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(54) PTC LIQUID HEATING DEVICE

(57) A PTC liquid heating device comprises a housing extending along a longitudinal axis and defining a liquid inlet and a liquid outlet. A PTC heating unit is inserted into the housing and extends along the longitudinal axis. The PTC heating unit includes a sleeve, a heat conductor and at least one PTC heating core. The heat conductor has a pair of metal profiles defining at least one chamber, the at least one chamber extending along the longitudinal axis to receive the at least one PTC heating core. The heat conductor is located in the sleeve and has a shape matching the sleeve. The PTC liquid heating device provides uniform and efficient heat transfer. In addition, the PTC liquid heating device has improved corrosion resistance and insulation properties, thereby prolonging the service life of the PTC liquid heating device.

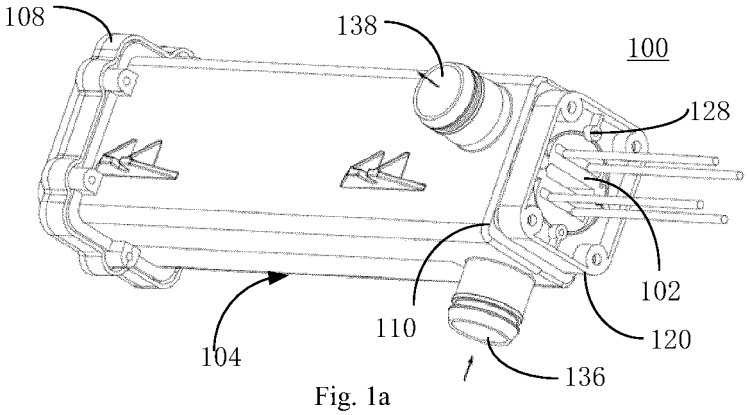

Fig. 1a

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Description

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to Chinese Patent Application Ser. No. CN201920379369.6, filed on March 25, 2019, the entire disclosure of which is hereby incorporated herein by reference.

RELATED FIELD

[0002] The present invention generally relates to a liquid heating device and in particular, the present invention relates to a PTC liquid heating device.

BACKGROUND

[0003] Currently, Positive Temperature Coefficient ("PTC") liquid heating devices have been widely used in products such as SPA pools, amusement pools, water dispensers, and foot tubs. Existing PTC liquid heating devices generally include a PTC heating element and have a heat transfer structure. The heat transfer structure typically includes a very complex structure, thereby having disadvantages such as a low heat transfer rate and uneven heat transfer.

SUMMARY

[0004] An object of the present invention is to solve the above problems in the existing PTC liquid heating devices and to provide a PTC liquid heating device wherein heat generated by a PTC heating element can be uniformly and efficiently transferred.

[0005] It is one aspect of the present invention to provide a PTC liquid heating device. The PTC liquid heating device comprise a housing extending along a longitudinal axis and defining a liquid inlet and a liquid outlet. A PTC heating unit is inserted into the housing and extends along the longitudinal axis. The PTC heating unit includes a sleeve, a heat conductor and at least one PTC heating core. The heat conductor has a pair of metal profiles defining at least one chamber. The at least one chamber extends along the longitudinal axis to receive the at least one PTC heating core. The heat conductor is located in the sleeve and has a shape matching the sleeve.

[0006] According to an embodiment of the present invention, the at least one chamber can define a first chamber and a second chamber. The first chamber can be located on a metal profile of the pair of metal profiles and extend along the longitudinal axis. The second chamber can be located between the pair of metal profiles and extend along the longitudinal axis.

[0007] According to an embodiment of the present invention, the at least one PTC heating core can comprise a pair of PTC heating cores located in the first chamber.

[0008] According to an embodiment of the present invention, the PTC liquid heating device can include a thermally conductive material located in the second chamber to improve heat transfer.

[0009] According to an embodiment of the present invention, the at least one PTC heating core can be located between the pair of metal profiles.

[0010] According to an embodiment of the present invention, the PTC liquid heating device can include an insulating layer located between the heat conductor and the sleeve. The insulating layer can extend about the heat conductor.

[0011] According to an embodiment of the present invention, the sleeve can have a generally cylindrical shape, and each metal profile of the pair of metal profiles can have a generally semi-cylindrical shape.

[0012] According to an embodiment of the present invention, the sleeve can be made from a corrosion resistant and thermally conductive material.

[0013] According to an embodiment of the present invention, the housing can comprise a housing body, a cover, a first baffle, and a second baffle. The housing body can extend between a first longitudinal end of the housing body and a second longitudinal end of the housing body. The first longitudinal end can define a first through hole and the second longitudinal end can define an opening. The cover can be detachably coupled to the second longitudinal end of the housing body to cover the opening of the housing body. The cover can define a first aperture. The first baffle can be detachably coupled to the first longitudinal end of the housing body. The first baffle can define a first bore in communication with the first through hole. The second baffle can be detachably coupled to the cover. The second baffle can define a first orifice in communication with the first aperture of the cover. The PTC heating unit can be inserted into the housing along the longitudinal axis and through the first through hole, the first aperture, the first bore and the first orifice. A stopper can be provided at an edge of the first aperture and at an edge of the first orifice to limit movement of the PTC heating unit along the longitudinal axis.

[0014] According to an embodiment of the present invention, the PTC liquid heating device can include a pair of flow guiding members located at opposite sides of the PTC heating unit. The pair of flow guiding members can be provided on an inner surface of the housing and extend from the first longitudinal end of the housing body along the longitudinal axis. The liquid inlet and the liquid outlet can be provided on the housing body and adjacent to the first longitudinal end of the housing body. Each flow guiding member of the pair of flow guiding members can have a length less than a distance between the first longitudinal end of the housing body and the cover. The pair of flow guiding members can fit against the PTC heating unit.

[0015] It is another aspect of the present invention to provide a PTC liquid heating device. The PTC liquid heating device comprises a housing extending along a longitudinal axis and defining a liquid inlet and a liquid outlet. A PTC heating unit is inserted into the housing and ex-

tends along the longitudinal axis. The PTC heating unit includes a PTC ceramic sheet, a pair of electrodes, a first insulating layer, and a first sleeve. The PTC ceramic sheet is located between the pair of electrodes. The first insulating layer extends about the pair of electrodes and the PTC ceramic sheet. The first sleeve extends about the first insulating layer. Each electrode of the pair of electrodes has a shape matching with a shape of the first sleeve.

[0016] According to an embodiment of the present invention, the PTC liquid heating device can include a second sleeve, located adjacent to the first sleeve and extending about the first sleeve.

[0017] According to an embodiment of the present invention, the first sleeve and the second sleeve can be made from a metallic material. The first sleeve can be made from aluminum. The second sleeve can be made from stainless steel.

[0018] According to an embodiment of the present invention, each of the first sleeve and the second sleeve can have a thickness of between 0.3mm-1.2mm.

[0019] According to an embodiment of the present invention, each of the first sleeve and the second sleeve can have a thickness of 0.5mm.

[0020] According to an embodiment of the present invention, the PTC liquid heating device can include a second insulating layer located between the first sleeve and the second sleeve, the second insulating layer extending about the first sleeve.

[0021] According to an embodiment of the present invention, the PTC liquid heating device can include a protective layer comprising a metal foil located between the first insulating layer and the first sleeve and extending about the first insulating layer.

[0022] According to an embodiment of the present invention, the protective layer can have a thickness of between 0.02mm and 0.06mm.

[0023] According to an embodiment of the present invention, the protective layer can have a thickness of 0.04mm.

[0024] According to an embodiment of the present invention, the PTC liquid heating device can include a second insulating layer located between the protective layer and the first sleeve. The second insulating layer can extend about the protective layer.

[0025] According to an embodiment of the present invention, the first sleeve can have a generally cylindrical shape, and each electrode of the pair of electrodes has a generally semi-cylindrical shape.

[0026] According to an embodiment of the present invention, the housing can comprise a housing body, a cover, a first baffle, and a second baffle. The housing body can extend between a first longitudinal end of the housing body and a second longitudinal end of the housing body. The first longitudinal end can define a first through hole. The second longitudinal end can define an opening. The cover can be detachably coupled to the second longitudinal end of the housing body to cover the opening of the housing bod. The cover can define a first aperture. The first baffle can be detachably coupled to the first longitudinal end of the housing body. The first baffle can define a first bore in communication with the first through hole. The second baffle can be detachably coupled to the cover. The second baffle can define a first orifice in communication with the first aperture of the cover. The PTC heating unit can be inserted into the housing along the longitudinal axis and through the first through hole, the first aperture, the first bore and the first orifice.

[0027] According to an embodiment of the present invention, the PTC liquid heating device can further include a stopper provided at an edge of the first aperture and at an edge of the first orifice to limit movement of the PTC heating unit along the longitudinal axis.

[0028] According to an embodiment of the present invention, the housing can comprise a housing body, a cover, and a flange. The housing body can have a first longitudinal end of the housing body and a second longitudinal end of the housing body. The first longitudinal end can be closed. The second longitudinal end can define an opening. The cover can be detachably coupled to the second longitudinal end of the hosing body to cover the opening of the housing body. The cover can define a first aperture. The flange can be detachably coupled to the cover. The flange can define a first bore in communication with the first aperture. The PTC heating unit can be inserted into the housing along the longitudinal axis and through the first bore and the first aperture. The PTC heating unit can be coupled to the flange via welding.

[0029] According to an embodiment of the present invention, the housing can comprise housing body and a flange. The housing body can have a first longitudinal end of the housing body and a second longitudinal end of the housing body. The first longitudinal end can be closed. The second longitudinal end can define an opening. The flange can be detachably connected to the second longitudinal end of the housing body to cover the opening of the housing. The flange can define a first bore. The PTC heating unit can be inserted into the housing along the longitudinal axis through the first bore. The PTC heating unit can be coupled to the flange via welding.

[0030] The heat transfer structure of the PTC liquid heating device constructed in accordance with embodiments of the present invention can provide uniform and efficient heat transfer. In addition, the PTC liquid heating device has improved corrosion resistance and insulation properties, thereby prolonging the service life of the PTC liquid heating device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] Other features and advantages of the present invention will be better understood from the alternative embodiments described in detail with reference to the accompany drawings, in which the same reference numerals identify the same or similar components.

Figure 1a is a perspective view of a PTC liquid heating device constructed in accordance with an embodiment of the present invention;
Figure 1b is an exploded view of the PTC liquid heating device;
Figure 1c is a perspective view of a housing body of the PTC liquid heating device;
Figure 1d is a cross-sectional side view of the PTC liquid heating device;
Figure 1e is cross-sectional top view of the PTC liquid heating device;
Figure 2a is an exploded view of a PTC heating unit of the PTC liquid heating device constructed according to an embodiment of the present invention;
Figure 2b is a cross-sectional view of the PTC heating unit of Figure 2a;
Figure 2c is a cross-sectional view of a PTC heating core of the PTC heating unit of Figure 2a;
Figure 3a is an exploded view of a PTC heating unit of the PTC liquid heating device constructed according to an embodiment of the present invention;
Figure 3b is a cross-sectional view of the PTC heating unit of Figure 3a;
Figure 3c is a cross-sectional view of a PTC heating core of the PTC heating unit of Fig. 3a;
Figure 4a is an exploded view of a PTC heating unit of the PTC liquid heating device constructed according to an embodiment of the present invention;
Figure 4b is a cross-sectional view of the PTC heating unit of Figure 4a;
Figure 4c is a cross-sectional view of a PTC heating core of the PTC heating unit of Figure 4a;
Figure 5a is a perspective view of a PTC liquid heating device constructed according to an embodiment of the present invention;
Figure 5b is an exploded view of the PTC liquid heating device;
Figure 5c is a cross-sectional side view of the PTC liquid heating device;
Figure 6 is a cross-sectional view of a PTC heating unit of the PTC liquid heating device;
Figure 7a is a perspective view of a PTC liquid heating device constructed according to an embodiment of the present disclosure;
Figure 7b is an exploded view of the PTC liquid heating device;
Figure 7c is a cross-sectional view of the PTC liquid heating device;
Figure 8a is a perspective view of a PTC liquid heating device constructed according to an embodiment of the present invention;
Figure 8b is an exploded view of the PTC liquid heating device;
Figure 8c is a cross-sectional view of the PTC liquid heating device;
Figure 9a is a perspective view of a PTC liquid heating device constructed according an embodiment of the present invention;
Figure 9b is an exploded view of the PTC liquid heating device;
Figure 9c is a cross-sectional view of the PTC liquid heating device;
Figure 10a is a perspective view of a PTC liquid heating device constructed according to an embodiment of the present invention;
Figure 10b is an exploded view of the PTC liquid heating device;
Figure 10c is a cross-sectional view of the PTC liquid heating device;
Figure 11a is an exploded view of a PTC liquid heating device constructed according to an embodiment of the present invention;
Figure 11b is a cross-sectional view of the PTC liquid heating device;
Figure 12 is a cross-sectional view of a PTC heating unit of the PTC liquid heating device constructed in accordance with an embodiment of the present invention;
Figure 13 is a cross-sectional view of a PTC heating unit of the PTC liquid heating device constructed in accordance with an embodiment of the present invention; and
Figure 14 is a cross-sectional view of a PTC heating unit of the PTC liquid heating device constructed in accordance with an embodiment of the present invention.

