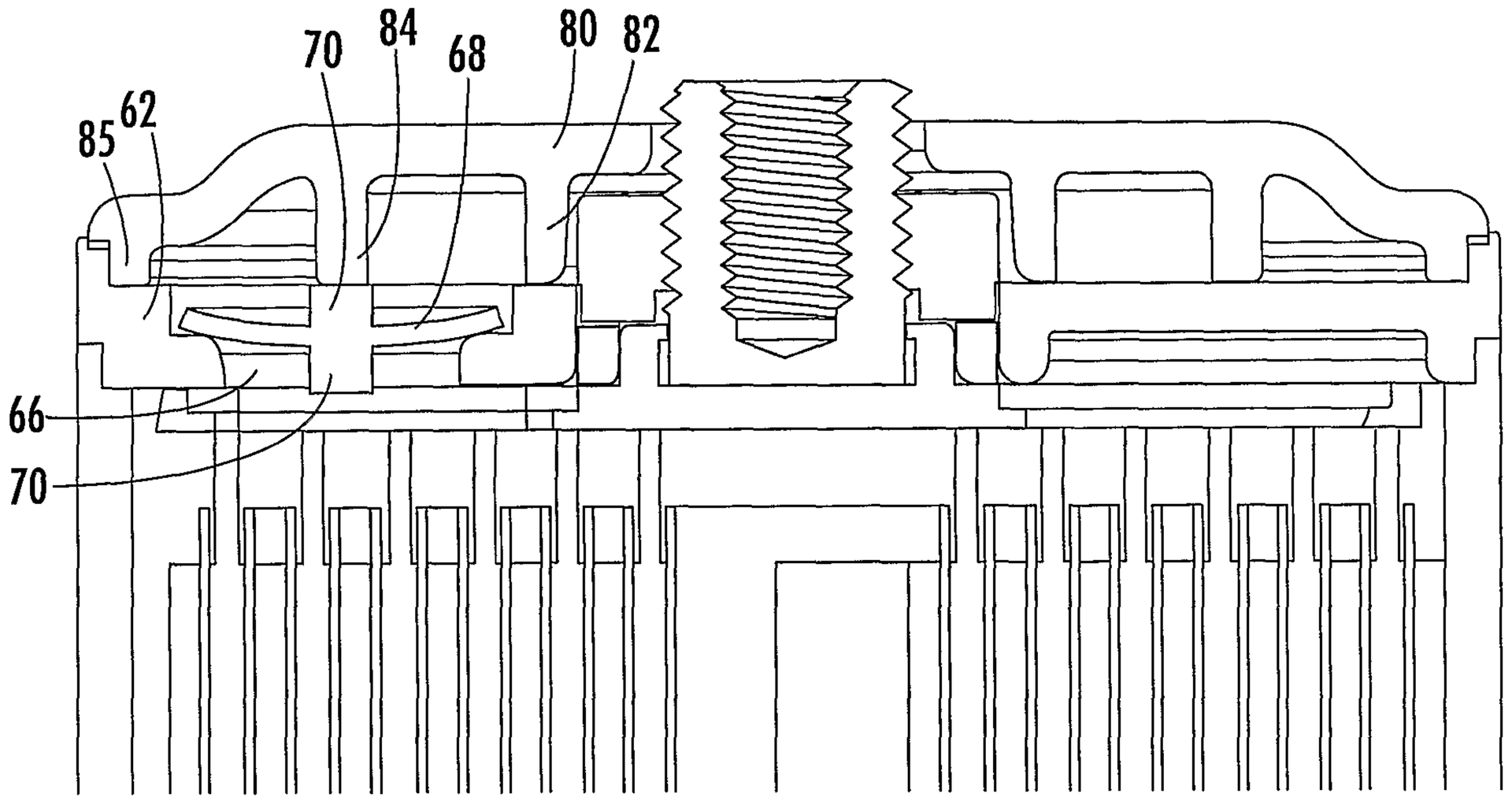



FIG. 6.

