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(54) Title: REACTION VESSEL FOR HEATING AND MIXING A FLUID

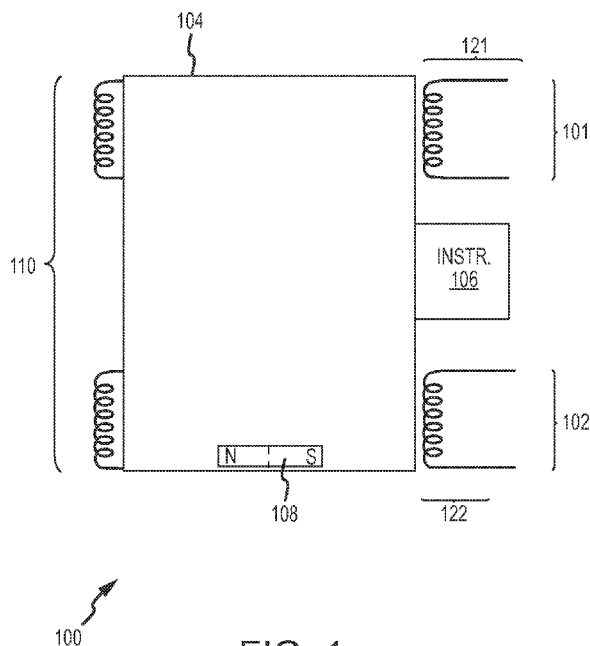


FIG. 1

(57) Abstract: A reaction vessel (100) for heating and mixing a fluid is provided. The reaction vessel (100) includes a chamber (104) adapted for receiving the fluid, a mixing member (108) located in the chamber (104), and a dual-action split electromagnetic coil (110). The dual-action split electromagnetic coil (110) includes a first coil portion (121) positioned to generate a first magnetic flux substantially in a first chamber portion (101) and at least a second coil portion (122) positioned to generate a second magnetic flux substantially in a second chamber portion (102) and substantially spaced apart from the first coil portion (121). The first coil portion (121) and the second coil portion (122) can be energized substantially simultaneously or substantially separately in order to move the mixing member (108) and/or to heat a fluid in the chamber (104).



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5 **REACTION VESSEL FOR HEATING AND MIXING A FLUID**

Background of the Invention

1. Field of the Invention

The invention is related to the field of reaction vessels, and in particular, to a reaction vessel for heating and mixing a fluid.

10 *2. Statement of the Problem*

In laboratory or field testing situations, a sample fluid can be tested and analyzed for certain properties. Prior to such a test, it is generally desirable that the sample fluid be thoroughly mixed or stirred. This may be necessary because if the sample fluid has not been collected recently, then the contents may have separated, settled, or otherwise
15 become non-uniform. An optimum test will rely on the uniformity of the sample fluid. An optimum test will rely on completeness of a chemical reaction. In addition, where the component or characteristic to be tested for is not plentiful, stirring of the sample fluid may bring a greater volume of the sample fluid into contact with a sensor or measurement device.

20 In addition, in some testing situations it may be further required to heat the fluid, either separately or concurrently with the mixing. In addition, a heating phase can be performed before, during or after a mixing phase. Heating may be needed to initiate or promote a desired chemical reaction or even to promote mixing of components of the fluid.

25 **Summary of the Invention**

A reaction vessel for heating and mixing a fluid is provided. The reaction vessel comprises a chamber adapted for receiving the fluid, a mixing member located in the chamber, and a dual-action split electromagnetic coil. The dual-action split
electromagnetic coil comprises a first coil portion positioned to generate a first magnetic
30 flux substantially in a first chamber portion and at least a second coil portion positioned to generate a second magnetic flux substantially in a second chamber portion and substantially spaced-apart from the first coil portion. The first coil portion and the second coil portion can be energized substantially simultaneously or substantially separately in order to move the mixing member and/or to heat a fluid in the chamber.

5 A reaction vessel for heating and mixing a fluid is provided. The reaction vessel comprises a chamber adapted for receiving the fluid, a mixing member located in the chamber, and a dual-action split electromagnetic coil. The dual-action split electromagnetic coil comprises a first coil portion positioned to generate a first magnetic flux substantially in a first chamber portion and at least a second coil portion positioned
10 to generate a second magnetic flux substantially in a second chamber portion and substantially spaced-apart from the first coil portion. The first coil portion and the second coil portion can be energized substantially simultaneously or substantially separately in order to move the mixing member and/or to heat a fluid in the chamber. The reaction vessel further comprises one or more instruments adapted to perform one
15 or more predetermined tests or measurements on the fluid. The first coil portion is located on a first side of the one or more instruments and the second coil portion is located on a second side of the one or more instruments and substantially opposite the first side.