DESCRIPTION OF THE ENABLING EMBODIMENT

[0032] The implementation and usage of the embodiments will be discussed in detail below. However, it should be understood that specific embodiments discussed herein are merely illustrative of specific ways to implement and use the present invention and do not limit the scope of the present invention. In the description regarding the structural positions of various components, representations of directions such as "upper", "lower", "top" and "bottom" are not absolute, but relative. When various components are arranged as shown in the drawings, these representations of directions are appropriate. However, when the positions of the various components in the drawings are changed, these representations of directions shall be changed accordingly. Accordingly, a PTC liquid heating device extending along a lengthwise direction can be defined as extending along a longitudinal axis A, as shown by way of example in Figure 1b. A widthwise direction of the PTC liquid heating device can be defined as a transverse direction **B**, as shown by way of example in Figure 1b.

[0033] Figures 1a to 1e illustrate a PTC liquid heating device **100** and its components constructed in accordance with an embodiment of the present invention. Figures 2a to 2c show a PTC heating unit **102** of the PTC liquid heating device **100** constructed in accordance with an embodiment of the present invention.

[0034] Referring to Figures 1a to le, the PTC liquid

heating device **100** includes a housing **104** and a PTC heating unit **102** inserted in the housing **104.** The housing **104,** extending along a longitudinal axis **A,** includes a housing body **106** and a cover **108.** The housing body **106** has a generally rectangular-shaped cross-section. The housing body **106** extends between a first longitudinal end **110** and a second longitudinal end **114.** The first longitudinal end **110** of the housing body **106** defines a first through hole **112** (shown in Figure Ic). The second longitudinal end **114** of the housing body **106** defines an opening **116.** The cover **108** is detachably coupled to the second longitudinal end **114** of the housing body **106** to cover the opening **116** of the housing body **106.** The cover **108** defines a first aperture **118** in communication with the first through hole **112.**

[0035] The housing **104** includes a first baffle **120** and a second baffle **122** for limiting movement of the PTC heating unit **102** along the longitudinal axis **A.** The first baffle **120** is detachably coupled to the first longitudinal end **110** of the housing body **106.** The first baffle **120** defines a first bore **124** in communication with the first through hole **112** of the first longitudinal end **110** of the housing body **106.** The second baffle **122** is detachably coupled to the cover **108.** The second baffle **122** defines a first orifice **126** in communication with the first aperture **118** of the cover **108.** A stopper **128** may be provided at an edge of the first bore **124** of the first baffle **120** (as best shown in Figure Ia). In addition, a stopper **130** may be provided at an edge of the first orifice **126** of the second baffle **122** to limit movement of the PTC heating unit **102** along the longitudinal axis **A.** It should be appreciated that the first through hole **112** of the first longitudinal end **110** of the housing body **106,** the first aperture **118** of the cover **108,** the first bore **124** of the first baffle **120,** and the first orifice **126** of the second baffle **122** each have a shape that matches the shape of the PTC heating unit **102.** It should be appreciated that there can be any number of the first through hole **112,** the first aperture **118,** the first bore **124,** and the first orifice **126.** According to an embodiment of the present invention, the PTC heating unit **102** has one first through hole **112,** one first aperture **118,** one first bore **124,** and one first orifice **126.** The PTC heating unit **102** is inserted into the housing **104** along the longitudinal axis **A** through the first bore **124,** the first through hole **112,** the first aperture **118,** and the first orifice **126.**

[0036] The housing **104** includes a pair of first seals **132** and a second seal **134.** A first seal **132** of the pair of first seals **132** is located between the first through hole **112** and the PTC heating unit **102.** Another first seal **132** of the pair of first seals **132** is located between the first aperture **118** of the cover **108** and the PTC heating unit **102.** The second seal **134** is located between the second longitudinal end **114** of the housing body **106** and the cover **108.**

[0037] As shown in Figures 1c to 1e, the housing body **106** of the housing **104** defines a liquid inlet **136** and a liquid outlet **138.** According to an embodiment of the present invention, the liquid inlet **136** and the liquid outlet 138 are located adjacent to the first longitudinal end **110** of the housing body **106.** A pair of flow guiding members **140** are located at opposite sides of the PTC heating unit **102.** Each flow guiding member **140** of the pair of flow guiding members **140** has a rib-shape and is located on an inner surface of the housing **104** and extends from the first longitudinal end **110** of the housing body **106** along the longitudinal axis **A.** The pair of flow guiding members **140** are respectively located on opposite sides of the housing body **106** along a transverse direction (i.e., on opposite sides of the PTC heating unit **102**), and they extend from the first longitudinal end **110** of the housing body **106** toward the PTC heating unit **102.** According to an embodiment of the present invention, the pair of flow guiding members **140** can be integrally formed with the housing body **106** and be tightly fit with the PTC heating unit **102.** Each flow guiding member **140** of the pair of the flow guiding members **140** has a length that is less than a distance between the first longitudinal end **110** of the housing body **106** and the cover **108.** The inner surface of the housing body **106**, the outer surface of the PTC heating unit **102,** and the pair of flow guiding members **140** collectively define a first liquid passage **142** and a second liquid passage **144.** Accordingly, fluid such as water can flow into the PTC liquid heating device **100** through the liquid inlet **136** near the first longitudinal end **110** of the housing body **106,** towards the cover **108** along the first liquid passage **142,** and enter the second liquid passage **144** through a gap between the flow guiding members **140** and the cover **108.** Then, the fluid can flow toward the first longitudinal end **110** of the housing body **106** along the second liquid passage **144,** and out of the PTC liquid heating device **100** through the liquid outlet **138** near the first longitudinal end **110** of the housing body **106.**

[0038] Figures 2a to 2c illustrates the PTC heating unit **102** constructed in accordance with an embodiment of the present invention. The PTC heating unit **102** includes a sleeve **146,** a heat conductor **148,** and at least one PTC heating cores **150.** According to an embodiment of the present invention, the PTC heating core **150** is sleeved inside the heat conductor **148** and the sleeve **146** extends about the heat conductor **148.** The sleeve **146** has a generally cylindrical shape and is adapted to accommodate the at least one PTC heating core **150** and the heat conductor **148.** The sleeve **146** may be made of a material with high thermal conductivity and corrosion resistance, such as but not limited to stainless steel.

[0039] The heat conductor **148** defines at least one chamber **154, 162** extending along the longitudinal axis **A** for receiving the at least one PTC heating core **150.** It should be appreciated that the heat conductor **148** may be made of a metal with high thermal conductivity, such as but not limited to aluminum or copper. According to an embodiment of the present invention, the heat conductor **148** includes a pair of metal profiles **152** opposite with respect to one another and located inside the sleeve

146. The pair of metal profiles **152** define the at least one chamber **154, 162,** extending along the longitudinal axis **A.** The at least one chamber **154, 162** includes a first chamber **154** and a second chamber **162.** The first chamber **154** is located on a metal profile **152** of the pair of metal profiles **152** and extends along the longitudinal axis **A.** According to an embodiment of the present invention, each metal profile **152** of the pair of metal profiles **152** has a semi-cylindrical shape and includes a first side portion **156** (at the cylindrical surface side) and a second side portion **158** opposite with respect to the first side portion **156.** An inner surface of the sleeve **146** is at least partially in contact with an outer surface of the first side portion **156** of the metal profile **152** to provide effective heat transfer performance. The second side portion **158** of the metal profile **152** defines a groove **160,** extending along the longitudinal axis **A.** The two metal profiles **152** are coupled to one another, and the grooves **160** of the second side portions **158** of the two metal profiles **152** are aligned to form the second chamber **162,** extending along the longitudinal axis **A.** The second chamber **162** can be filled with a thermally conductive material, such as alumina powder or a thermally conductive adhesive to improve heat transfer performance.

[0040] According to an embodiment of the present invention, the PTC heating core **150** includes a PTC ceramic sheet **164,** a pair of electrodes **166,** a first insulating layer **168,** a protective layer **170,** and a second insulating layer **172.** The pair of electrodes **166,** spaced apart from one another, are made of a material with high electrical conductivity and thermal conductivity, such as but not limited to aluminum or copper. The PTC ceramic sheet **164** is located between the pair of electrodes **166.** The first insulating layer **168,** the protective layer **170,** and the second insulating layer **172** extend about the PTC ceramic sheet **164** and the pair of electrodes **166.** It should be appreciated that each layer of the first insulating layer **168** or the second insulating layer **172** can include at least one layer of insulating film. According to an embodiment of the present embodiment, the first insulating layer **168** includes four layers of insulating film, while the second insulating layer **172** includes two layers of insulating film. The insulating film may be an imine film. The protective layer **170** is disposed between the first insulating layer **168** and the second insulating layer **172.** The protective layer **170** is a thin metal sheet made from a metal with high thermal conductivity to prevent the insulating layers from being pierced by solid particles. It should be appreciated that the PTC ceramic sheet **164,** the electrodes **166,** the first insulating layer **168,** the protective layer **170,** and the second insulating layer **172** are in close contact with each other to provide effective heat transfer.

[0041] Figures 3a to 3c illustrate a PTC heating unit **102'** of the PTC liquid heating device **100** constructed in accordance with an embodiment of the present invention. The PTC heating unit **102'** includes a sleeve **146',** a heat conductor **148',** and a PTC heating core **150'.**

[0042] The sleeve **146'** has a generally cylindrical shape and is adapted to receive the PTC heating core **150'** and the heat conductor **148'.** It should be appreciated that the sleeve **146'** can be made from a material with high thermal conductivity and corrosion resistance, such as but not limited to stainless steel.

[0043] The heat conductor **148'** defines a chamber **162',** extending along the longitudinal axis **A** for receiving the PTC heating core **150'.** The heat conductor **148'** can be made from a metal with high thermal conductivity, such as but not limited to aluminum or copper. The heat conductor **148'** includes a pair of metal profiles **152'** opposite of one another inside the sleeve **146'.** Each metal profile **152'** of the pair of metal profiles **152'** has a semi-cylindrical shape and includes a first side portion **156'** (at the cylindrical surface side) and a second side portion **158'** opposite of the first side portion **156'.** According to an embodiment of the present invention, an inner surface of the sleeve **146'** is at least partially in contact with an outer surface of the first side portion **156'** of the metal profile **152'** to provide effective heat transfer performance. The second side portion **158'** of the metal profile **152'** defines a groove **160',** extending along the longitudinal axis **A.** The pair of metal profiles **152'** are coupled to one other, and the grooves **160'** of the second side portions **158'** of the two metal profiles **152'** are aligned to form the chamber **162',** extending therebetween. The PTC heating core **150'** is located in the chamber **162'.**

[0044] The PTC heating core **150'** of the PTC heating unit **102'** has substantially the same structure as that of the PTC heating core **150** shown in Figure 2c. The PTC heating core **150'** includes a PTC ceramic sheet **164',** a pair of electrodes **166',** a first insulating layer **168',** a protective layer **170',** and a second insulating layer **172'.** The PTC ceramic sheet **164'** is located between the pair of electrodes **166'.** The first insulating layer **168'** extends about the PTC ceramic sheet **164'** and the pair of electrodes **166'.** The protective layer **170'** extends about the first insulating layer **168'.** The second insulating layer **172'** extends about the protective layer **170'.** According to an embodiment of the present invention, the PTC heating core **150'** can include a casing **174',** made from an aluminum, extending about the second insulating layer **172'** for protecting the PTC ceramic sheet **164',** the pair of electrodes **166',** the first insulating layer **168',** the protective layer **170'** and the second insulating layer **172'.**

[0045] Figures 4a to 4c illustrates a PTC heating unit **102"** of the PTC liquid heating device **100** constructed in accordance with an embodiment of the present invention. The PTC heating unit **102"** includes a sleeve **146",** a heat conductor **148",** and a PTC heating core **150".** The sleeve **146"** has a generally cylindrical shape and receives the PTC heating core **150"** and the heat conductor **148".** The heat conductor **148"** defines a chamber **162",** extending along the longitudinal axis **A** for receiving the PTC heating core **150".** The heat conductor **148"** may be made of a metal with high thermal conductivity, such as but not limited to aluminum or copper. According

to an embodiment of the present invention, the heat conductor **148"** includes a pair of metal profiles **152"** opposite of one another inside the sleeve **146".** Each metal profile **152"** of the pair of metal profiles **152"** has a generally semi-cylindrical shape. The pair of metal profiles **152"** are spaced apart inside the sleeve **146"** to define the chamber **162",** extending therebetween. The PTC heating core **150"** is located in the chamber **162** and extending along the longitudinal axis **A.**

[0046] The PTC heating core **150"** in the PTC heating unit **102"** has substantially the same structure as the PTC heating core **150** of the PTC heating unit **102** shown in Figure 2c. The PTC heating core **150"** includes a PTC ceramic sheet **164",** a pair of electrodes **166",** a first insulating layer **168",** a protective layer **170",** and a second insulating layer **172".** The PTC heating core **150"** is located between the pair of electrodes **166".** The first insulating layer **168"** extends about the pair of electrodes **166"** and the PTC ceramic sheet **164".** The protective layer **170"** extends about the first insulating layer **168".** The second insulating layer **172"** extends about the protective layer **170".** According to an embodiment of the present invention, the PTC heating unit **102"** includes a third insulating layer **176"** located in the sleeve **146".** The third insulating layer **176"** extends about the PTC heating core **150"** and the heat conductor **148"** wherein the third insulating layer **176"** includes at least one layer of insulating film (for example, imide film). In addition, both ends of the third insulating layer **176"** can be closed to provide better insulation and waterproof properties.