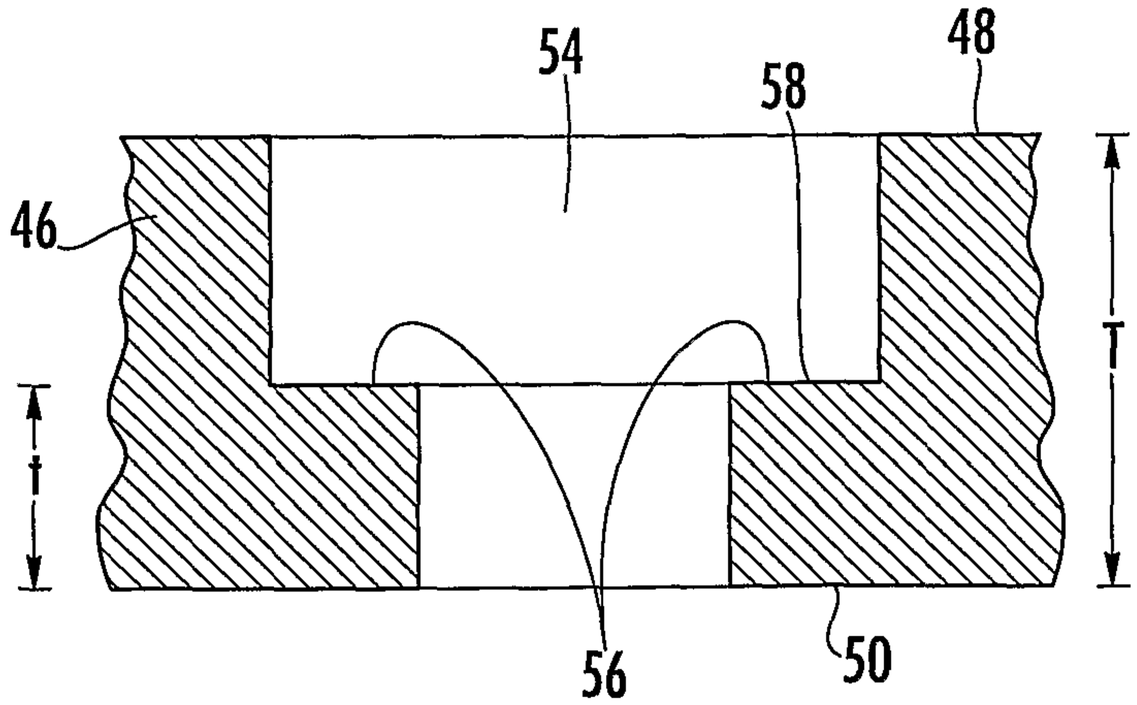



FIG. 5.