 A method of forming a reaction vessel for heating and mixing a fluid is provided.
20 The method comprises providing a chamber adapted for receiving the fluid, providing a mixing member located in the chamber, and providing a dual-action split electromagnetic coil. The dual-action split electromagnetic coil comprises a first coil portion positioned to generate a first magnetic flux substantially in a first chamber portion and at least a second coil portion positioned to generate a second magnetic flux
25 substantially in a second chamber portion and substantially spaced-apart from the first coil portion. The first coil portion and the second coil portion can be energized substantially simultaneously or substantially separately in order to move the mixing member and/or to heat a fluid in the chamber.

ASPECTS

30 One aspect of the invention includes a reaction vessel for heating and mixing a fluid, comprising:

- a chamber adapted for receiving the fluid;
- a mixing member located in the chamber; and
- a dual-action split electromagnetic coil, comprising:

35 a first coil portion positioned to generate a first magnetic flux substantially in a first chamber portion; and

5 at least a second coil portion positioned to generate a second magnetic flux substantially in a second chamber portion and substantially spaced-apart from the first coil portion, wherein the first coil portion and the second coil portion can be energized substantially simultaneously or substantially separately in order to move the mixing member and/or to heat a fluid in the chamber.

10 Preferably, the mixing member being substantially magnetic.

 Preferably, the mixing member being substantially magnetically responsive.

 Preferably, the second coil portion being independently energized from the first coil portion.

 Preferably, the second coil portion and the first coil portion being commonly
15 energized.

 Preferably, one or more instruments adapted to perform one or more predetermined tests or measurements on the fluid.

 Preferably, one or more instruments adapted to perform one or more predetermined tests or measurements on the fluid, wherein the first coil portion is
20 located on a first side of the one or more instruments and the second coil portion is located on a second side of the one or more instruments and substantially opposite the first side.

 Preferably, the first and second coil portions and being energized by a direct current (DC) electrical signal in order to heat the chamber and the fluid.

25 Preferably, the first coil portion and the second coil portion being energized by an alternating current (AC) electrical signal in order to move the mixing member within the chamber.

 Preferably, the first coil portion and the second coil portion being substantially simultaneously energized by an alternating current (AC) electrical signal in order to
30 move the mixing member within the chamber.

 Another aspect of the invention comprises a reaction vessel for heating and mixing a fluid, comprising:

 a chamber adapted for receiving the fluid;

 a mixing member located in the chamber;

35 a dual-action split electromagnetic coil, comprising:

5 a first coil portion positioned to generate a first magnetic flux substantially in a first chamber portion; and

at least a second coil portion positioned to generate a second magnetic flux substantially in a second chamber portion and substantially spaced-apart from the first coil portion, wherein the first coil portion and the second coil portion can be
10 energized substantially simultaneously or substantially separately in order to move the mixing member and/or to heat a fluid in the chamber; and

one or more instruments adapted to perform one or more predetermined tests or measurements on the fluid, wherein the first coil portion is located on a first side of the one or more instruments and the second coil portion is located on a second side of the
15 one or more instruments and substantially opposite the first side.

Preferably, the mixing member being substantially magnetic.

Preferably, the mixing member being substantially magnetically responsive.

Preferably, the second coil portion being independently energized from the first coil portion.

20 Preferably, the second coil portion and the first coil portion being commonly energized.

Preferably, the first coil portion and the second coil portion being energized by a direct current (DC) electrical signal in order to heat the chamber and the fluid.

Preferably, the first coil portion and the second coil portion being energized by
25 an alternating current (AC) electrical signal in order to move the mixing member within the chamber.

Preferably, the first coil portion and the second coil portion being substantially simultaneously energized by an alternating current (AC) electrical signal in order to move the mixing member within the chamber.

30 Another aspect of the invention comprises a method of forming a reaction vessel for heating and mixing a fluid, comprising:

providing a chamber adapted for receiving the fluid;

providing a mixing member located in the chamber; and

providing a dual-action split electromagnetic coil, comprising:

35 a first coil portion positioned to generate a first magnetic flux substantially in a first chamber portion; and

5 at least a second coil portion positioned to generate a second magnetic flux substantially in a second chamber portion and substantially spaced-apart from the first coil portion, wherein the first coil portion and the second coil portion can be energized substantially simultaneously or substantially separately in order to move the mixing member and/or to heat a fluid in the chamber.

10 Preferably, the method further comprises the mixing member being substantially magnetic.

Preferably, the method further comprises the mixing member being substantially magnetically responsive.

15 Preferably, the method further comprises the second coil portion being independently energized from the first coil portion.

Preferably, the method further comprises the second coil portion and the first coil portion being commonly energized.