[0047] Figures 5a to 5c illustrate a PTC liquid heating device **200** constructed in accordance with an embodiment of the present invention. Figure 6 is provides a cross-sectional view of the PTC heating unit **202** of the PTC liquid heating device **200.** The PTC liquid heating device **200** includes a housing **204** and a pair of PTC heating units **202** inserted into the housing **204.** The housing **204,** extending along a longitudinal axis **A,** includes a housing body **206** and a cover **208.** The housing body **206** has a generally cylindrical shape and a generally rectangular-shaped cross-section. The housing body **206** extends between a first longitudinal end **210** and a second longitudinal end **214.** The first longitudinal end **210** of the housing body **206** defines a first through hole (not shown), and the second longitudinal end **214** defines an opening **216.** The cover **208** is detachably coupled to the second longitudinal end **214** of the housing body **206** to cover the opening **216** of the housing body **206.** The cover **208** defines a first aperture **218** in communication with the first through hole (not shown).

[0048] The housing **204** includes a first baffle **220** and a second baffle **222** for limiting movement of the PTC heating units **202** along the longitudinal axis **A.** The first baffle **220** is detachably coupled to the first longitudinal end **210** of the housing body **206.** The first baffle **220** defines a first bore **224** in communication with the first through hole of the first longitudinal end **210** of the housing body **206.** As shown in Figure 5b, there is actually a pair of first bores **224,** each of which is in communication with a corresponding first through hole. The second baffle **222** is detachably coupled to the cover **208.** The second baffle **222** defines a first orifice **226** in communication with the first aperture **218** of the cover **208.** Again, as shown in Figure 5b, there is actually a pair of first orifices **226,** each of which is in communication with a corresponding first aperture **218** of cover **208.** A stopper **228** may be provided at an edge of the first bore **224** of the first baffle **220** (as best shown in Figure 5a). In addition, a stopper **230** may be provided at an edge of the first orifice **226** of the second baffle **222** (as best shown in Figures 5b and 5c) for restricting movement of the PTC heating unit **202** along the longitudinal axis **A.** The first through holes of the first longitudinal end **210** of the housing body **206,** the first apertures **218** of the cover **208,** the first bores **224** of the first baffle **220,** and the first orifices **226** of the second baffle **222** each have a shape that matches with the shape of the PTC heating units **202.** According to an embodiment of the present invention, there are two of the first through hole, two of the first aperture **218,** two of the first bore **224,** and two of the first orifice **226.** The PTC heating units **202** are inserted into the housing **204** along the longitudinal axis **A** through the first bores **224,** the first through holes of the first longitudinal end **210** of the housing body **206,** the first apertures **218,** and the first orifices **226.**

[0049] The housing **204** includes a plurality of first seals **232** and a second seal **234.** Two first seals **232** of the plurality of first seals **232** are located between the first through holes of the first longitudinal end **210** of the housing body **206** and the PTC heating units **202.** Another two first seals **232** of the plurality of first seals **232** are located between the first apertures **218** and the PTC heating units **202.** The second seal **234** is located between the second longitudinal end **214** of the housing body **206** and the cover **208.**

[0050] As shown in Figure 5c, the housing body **206** defines a liquid inlet **236** and a liquid outlet **238.** According to an embodiment of the present invention, the liquid inlet **236** and the liquid outlet **238** are located adjacent to the first longitudinal end **210** of the housing body **206.** A flow guiding member **240** is located inside of the housing body **206.** The flow guiding member **240** has a generally rectangular shape and extends from the first longitudinal end **210** of the housing body **206** along the longitudinal axis **A.** Both ends of the flow guiding member **240** lie along a transverse direction are respectively coupled to the housing body **206.** According to an embodiment of the present invention, the flow guiding member **240** can be integrally formed with the housing body **206,** and there is a pair of PTC heating units **202,** wherein one PTC heating unit **202** of the pair of PTC heating units **202** is separated from the other PTC heating unit **202** by the flow guiding member **240.** It should be appreciated that the flow guiding member **240** can have a length that is less than a distance between the first longitudinal end **210** of the housing body **206** and the cover **208.** An inner

surface of the housing body **206,** an outer surfaces of the PTC heating units **202,** and the flow guiding member **240** collectively define a first liquid passage **242,** and a second liquid passage **244.** Fluid such as water can flow into the PTC liquid heating device **200** through the liquid inlet **236** near the first longitudinal end **210** of the housing body **206,** towards the cover **208** along the first liquid passage **242,** and enters the second liquid passage **244** through the gap between the flow guiding member **240** and the cover **208.** Then, the fluid can flow toward the first longitudinal end **210** of the housing body **206** along the second liquid passage **244,** and out of the PTC liquid heating device **200** through the liquid outlet **238** near the first longitudinal end **210** of the housing body **206.**

[0051] As shown in Figure 6, each PTC heating unit **202** includes a PTC ceramic sheet **263,** a pair of electrodes **265,** an insulating layer **267,** a first sleeve **269,** and a second sleeve **271.** Each electrode **265** of the pair of electrodes **265** can be made from a material with high electrical conductivity and thermal conductivity, such as but not limited to aluminum or copper. Each electrode **265** of the pair of electrodes **265** has a semi-cylindrical shape wherein the shape of the electrodes **265** matches with that of the first sleeve **269,** thereby allowing the electrode **265** to provide effective transfer of the heat generated by the PTC ceramic sheet **263.** The insulating layer **267** extends about the pair of electrodes **265** and the PTC ceramic sheet **263.** The PTC ceramic sheet **263,** the pair of electrodes **265** and the insulating layer **267** are disposed within the first sleeve **269.** The first sleeve **269** is disposed within the second sleeve **271.** In other words, the first sleeve **269** extends about the insulating layer **267** and the second sleeve **271** extends about the first sleeve **269.** It should be appreciated that the first sleeve **269** and the second sleeve **271** can be made from a metal having high thermal conductivity. Surfaces of the first sleeve **269** and the second sleeve **271** may also be subjected to an anti-corrosion treatment. According to an embodiment of the present invention, the first sleeve **269** can be made from aluminum and the second sleeve **271** can be made from stainless steel. This arrangement of the two sleeves **269, 271** can provide improved corrosion resistance and higher mechanical strength. In the event that the second sleeve **271** is corroded and/or cracked, the first sleeve **269** can still protect the internal components (e.g., the insulating layer **267**), thereby reducing the risk that liquid to be heated becomes charged (by electricity from the PTC ceramic sheet **263** and the pair of electrodes **265**) and improving the safety of the PTC heating unit **202.**

[0052] Figures. 7a to 7c illustrate a PTC liquid heating device **300** constructed according to an embodiment of the present invention. The PTC liquid heating device **300** is similar to the PTC liquid heating device **200** shown in Figures 5a-5c. The main differences are that the PTC liquid heating device **300** includes a plurality of four PTC heating units **302,** and the housing body **306** has a generally circular shape. The PTC liquid heating device **300** includes a housing **304** and the plurality of four PTC heating units **302** inserted into the housing **304.**

[0053] The housing **304** includes a housing body **306** and a cover **308.** The housing body **306** has a generally cylindrical shape and a generally circular-shaped cross-section. The housing body **306** extends between a first longitudinal end **310** and a second longitudinal end **314.** The first longitudinal end **310** of the housing body **306** defines a first through hole (not shown, one for each PTC hearing unit **302**). The second longitudinal end **314** defines an opening **316.** The cover **308** is detachably coupled to the second longitudinal end **314** of the housing body **306** to cover the opening **316** of the housing body **306.** The cover **308** defines a plurality of first apertures **318,** wherein the plurality of apertures **318,** are in communication with the opening **316.**

[0054] The housing **304** includes a first baffle **320** and a second baffle **322** to limit movement of the PTC heating units **302** along the longitudinal axis **A.** The first baffle **320** is detachably coupled to the first longitudinal end **310** of the housing body **306.** The first baffle **320** defines a plurality of first bores **324** in respective communication with corresponding first through holes (not shown). The second baffle **322** is detachably coupled to the cover **308.** The second baffle **322** defines a plurality of first orifices **326,** wherein each first orifice **326** of the plurality of first orifices **326** is in communication with a corresponding first aperture **318** of the plurality of first apertures **318.** According to an embodiment of the present invention, the first through holes of the first longitudinal end **310** of the housing body **306,** the plurality of first apertures **318,** the plurality of first bores **324,** and the plurality of first orifice **326** of the second baffle **322** each have a shape that matches with the shape of the PTC heating units **302.** According to an embodiment of the present invention, there are four of the first apertures **318** in the cover **308,** four of the first bores **324** in the first baffle **320,** and four of the first orifices **326** in the second baffle **322.** Each PTC heating unit **302** of the plurality of PTC heating units **302** is inserted into the housing **304** along the longitudinal axis **A** through a corresponding first bore **324** in the first baffle **320,** a corresponding first through hole of the first longitudinal end **310** of the housing body **306,** a corresponding first aperture **318** in the cover **308,** and a corresponding first orifice **326** in the second baffle **322.**

[0055] The housing **304** includes a plurality of first seals **332** and a second seal **334.** Each first seal **332** of the plurality of first seals **332** is located between a corresponding first through hole of the first longitudinal end **310** of the housing body **306** and a corresponding PTC heating units **302.** In addition, each first seal **332** of the plurality of first seals **332** is located between a corresponding first aperture **318** in the cover **308** and a corresponding PTC heating unit **302.** The second seal **334** is located between the second longitudinal end **314** of the housing body **306** and the cover **308.**

[0056] As best shown in Figure 7c, the housing body **306** of the housing **304** defines a liquid inlet **336** and a

liquid outlet **338.** According to an embodiment of the present invention, the liquid inlet **336** and the liquid outlet **338** are located adjacent to the first longitudinal end **310** of the housing body **306.** A flow guiding member **340** is located inside of the housing body **306.** The flow guiding member **340** has a generally rectangular shape and extends from the first longitudinal end **310** of the housing body **306** along the longitudinal axis **A.** Both ends of the flow guiding member **340** lie along a transverse direction are coupled to the housing body **306.** According to an embodiment of the present embodiment, the flow guiding member **340** can be integrally formed with the housing body **306,** and there is a plurality of four PTC heating units **302** located in the housing body **306,** wherein two PTC heating unit **302** of the plurality of four PTC heating unit **302** is separated from the other two PTC heating units **302** of the plurality of four PTC heating unit **302** by the flow guiding member **340.** It should be appreciated that the flow guiding member **340** can have a length that is less than a distance between the first longitudinal end **310** of the housing body **306** and the cover **308.** Each PTC heating unit **302** of the plurality of PTC heating units **302** of the PTC liquid heating device **300** has the same structure as that of the PTC heating unit **202** of the PTC liquid heating device **200,** as illustrated in Figure 6.

[0057] Figures 8a to 8c illustrates a PTC liquid heating device **400** constructed in accordance with an embodiment of the present invention. The PTC liquid heating device **400** includes a housing **404** and a plurality of four PTC heating units **402** inserted into the housing **404.**

[0058] The housing **404,** extending along a longitudinal axis **A,** includes a housing body **406** and a cover **408.** The housing body **406** has a generally cylindrical shape and a generally rectangular-shaped cross-section. The housing body **406** extends between a first longitudinal end **410** and a second longitudinal end **414,** wherein the first longitudinal end **410** of the housing body **406** is closed and the second longitudinal end **414** defines an opening **416.** The cover **408** is detachably coupled to the second longitudinal end **414** of the housing body **406** to cover the opening **416** of the housing body **406.** The cover **408** defines a plurality of first apertures **418.** The housing **404** includes a flange **417** detachably coupled to the cover **408.** The flange **417** defines a plurality of first through holes **419,** wherein each first through hole **419** of the plurality of first through holes **419** is in communication with a corresponding first aperture **418** of the plurality of first apertures **418** in the cover **408.** It should be appreciated that each first aperture **418** of the plurality of first apertures **418** and each first through hole **419** of the plurality of first through holes **419** has a shape that matches with the shape of a corresponding PTC heating unit **402.** According to an embodiment of the present invention, each PTC heating unit **402** of the plurality of PTC heating units **402** is inserted into the housing **404** along the longitudinal axis **A** through a corresponding first through hole **419** of the plurality of first through holes **419** and a corresponding first aperture **418** of the plurality of first apertures **418.** It should be appreciated that, according to an embodiment of the present invention, the PTC heating units **402** may be coupled to the flange **417** by welding.