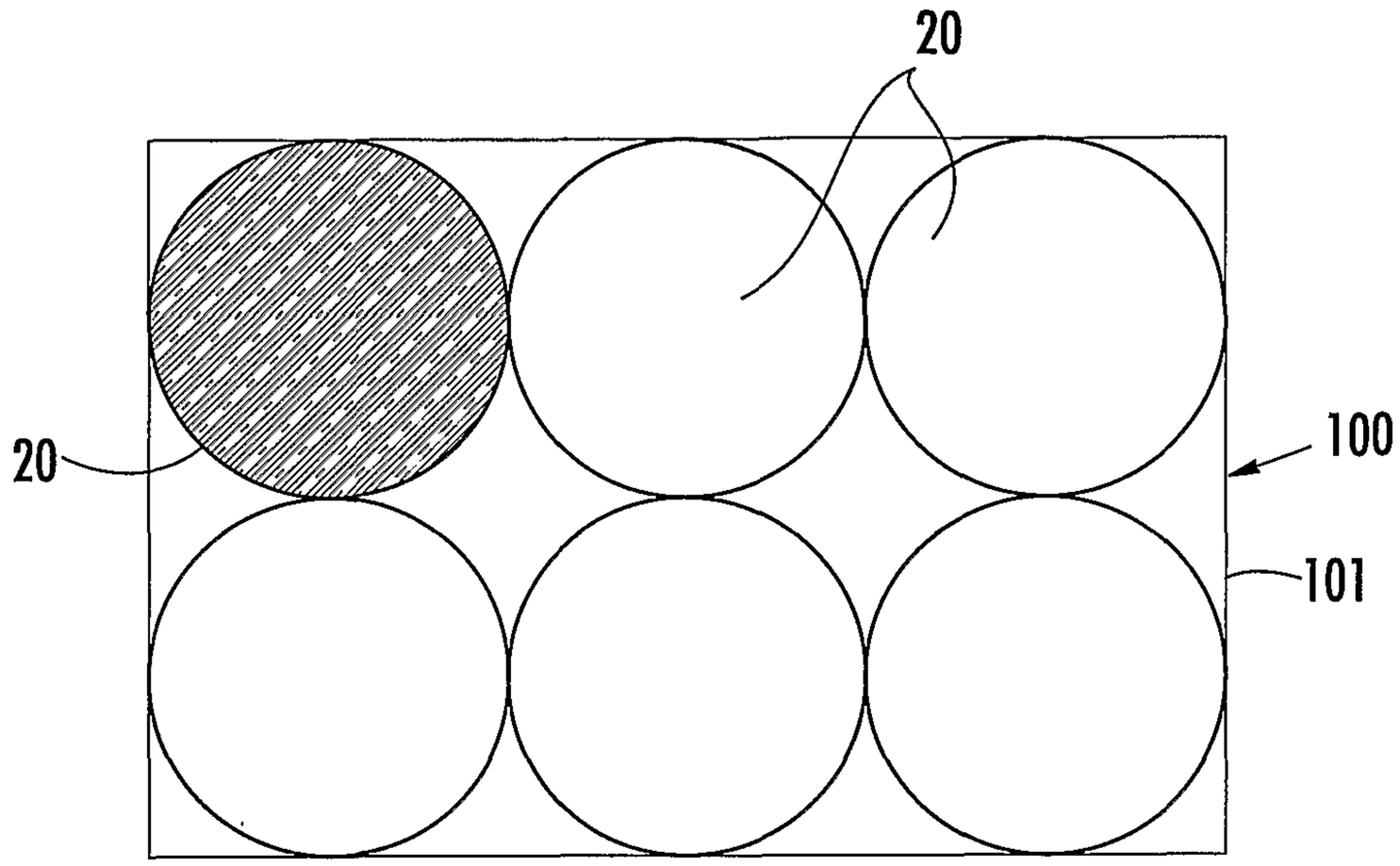
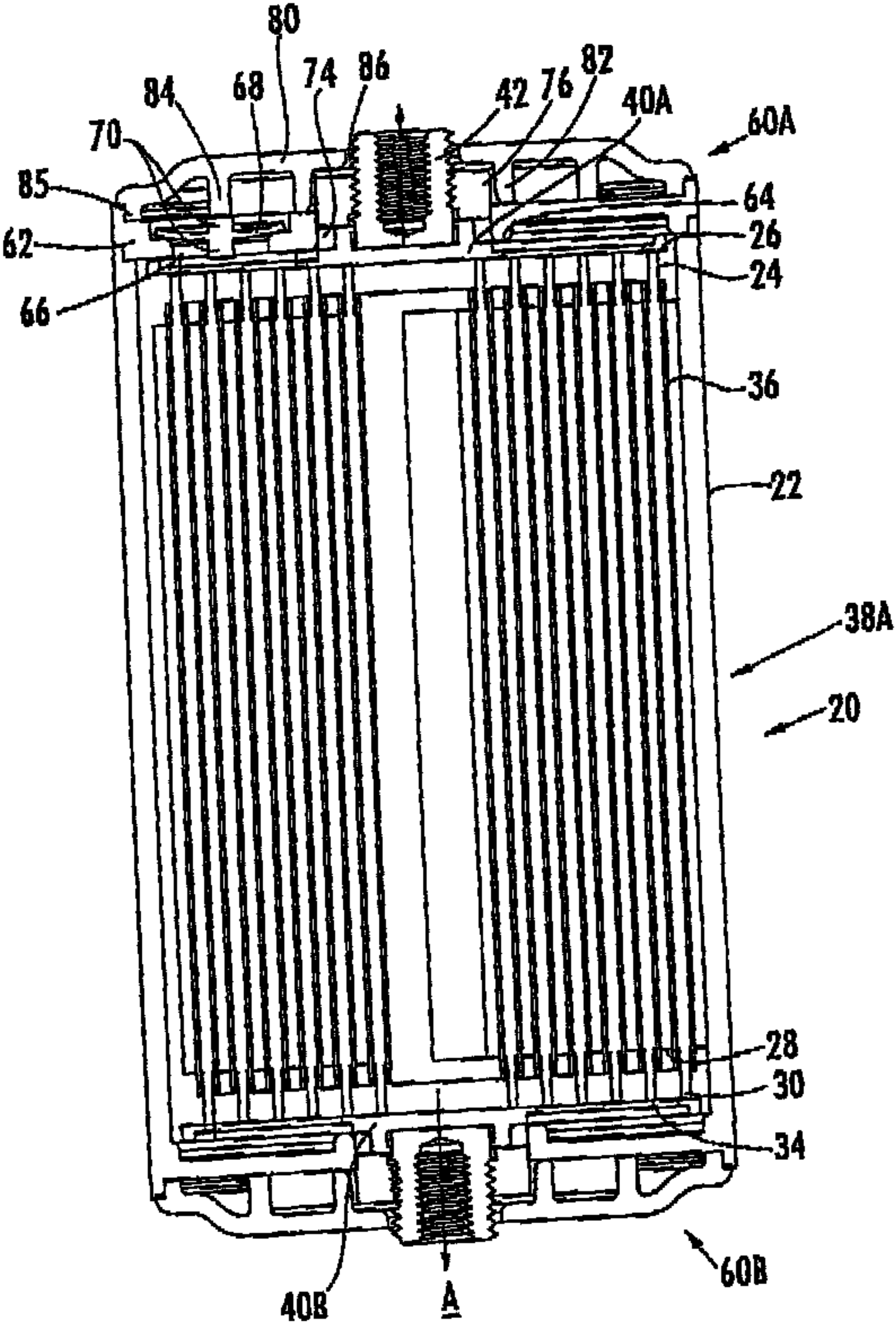



FIG. 7.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