[0059] The housing **404** includes a plurality of first seals **432** and a second seal **434.** Each first seal **432** of the plurality of first seals **432** is located between a corresponding first aperture **418** of the plurality of first apertures **418** of the cover **408** and a corresponding PTC heating unit **402** of the plurality of PTC heating units **402.** The second seal **434** is located between the second longitudinal end **414** of the housing body **406** and the cover **408.**

[0060] The housing body **406** of the housing **404** defines a liquid inlet **436** and a liquid outlet **438.** According to an embodiment of the present invention, the liquid inlet **436** and the liquid outlet **438** are located adjacent to the first longitudinal end **410** of the housing body **406.** A flow guiding member **440** is located inside the housing body **406.** The flow guiding member **440** has a generally rectangular shape and extends from the first longitudinal end **410** of the housing body **406** along the longitudinal axis **A.** Both ends of the flow guiding member **440** lie along a transverse direction and are respectively coupled to the housing body **406.** According to an embodiment of the present invention, the flow guiding member **440** can be integrally formed with the housing body **406** and there is a plurality of four PTC heating units **402** located in the housing body **406,** wherein two PTC heating units **402** of the plurality of four PTC heating units **402** are separated from the other two PTC heating units **402** of the plurality of four PTC heating unit **402** by the flow guiding member **440.** It should be appreciated that the flow guiding member **440** can have a length less than a distance between the first longitudinal end **410** of the housing body **406** and the cover **408.** Each PTC heating unit **402** of the plurality of PTC heating units **402** of the PTC liquid heating device **400** can have the same structure as that of the PTC heating unit **202** of the PTC liquid heating device **200,** as illustrated in Figure 6.

[0061] Figures 9a to 9c illustrates a PTC liquid heating device **500** constructed in accordance with an embodiment of the present invention. The PTC liquid heating device **500** is similar to the PTC liquid heating device **400,** as shown in Figures 8a-8c, and the main difference is that the PTC liquid heating device **500** does not include a cover. The PTC liquid heating device **500** includes a housing **504** and a plurality of four PTC heating units **502** inserted into the housing **504.**

[0062] The housing **504,** extending along a longitudinal axis **A,** includes a housing body **506** and a flange **517.** The housing body **506** has a generally cylindrical shape and a generally rectangular shaped cross-section. The housing body **506** extends between a first longitudinal end **510** and a second longitudinal end **514,** wherein the first longitudinal end **510** of the housing body **506** is closed and the second longitudinal end **514** defines an opening **516.** The flange **517** is detachably coupled to

the second longitudinal end **514** of the housing body **506** to cover the opening **516** of the housing body **506.** The flange **517** defines a plurality of first through holes **519** in communication with the opening **516.** It should be appreciated that each first through hole **519** of the plurality of first through holes **519** can have a shape that matches with the shape of a corresponding PTC heating unit **502.** According to an embodiment of the present invention, each PTC heating unit **502** of the plurality of PTC heating units **502** is inserted into the housing **504** along the longitudinal axis **A** through a corresponding first through hole **519** of the plurality of first through holes **519.** It should be appreciated that, according to an embodiment of the present invention, the PTC heating units **502** may be coupled to the flange **517** by welding. The housing **504** also includes a seal **533** disposed between the second longitudinal end **514** of the housing body **506** and the flange **517.**

[0063] As best shown in Figure 9c, the housing body **506** of the housing **504** defines a liquid inlet **536** and a liquid outlet **538.** According to an embodiment of the present invention, the liquid inlet **536** and the liquid outlet **538** are located adjacent to the first longitudinal end **510** of the housing body **506.** A flow guiding member **540** is located in the housing body **506.** The flow guiding member **540** has a generally rectangular shape and extends from the first longitudinal end **510** of the housing body **506** along the longitudinal axis **A.** Both ends of the flow guiding member **540** lie along a transverse direction and are coupled to the housing body **506.** According to an embodiment of the present invention, the flow guiding member **540** can be integrally formed with the housing body **506,** and there is a plurality of four PTC heating units **502** located in the housing body **506,** wherein two PTC heating units **502** of the plurality of four PTC heating units **502** are separated from the other two PTC heating units **502** of the plurality of four PTC heating units **502** by the flow guiding member **540.** It should be appreciated that the flow guiding member **540** can have a length less than a distance between the first longitudinal end **510** of the housing body **506** and the flange **517.** Each PTC heating unit **502** of the plurality of PTC heating units **502** of the PTC liquid heating device **500** can have the same structure as that of the PTC heating unit **202** of the PTC liquid heating device **200,** as illustrated in Figure 6.

[0064] Figures 10a to 10c illustrate a PTC liquid heating device **600** constructed in accordance with an embodiment of the present invention. The PTC liquid heating device **600** includes a housing **604** and a pair of PTC heating cores **650.**

[0065] The housing **604,** extending along a longitudinal axis **A,** includes a housing body **606,** a flange **617,** and a pair of rectangular tubes **621.** The housing body **606** has a generally rectangular-shaped cross-section. The housing body **606** extends between a first longitudinal end **610** and a second longitudinal end **614,** wherein the first longitudinal end **610** of the housing body **606** is closed and the second longitudinal end **614** defines an opening **616.** The flange **617** is detachably coupled to the second longitudinal end **614** of the housing body **606** to cover the opening **616** of the housing body **606.** The rectangular tubes **621** couples with the flange **617** via welding. The rectangular tubes **621,** at least partially positioned within the housing body **606,** are spaced apart from one another and extending along the longitudinal axis **A.** The PTC heating core **650** each have a generally rectangular shape and are inserted into respective rectangular tubes **621** to transfer heat to the liquid via the rectangular tube **621.** The housing **604** includes a seal **633** located between the second longitudinal end **614** of the housing body **606** and the flange **617.**

[0066] The housing body **606** of the housing **604** defines a liquid inlet **636** and a liquid outlet **638.** According to an embodiment of the present invention, the liquid inlet **636** and the liquid outlet **638** are located adjacent to the first longitudinal end **610** of the housing body **606.** A flow guiding member **640** is located inside of the housing body **606.** The flow guiding member **640** has a generally rectangular shape and extends from the first longitudinal end **610** of the housing body **606** along the longitudinal axis **A.** Both ends of the flow guiding member **640** lie in a transverse direction and are coupled to the housing body **606.** According to an embodiment of the present invention, the flow guiding member **640** can be integrally formed with the housing body **606** and there is a pair of PTC heating cores **650** located in the housing body **606,** wherein each PTC heating core **650** of the pair of PTC heating cores **650** is separated from the other PTC heating core **650** of the pair of PTC heating cores **650** by the flow guiding member **640.** It should be appreciated that the flow guiding member **640** can have a length less than a distance between the first longitudinal end **610** of the housing body **606** and the flange **617.** Each PTC heating core **650** of the pair of PTC heating cores **650** of the PTC liquid heating device **600** has the same structure as that of the PTC heating unit **150,** as illustrated in Figure 2c.

[0067] It should be appreciated that any gap between the components of the PTC heating unit or the PTC heating core **650,** according to embodiments the present invention, may be filled with a thermally conductive material, such as alumina powder or thermally conductive adhesive to further improve heat transfer efficiency.

[0068] Figures 11a and 11b illustrate a PTC liquid heating device **700** constructed according to an embodiment of the present invention. The PTC liquid heating device **700** includes a housing **704** and a plurality of four PTC heating units **702** inserted into the housing **704.**

[0069] The housing **704,** extending along a longitudinal axis **A,** includes a housing body **706** and a cover **708.** The housing body **706** has a generally rectangular shape. The housing body **706** extends between a first longitudinal end **710** and a second longitudinal end **714.** The first longitudinal end **710** of the housing body **706** defines a plurality of first through holes (not shown). The second longitudinal end **714** defines an opening **716** in communication with the first through holes. The cover **708** is

detachably coupled to the second longitudinal end **714** of the housing body **706** to cover the opening **716** of the housing body **706.** The cover **708** defines a plurality of first apertures **718** in communication with the opening **716.**

[0070] The housing **704** includes a baffle **720** detachably coupled to the first longitudinal end **710** of the housing body **706.** The baffle **720** defines a plurality of first bores **724** in communication with the first through holes of the first longitudinal end **710** of the housing body **706.** According to an embodiment of the present invention, each first bore **724** of the plurality of first bores **724** and each first aperture **718** of the plurality of first apertures **718** can have a shape that matches with the shape of a corresponding PTC heating unit of the plurality of PTC heating units **702.** According to an embodiment of the present invention, the plurality of first apertures **718** includes a plurality of four first apertures **718,** and the plurality of first bores **724** includes a plurality of four first bores **724.** Each PTC heating unit **702** of the plurality of the plurality of PTC heating units **702** is inserted into the housing **704** along the longitudinal axis **A** through a corresponding the first bore **724** in the baffle **720** and a corresponding first aperture **718** in the cover **708.**

[0071] A flange **717** is detachably coupled to the second longitudinal end **714** of the housing body **706** to cover the opening **716** of the housing body **706.** The flange **717** defines a plurality of first through holes **719.** It should be appreciated that each first through hole **719** of the plurality of first through holes **719** has a shape that matches with the shape of a corresponding PTC heating unit **702.** According to an embodiment of the present invention, each PTC heating unit **702** of the plurality of PTC heating units **702** is inserted into the housing **704** along the longitudinal axis **A** through a corresponding first through hole **719** of the plurality of first through holes **719.** It should be appreciated that, according to an embodiment of the present invention, the PTC heating units **702** may be coupled to the flange **717** by welding.

[0072] The housing **704** includes a plurality of first seals **732** and a second seal **734.** Each first seal **732** of the plurality of first seals **732** is located between a corresponding first bore **724** of the plurality of first bores **724** of the baffle **720** and a corresponding PTC heating units **702.** In addition, each first seal **732** of the plurality of the first seals **732** is located between a corresponding first aperture **718** of the cover **708** and flange **717.** The second seal **734** is located between the second longitudinal end **714** of the housing body **706** and the cover **708.**

[0073] As best shown in Figure 11b, the housing body **706** of the housing **704** defines a liquid inlet **736** and a liquid outlet **738.** According to an embodiment of the present invention, the liquid inlet **736** and the liquid outlet **738** are located adjacent to the first longitudinal end **710** of the housing body **706.** A flow guiding member **740** is located inside the housing body **706.** The flow guiding member **740** has a generally rectangular shape and extends from the first longitudinal end **710** of the housing body **706** along the longitudinal axis **A.** Both ends of the flow guiding member **740** lie along a transverse direction and are coupled to the housing body **706.** According to an embodiment of the present embodiment, the flow guiding member **740** can be integrally formed with the housing body **706** and there is a plurality of four PTC heating units **702** located in the housing body **706,** wherein two PTC heating units **702** of the plurality of four PTC heating units **702** is separated from the other two PTC heating units **702** of the plurality of four PTC heating units **702** by the flow guiding member **740.** According to an embodiment of the present invention, each PTC heating unit **702** of the PTC heating units **702** has a length that is longer than the housing body **706** whereby each end of the PTC unit **702** respectively extends beyond the first longitudinal end **710** and the second longitudinal end **714 of** the housing body **706.** It should be appreciated that the flow guiding member **740** has a length that is less than a distance between the first longitudinal end **710** of the housing body **706** and the cover **708.**

[0074] Figure 12 illustrates a cross-sectional view of the PTC heating unit **702** constructed in accordance with an embodiment of the present invention. The PTC heating unit **702** includes a PTC ceramic sheet **763,** a pair of electrodes **765,** a first insulating layer **767,** a first sleeve **769,** a second insulating layer **768** and a second sleeve **771.** Each electrode **765** of the pair of electrodes **765** can be made from a material with high electrical conductivity and thermal conductivity, such as but not limited to aluminum or copper. Each electrode **765** of the pair of electrodes **765** has a semi-cylindrical shape, such that the shape of the electrode **765** matches with that of the first sleeve **769,** thereby allowing the electrode **765** to provide effective transfer of heat generated by the PTC ceramic sheet **763.** The first insulating layer **767** extends about the pair of electrodes **765** and the PTC ceramic sheet **763.** The PTC ceramic sheet **763,** the two electrodes **765** and the first insulating layer **767** are located inside of the first sleeve **769.** The second insulating layer **768** extends about the first sleeve **769.** The second sleeve **771** extends about the second insulating layer **768** and the first sleeve **769.** According to an embodiment of the present invention, the first sleeve **769** can be made from aluminum, and the second sleeve **771** can be made from a corrosion resistant material, such as but not limited to stainless steel. In the event that the second sleeve **771** is corroded or cracked, the first sleeve **769** can still protect the internal components (e.g., the insulating layer **767**), thereby reducing the risk that liquid to be heated becomes charged (by electricity from the PTC ceramic sheet **763** and the pair of electrodes **765**) and improving the safety performance. The first sleeve **769** and the second sleeve **771** can have a thickness of between 0.3mm-1.2mm and in particular, a thickness of 0.5mm.

[0075] Figure 13 illustrates a cross-sectional view of a PTC heating unit **802** constructed in accordance with an embodiment of the present invention. The PTC heating unit **802** includes a PTC ceramic sheet **863,** a pair of

electrodes **865,** a first insulating layer **867,** a protective layer **869,** a second insulating layer **868** and a sleeve **871.** Each electrode **865** of the pair of electrodes **865** can be made from a material with high electrical conductivity and thermal conductivity, such as but not limited to aluminum or copper. According to an embodiment of the present invention, each electrode **865** of the pair of electrodes **865** can have a semi-cylindrical shape, such that the shape of the electrode **865** matches with that of the protective layer **869,** thereby allowing the electrode **865** to provide effective transfer of heat generated by the PTC ceramic sheet **863.** The first insulating layer **867** extends about the pair of electrodes **865** and the PTC ceramic sheet **863.** The PTC ceramic sheet **863,** the two electrodes **865** and the first insulating layer **867** are located inside of the protective layer **869.** The second insulating layer **868** extends about the protective layer **869.** The sleeve **871** extends about the second insulating layer **868** and the protective layer **869.** According to an embodiment of the present invention, the protective layer **869** comprises a metal foil located between the first insulating layer **867** and the second insulating layer **868.** The metal foil can have a thickness of between 0.02mm and 0.06mm, and, in particular, the metal foil **869** can have a thickness of 0.04mm. In the event that the second insulating layer **868** is punctured by particles during production, the protective layer **869** is able to protect the first insulating layer **867** from additional puncturing from the particles. According to an embodiment of the present invention, the sleeve **871** can be made from a corrosion resistant material, such as but not limited to stainless steel.

[0076] Figure 14 illustrates a cross-sectional view of a PTC heating unit **902** constructed in accordance with an embodiment of the present invention. The PTC heating unit **902** includes a PTC ceramic sheet **963,** a pair of electrodes **965,** a first insulating layer **967,** a protective layer **969,** a second insulating layer **968,** a first sleeve **971** and a second sleeve **973.** Each electrode **965** of the pair of electrodes **965** can be made from a material with high electrical conductivity and thermal conductivity, such as but not limited to aluminum or copper. According to an embodiment of the present invention, each electrode **965** of the pair of electrodes **965** can have a semi-cylindrical shape, such that the shape of the electrodes **965** matches with that of the protective layer **969,** thereby allowing the electrodes **965** to provide effective transfer of heat generated by the PTC ceramic sheet **963.** The first insulating layer **967** extends about the pair of electrodes **965** and the PTC ceramic sheet **963.** The PTC ceramic sheet **963,** the pair of electrodes **965** and the first insulating layer **967** are located inside of the protective layer **969.** The second insulating layer **968** extends about the protective layer **969.** According to an embodiment of the present invention, the protective layer **969** comprises a metal foil located between the first insulating layer **967** and the second insulating layer **968.** The metal foil **969** can have a thickness of between 0.02mm and 0.06mm, and, in particular, the metal foil **969** can have a thickness of 0.04mm. In the event that the second insulating layer **868** is punctured by particles during production, the protective layer **969** is able to protect the first insulating layer **967** from additional puncturing from the particles. The first sleeve **971** extends about the second insulating layer **968** and the protective layer **969.** The second sleeve **973** is located adjacent to the first sleeve **971** and extends about the first sleeve **971.** According to an embodiment of the present invention, the first sleeve **971** can be made from aluminum and the second sleeve **973** can be made from a corrosion resistant material, such as but not limited to stainless steel. In the event that the second sleeve **973** is corroded or cracked, the first sleeve **971** can still protect the internal components (e.g., the insulating layer **967**), thereby reducing the risk that liquid to be heated becomes charged (by electricity from the PTC ceramic sheet **963** and the pair of electrodes **965**) and improving the safety performance. The first sleeve **971** and the second sleeve **973** can have a thickness of between 0.3mm-1.2mm and in particular, a thickness of 0.5mm.

[0077] It should be understood that the embodiments shown in Figures la-13 illustrate the shapes, sizes and arrangements of various alternative components of PTC liquid heating devices according to embodiments of the present invention which are merely illustrative and not restrictive. Other shapes, sizes, and arrangements can be employed without departing from the spirit and scope of the present invention.

[0078] The technical content and technical features of the present invention have been disclosed above. However, it should be understood that those skilled in the art can make various variations and improvements to the above disclosed concepts under the inventive idea of the present invention, and all these variations and improvements belong to the scope of protection of the present invention. The description for the above embodiments is illustrative and not restrictive, and the scope of protection of the present invention is determined by the claims.

Claims

1. A PTC liquid heating device, comprising:

a housing extending along a longitudinal axis and defining a liquid inlet and a liquid outlet; and
a PTC heating unit inserted into said housing and extending along said longitudinal axis;
wherein said PTC heating unit includes a sleeve, a heat conductor and at least one PTC heating core;
wherein said heat conductor has a pair of metal profiles defining at least one chamber, said at least one chamber extending along said longitudinal axis to receive said at least one PTC heating core; and

wherein said heat conductor is located in said sleeve and has a shape matching said sleeve.

2. The PTC liquid heating device according to claim 1, wherein said at least one chamber defines a first chamber and a second chamber;
wherein said first chamber is located on a metal profile of said pair of metal profiles, said first chamber extending along said longitudinal axis; and
wherein said second chamber is located between said pair of metal profiles, said second chamber extending along said longitudinal axis.

3. The PTC liquid heating device according to claim 2, wherein said at least one PTC heating core comprises a pair of PTC heating cores located in said first chamber; or
said PTC liquid heating device further includes a thermally conductive material located in said second chamber to improve heat transfer.

4. The PTC liquid heating device according to claim 1 having one of the following features i) to iv):

i) said at least one PTC heating core is located between said pair of metal profiles;
ii) said PTC liquid heating device further including an insulating layer located between said heat conductor and said sleeve, said insulating layer extending about said heat conductor;
iii) said sleeve has a generally cylindrical shape, and each metal profile of said pair of metal profiles has a generally semi-cylindrical shape;
iv) said sleeve is made from a corrosion resistant and thermally conductive material.

5. The PTC liquid heating device according to claim 1, wherein said housing comprises:

a housing body extending between a first longitudinal end of said housing body and a second longitudinal end of said housing body, said first longitudinal end defining a first through hole, said second longitudinal end defining an opening;
a cover detachably coupled to said second longitudinal end of said housing body to cover said opening of said housing body, said cover defining a first aperture;
a first baffle detachably coupled to said first longitudinal end of said housing body, said first baffle defining a first bore in communication with said first through hole; and
a second baffle detachably coupled to said cover, said second baffle defining a first orifice in communication with said first aperture of said cover;
wherein said PTC heating unit is inserted into said housing along said longitudinal axis and through said first through hole, said first aperture, said first bore and said first orifice; and
wherein a stopper is provided at an edge of said first aperture and at an edge of said first orifice to limit movement of said PTC heating unit along said longitudinal axis.

6. The PTC liquid heating device according to claim 5, further including a pair of flow guiding members located at opposite sides of said PTC heating unit, said pair of flow guiding members being provided on an inner surface of said housing and extending from said first longitudinal end of said housing body along said longitudinal axis;
wherein said liquid inlet and said liquid outlet are provided on said housing body and adjacent to said first longitudinal end of said housing body;
wherein each flow guiding member of said pair of flow guiding members has a length less than a distance between said first longitudinal end of said housing body and said cover; and
wherein said pair of flow guiding members fit against said PTC heating unit.

7. A PTC liquid heating device comprising:

a housing extending along a longitudinal axis and defining a liquid inlet and a liquid outlet; and
a PTC heating unit inserted into said housing and extending along said longitudinal axis;
wherein said PTC heating unit includes a PTC ceramic sheet, a pair of electrodes, a first insulating layer, and a first sleeve;
wherein said PTC ceramic sheet is located between said pair of electrodes;
wherein said first insulating layer extends about said pair of electrodes and said PTC ceramic sheet, and said first sleeve extends about said first insulating layer; and
wherein each electrode of said pair of electrodes has a shape matching with a shape of said first sleeve.

8. The PTC liquid heating device according to claim 7, further including a second sleeve, located adjacent to said first sleeve and extending about said first sleeve.

9. The PTC liquid heating device according to claim 8 having one of the following features a) to d):

a) said first sleeve and said second sleeve are made from a metallic material, said first sleeve being made from aluminum, said second sleeve being made from stainless steel;
b) each of said first sleeve and said second sleeve has a thickness of between 0.3mm-

1.2mm;
c) each of said first sleeve and said second sleeve has a thickness of 0.5mm;
d) said PTC liquid heating device further including a second insulating layer located between said first sleeve and said second sleeve, said second insulating layer extending about said first sleeve.

10. The PTC liquid heating device according to claim 7, further including a protective layer comprising a metal foil located between said first insulating layer and said first sleeve, said protective layer extending about said first insulating layer; or
in said PTC liquid heating device, said first sleeve has a generally cylindrical shape, and each electrode of said pair of electrodes has a generally semi-cylindrical shape.

11. The PTC liquid heating device according to claim 10, wherein said protective layer has a thickness of between 0.02mm and 0.06mm; or said protective layer has a thickness of 0.04mm.

12. The PTC liquid heating device according to claim 10, further including a second insulating layer located between said protective layer and said first sleeve, said second insulating layer extending about said protective layer.

13. The PTC liquid heating device according to claim 7, wherein said housing comprises:

a housing body extending between a first longitudinal end of said housing body and a second longitudinal end of said housing body, said first longitudinal end defining a first through hole, said second longitudinal end defining an opening;
a cover detachably coupled to said second longitudinal end of said housing body to cover said opening of said housing body, said cover defining a first aperture;
a first baffle detachably coupled to said first longitudinal end of said housing body, said first baffle defining a first bore in communication with said first through hole; and
a second baffle detachably coupled to said cover, said second baffle defining a first orifice in communication with said first aperture of said cover;
wherein said PTC heating unit is inserted into said housing along said longitudinal axis and through said first through hole, said first aperture, said first bore and said first orifice;
preferably said PTC liquid heating device further includes a stopper provided at an edge of said first aperture and at an edge of said first orifice to limit movement of said PTC heating unit along said longitudinal axis.

14. The PTC liquid heating device according to claim 7, wherein said housing comprises:

a housing body having a first longitudinal end of said housing body and a second longitudinal end of said housing body, said first longitudinal end being closed, said second longitudinal end defining an opening;
a cover detachably coupled to said second longitudinal end of said hosing body to cover said opening of said housing body, said cover defining a first aperture;
a flange detachably coupled to said cover, said flange defining a first bore in communication with said first aperture;
wherein said PTC heating unit is inserted into said housing along said longitudinal axis and through said first bore and said first aperture, said PTC heating unit being coupled to said flange via welding.

15. The PTC liquid heating device according to claim 7, wherein said housing comprises:

a housing body having a first longitudinal end of said housing body and a second longitudinal end of said housing body, said first longitudinal end being closed, said second longitudinal end defining an opening;
a flange detachably connected to said second longitudinal end of said housing body to cover said opening of said housing, said flange defining a first bore;
wherein said PTC heating unit is inserted into said housing along said longitudinal axis through said first bore, and said PTC heating unit is coupled to said flange via welding.

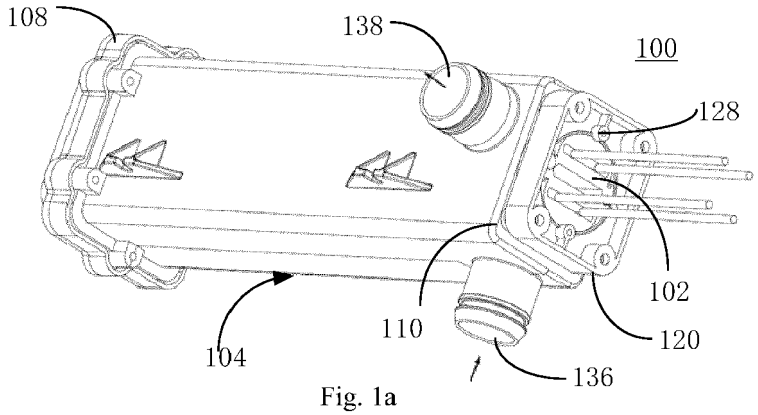

Fig. 1a

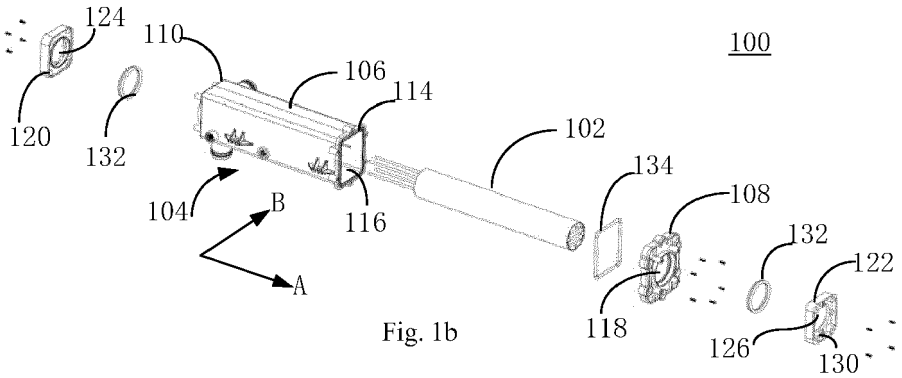

Fig. 1b

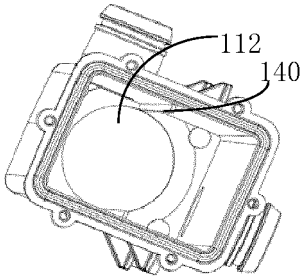

Fig. 1c

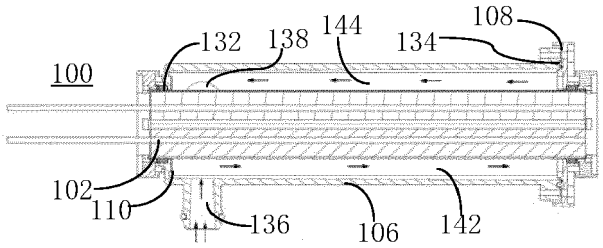

Fig. 1d

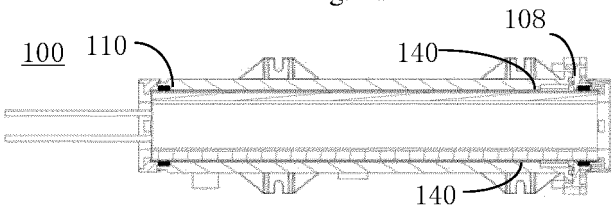

Fig. 1e

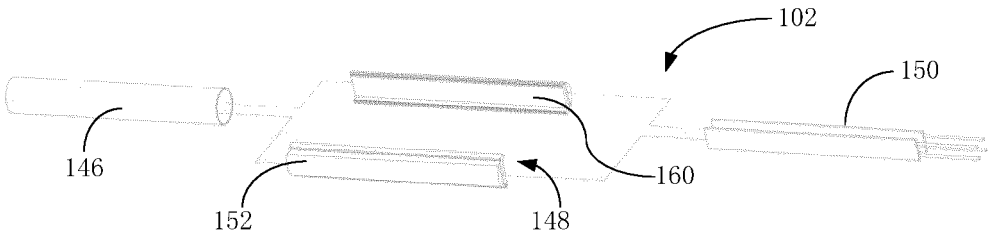

Fig. 2a

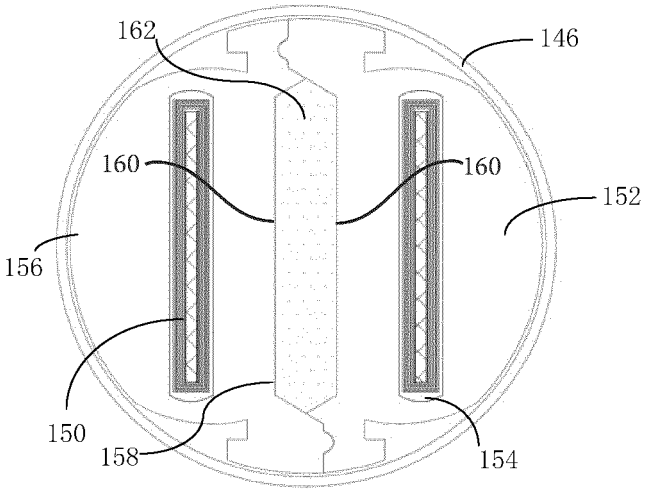

Fig. 2b

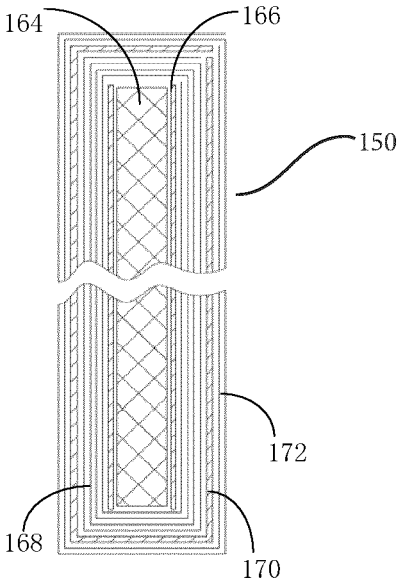

Fig. 2c

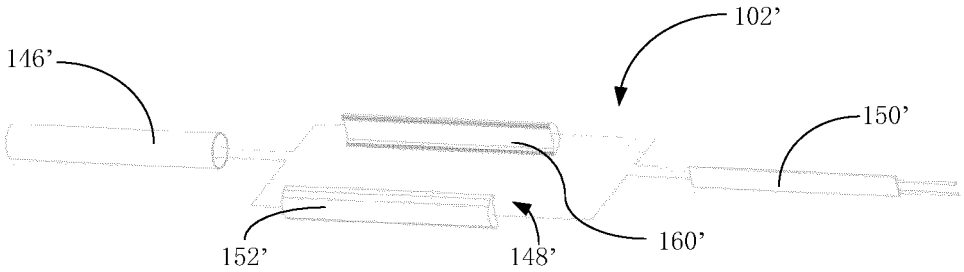

Fig. 3a

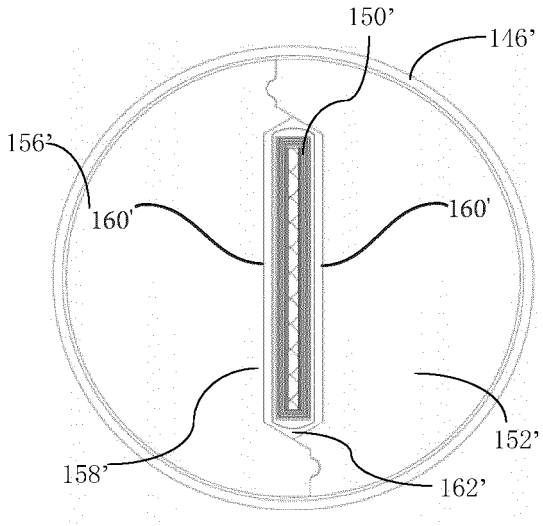

Fig. 3b

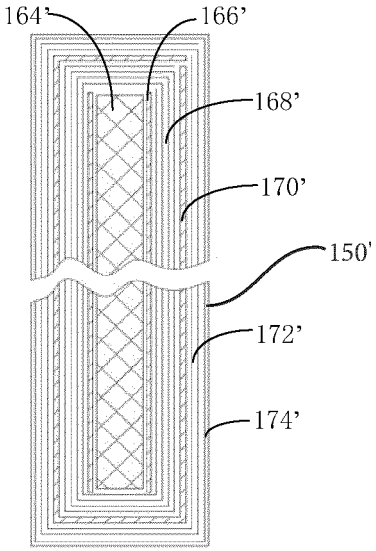

Fig. 3c

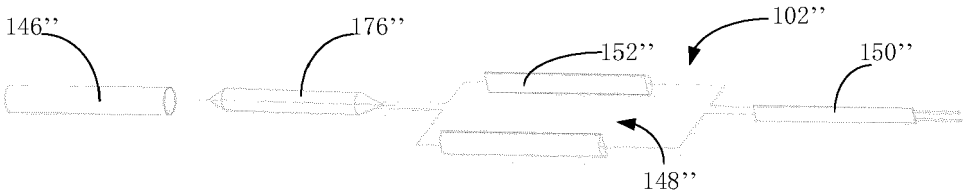

Fig. 4a

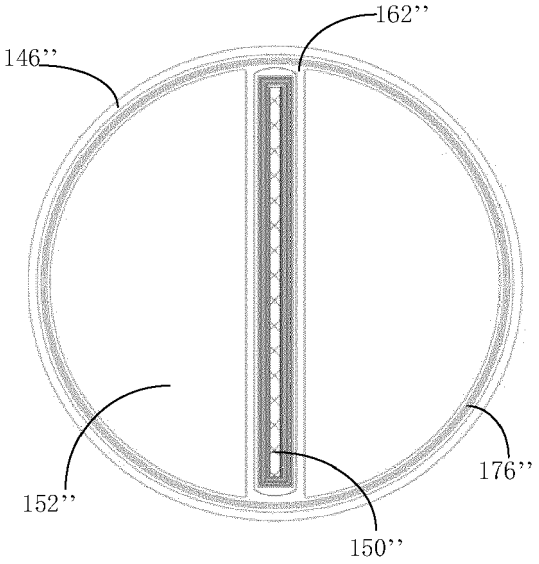

Fig. 4b

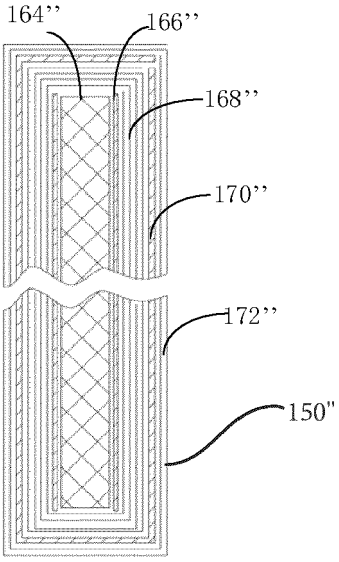

Fig. 4c

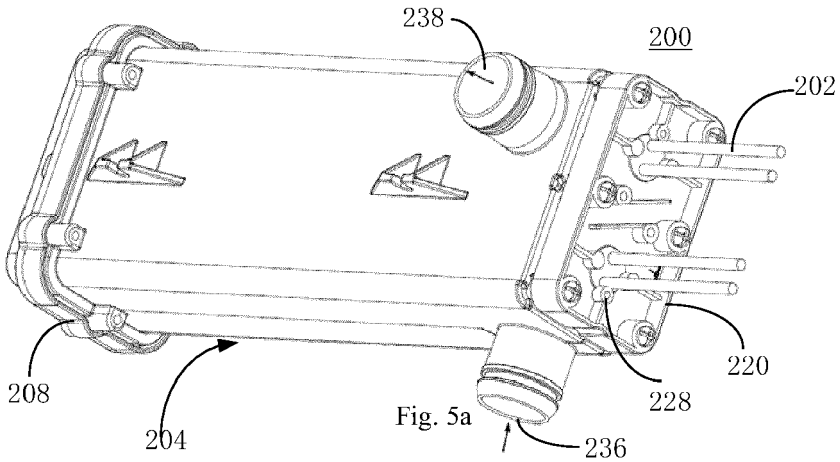

Fig. 5a

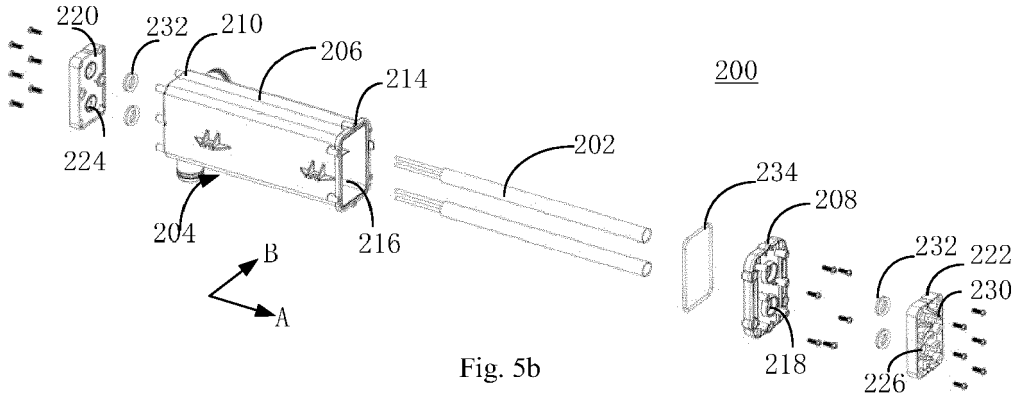

Fig. 5b

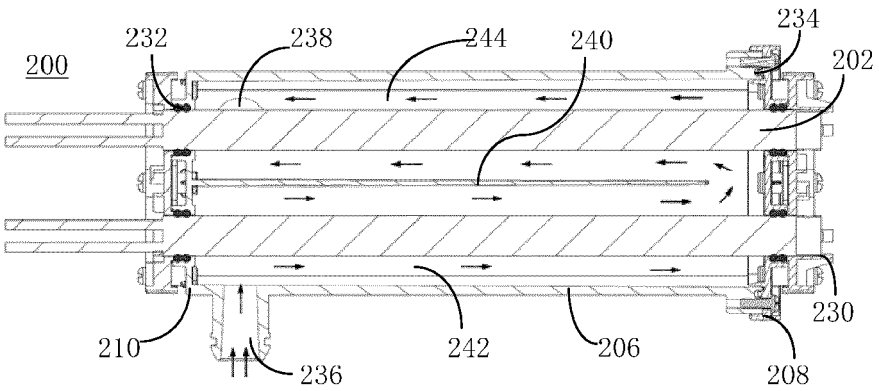

Fig. 5c

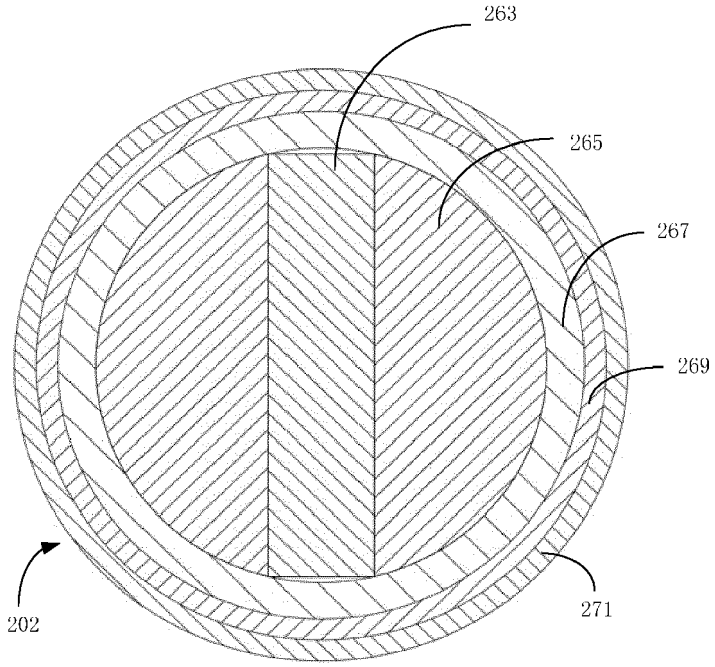

Fig. 6

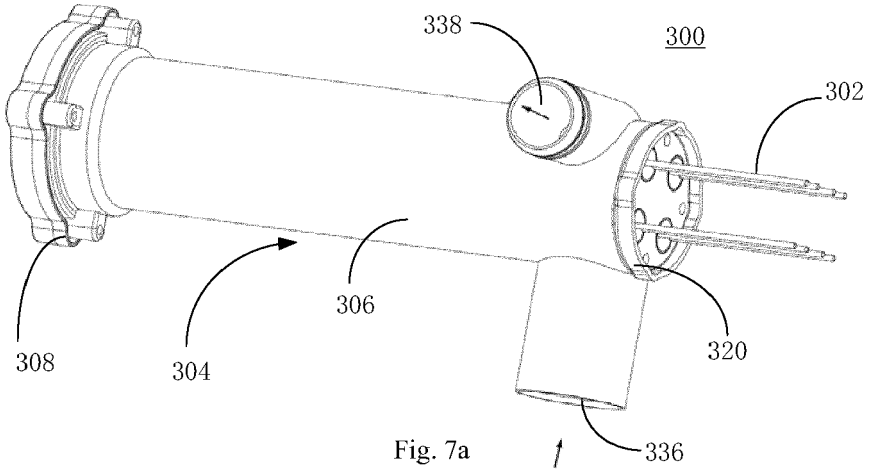

Fig. 7a

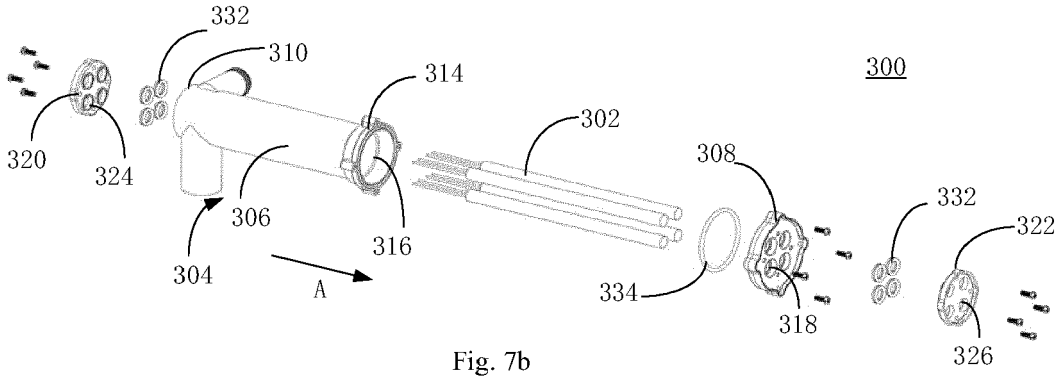

Fig. 7b

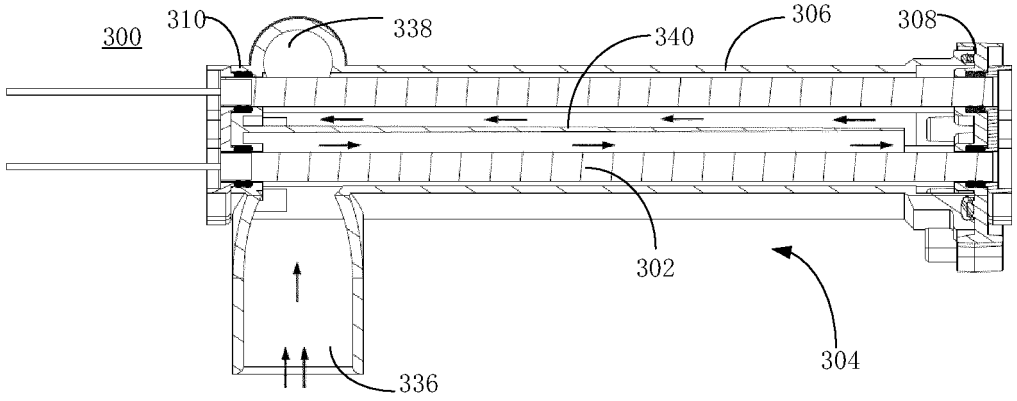

Fig. 7c

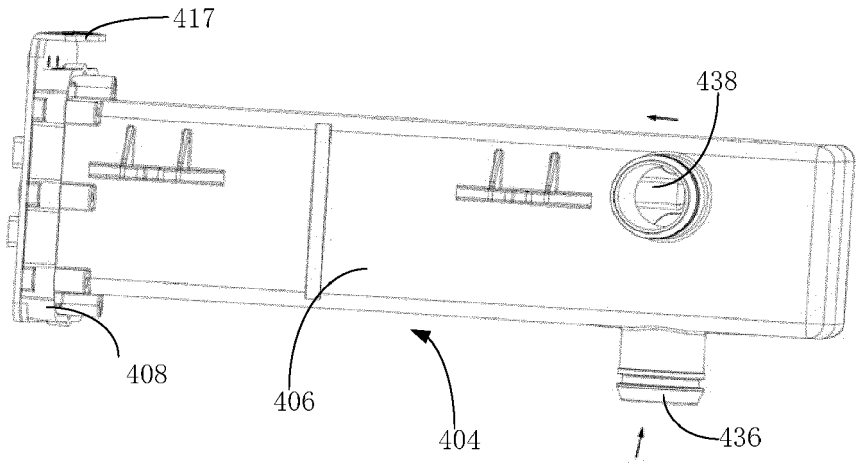

Fig. 8a

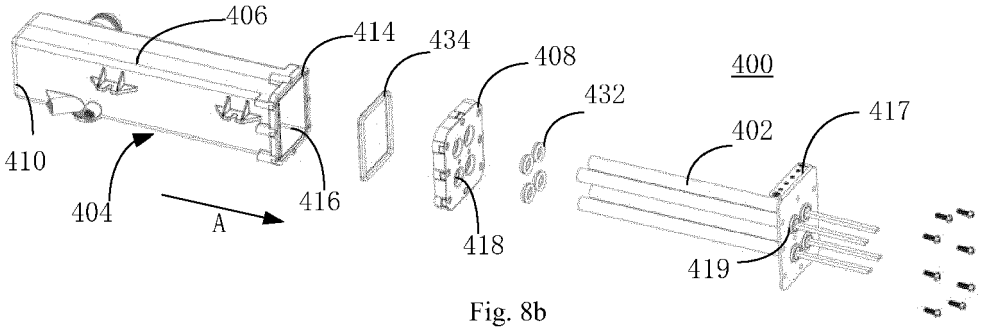

Fig. 8b

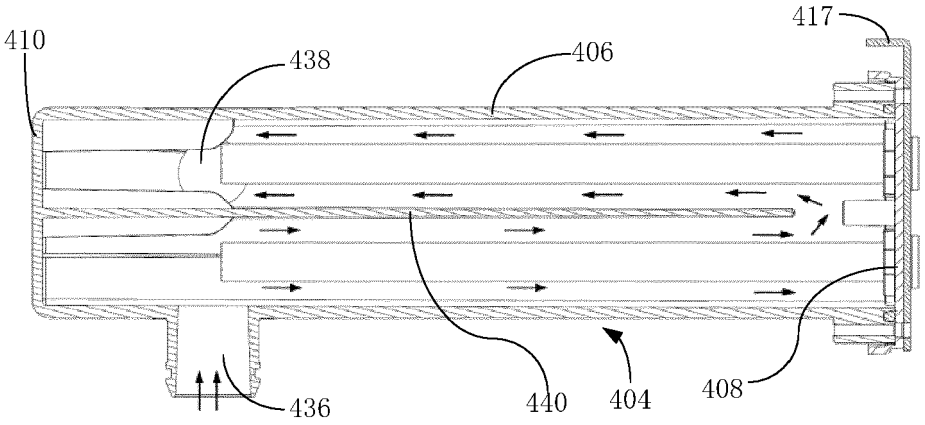

Fig. 8c

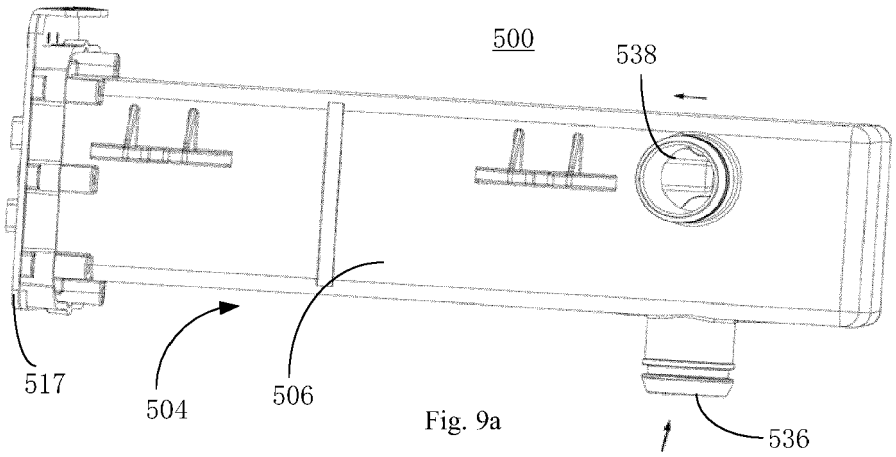

Fig. 9a

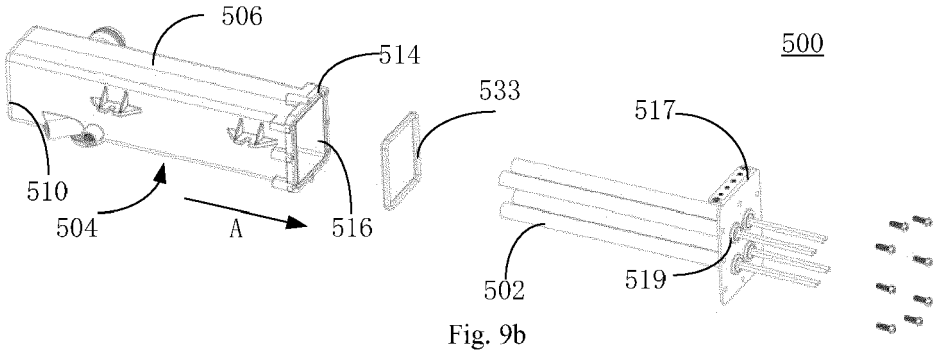

Fig. 9b

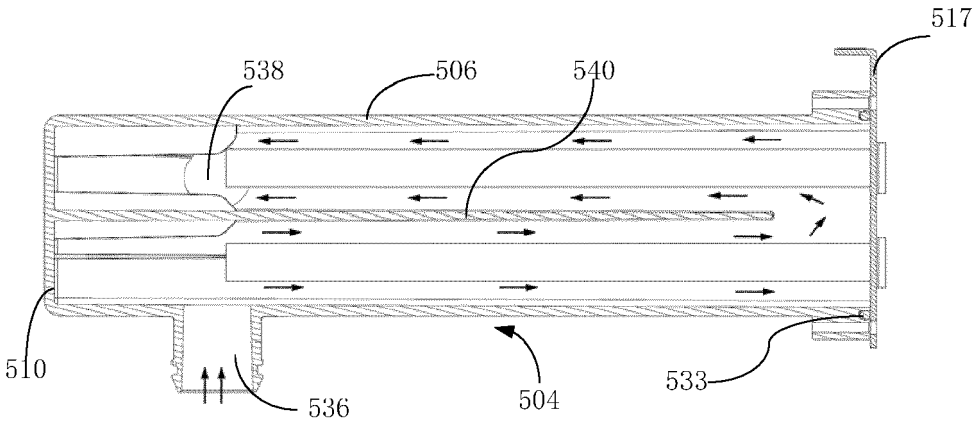

Fig. 9c

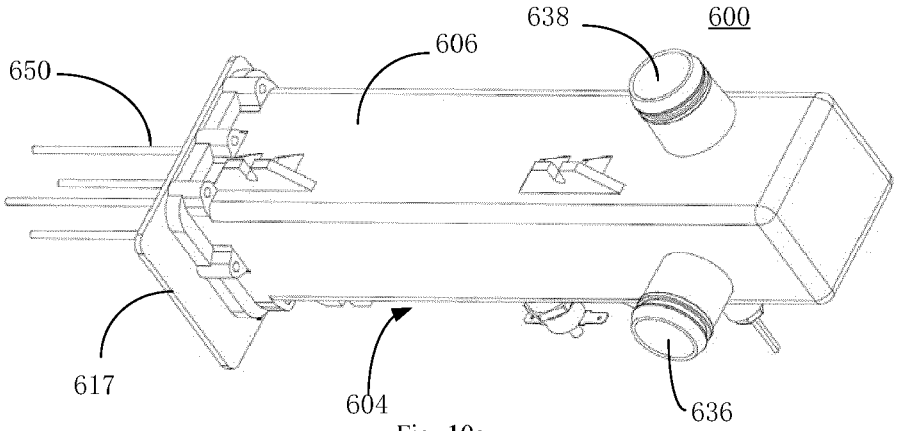

Fig. 10a

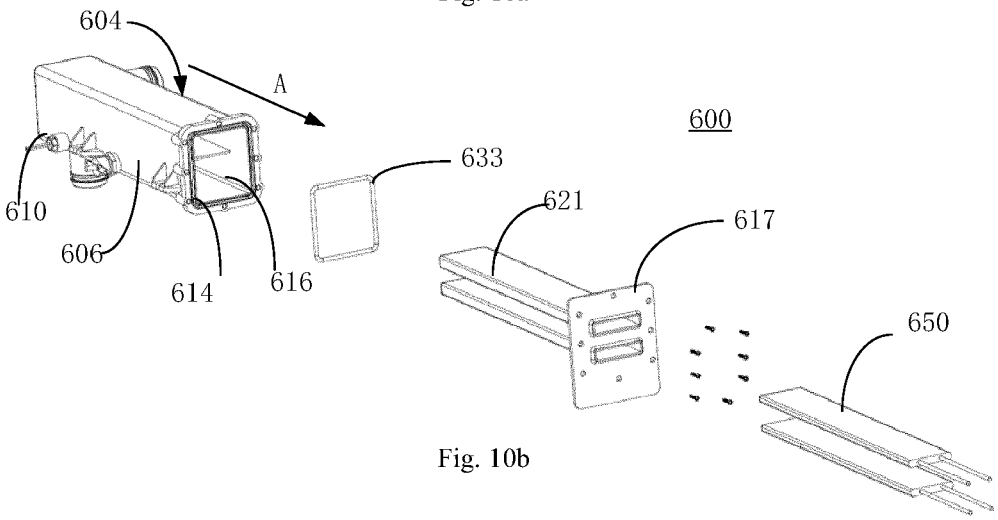

Fig. 10b

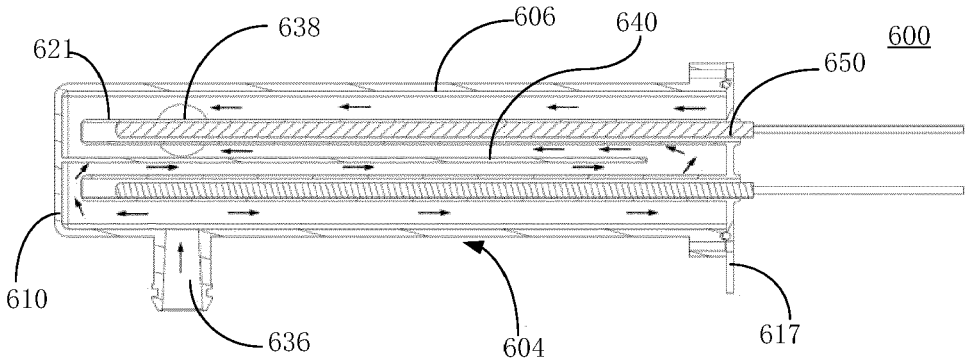

Fig. 10c

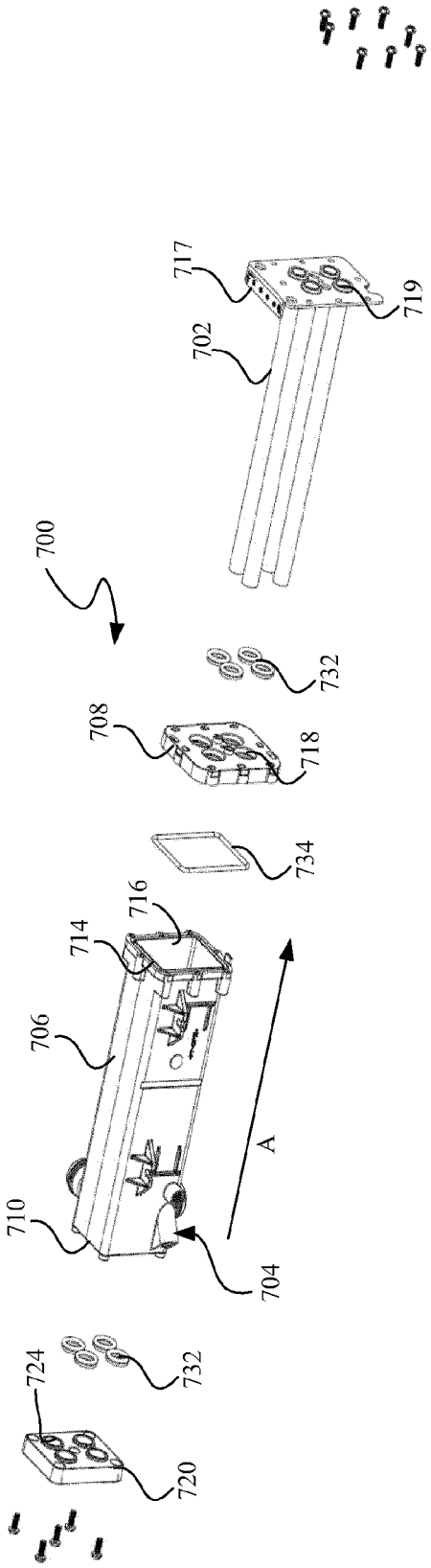

Fig. 11a

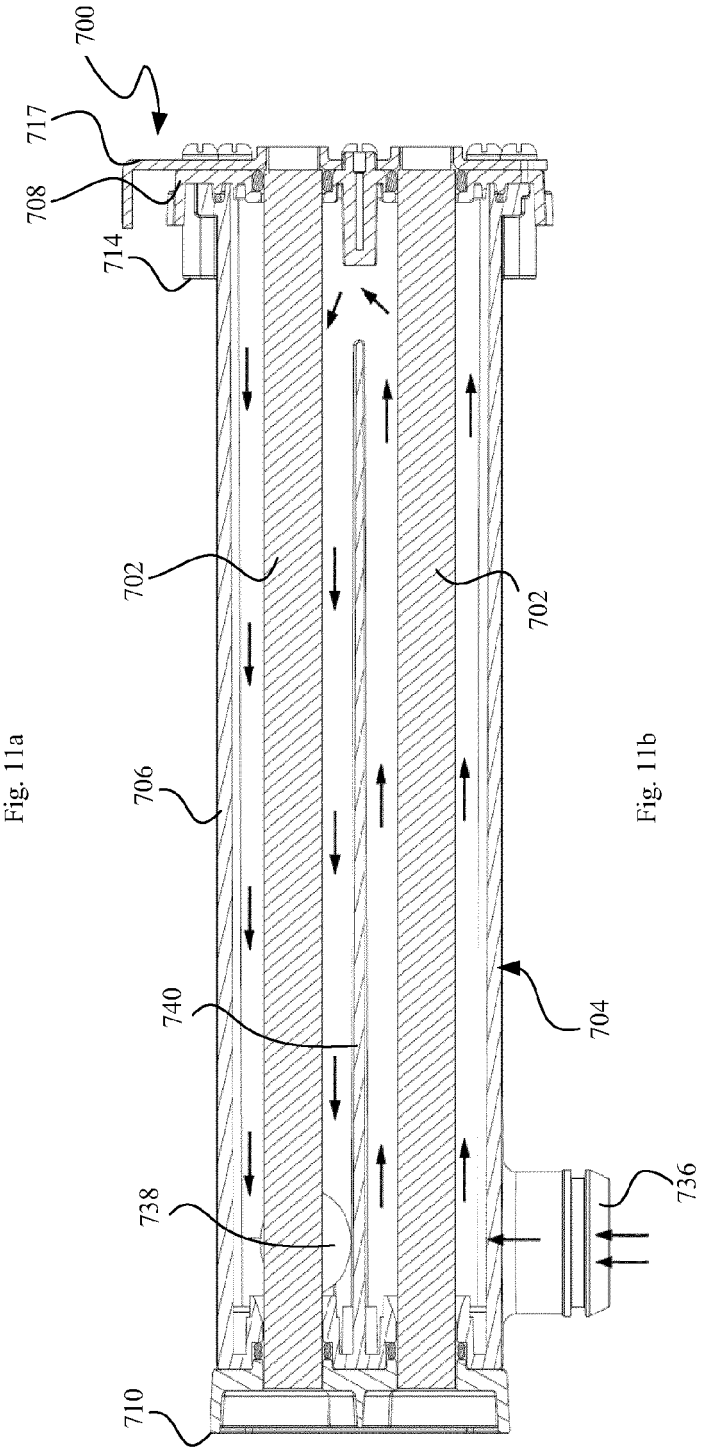

Fig. 11b

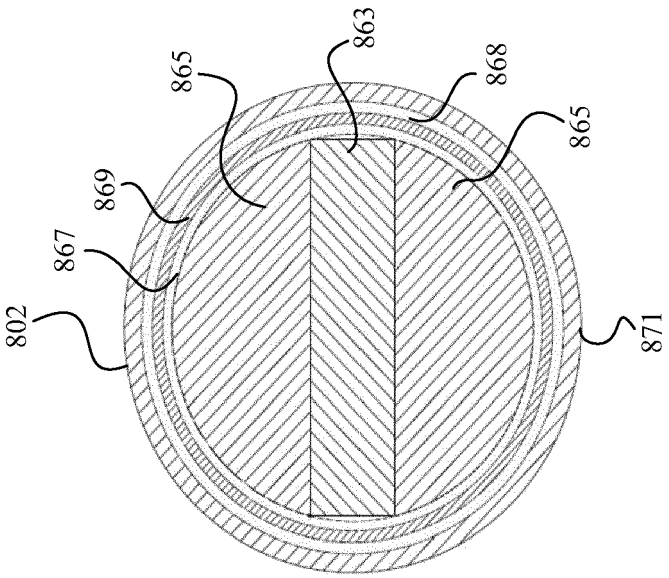

Fig. 13

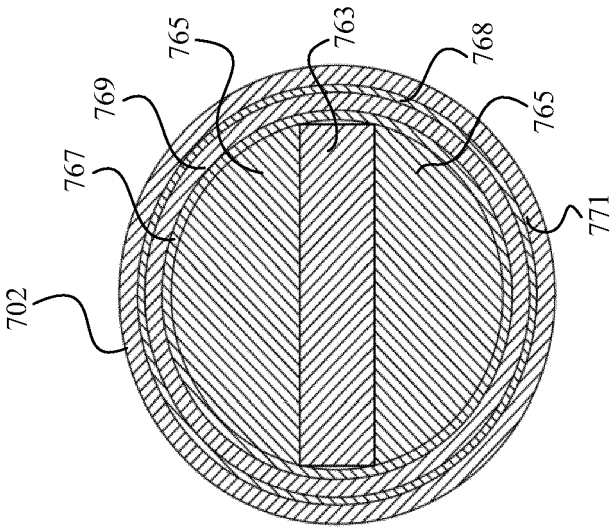

Fig. 12

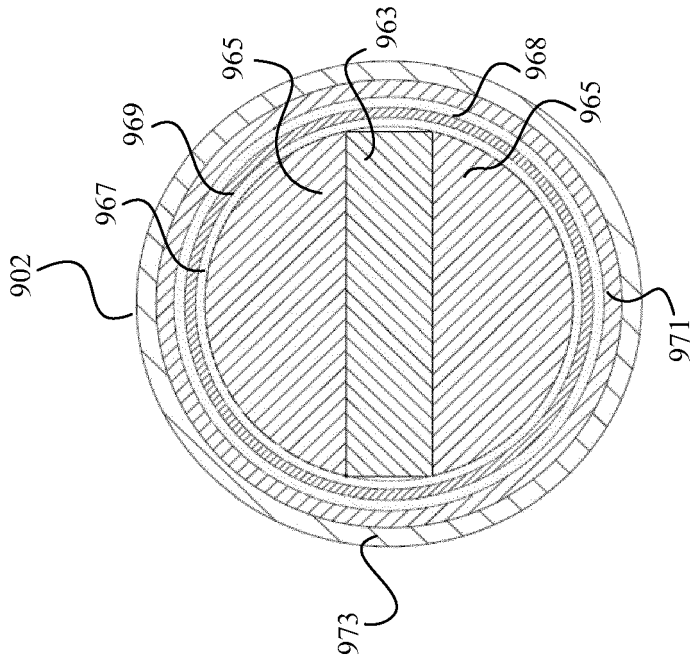

Fig. 14

REFERENCES CITED IN THE DESCRIPTION

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