Preferably, the method further comprising providing one or more instruments adapted to perform one or more predetermined tests or measurements on the fluid.

20 Preferably, the method further comprising providing one or more instruments adapted to perform one or more predetermined tests or measurements on the fluid, wherein the first coil portion is located on a first side of the one or more instruments and the second coil portion is located on a second side of the one or more instruments and substantially opposite the first side.

25 Preferably, the method further comprises the first and second coil portions being energized by a direct current (DC) electrical signal in order to heat the chamber and the fluid.

30 Preferably, the method further comprises the first coil portion and the second coil portion being energized by an alternating current (AC) electrical signal in order to move the mixing member within the chamber.

Preferably, the method further comprises the first coil portion and the second coil portion being substantially simultaneously energized by an alternating current electrical signal in order to move the mixing member within the chamber.

Description of the Drawings

35 The same reference number represents the same element on all drawings. It should be understood that the drawings are not necessarily to scale.

5 FIG. 1 shows a reaction vessel for heating and mixing a fluid according to an embodiment of the invention.

 FIG. 2 shows the reaction vessel during a first cycle of an AC energization according to an embodiment of the invention.

 FIG. 3 shows the reaction vessel during a second cycle of an AC energization
10 according to an embodiment of the invention.

 FIG. 4 shows the mixing member according to an embodiment of the invention.

 FIG. 5 shows an exterior elevation of an optical instrument including the reaction vessel according to an embodiment of the invention.

 FIG. 6 is a cross-section AA of the optical instrument of FIG. 5.

15 FIG. 7 shows a reaction vessel including more than two coil portions according to an embodiment of the invention.

 FIG. 8 shows a dual-action split electromagnetic coil according to an embodiment of the invention.

 FIG. 9 shows the dual-action split electromagnetic coil according to an
20 embodiment of the invention.

 FIG. 10 shows the dual-action split electromagnetic coil according to an embodiment of the invention.

 FIG. 11 shows the dual-action split electromagnetic coil according to an embodiment of the invention.

25 **Detailed Description of the Invention**

 FIGS. 1-11 and the following description depict specific examples to teach those skilled in the art how to make and use the best mode of the invention. For the purpose of teaching inventive principles, some conventional aspects have been simplified or omitted. Those skilled in the art will appreciate variations from these examples that fall
30 within the scope of the invention. Those skilled in the art will appreciate that the features described below can be combined in various ways to form multiple variations of the invention. As a result, the invention is not limited to the specific examples described below, but only by the claims and their equivalents.

 FIG. 1 shows a reaction vessel 100 for heating and mixing a fluid according to an
35 embodiment of the invention. The reaction vessel 100 includes a chamber 104 including a first chamber portion 101 and a second chamber portion 102 and a mixing

5 member 108 that is located inside the chamber 104. A dual-action split electromagnetic coil 110 is located around at least part of the chamber 104. The reaction vessel 100 can include one or more instruments 106 that are configured to perform one or more predetermined tests or measurements on the fluid.

The reaction vessel 100 can comprise any manner of vessel for holding a fluid.

10 The reaction vessel 100 can be employed for performing mixing of two or more substances. The reaction vessel 100 can be employed for agitating of two or more substances. The reaction vessel 100 can be employed for initiating, promoting, accelerating, decelerating, inhibiting, or halting chemical reactions.

The fluid can be stirred in order to create a homogenous sample. The fluid can
15 be stirred in order to mix two or more components of the sample. The fluid can be stirred in order to mix and distribute solids or liquids in suspension in the sample. The dual-action split electromagnetic coil 110 is configured to perform a heating function when energized according to a first energization. The dual-action split electromagnetic coil 110 is further configured to move the mixing member 108 and
20 perform a mixing or agitating function when energized according to a second energization. The dual-action split electromagnetic coil 110 is further configured to perform both a mixing/agitation function and a heating function when energized according to a third energization.

The chamber 104 can be open or can be substantially fluid tight. The chamber
25 104 can include any manner of ports or conduits for fluid transfer. The chamber 104 can include any manner of removable access hatches. The chamber 104 can hold any manner of fluid, including liquids, slurries, or gases. The chamber 104 can be formed of any manner of non-magnetic (or non-magnetically-reactive) material. For example, the chamber 104 can be formed of a polymer. Alternatively, the chamber 104 can be
30 formed of non-ferrous metals or glass, for example. However, other materials are contemplated and are within the scope of the description and claims.

The mixing member 108 is configured to be moved within the chamber 104 by the dual-action split electromagnetic coil 110. The mixing member 108 can be formed of a magnetic material and can be substantially magnetic. As a result, the mixing
35 member 108 can include North (N) and South (S) poles, as shown in the figure. The mixing member 108 can be formed in any manner and can optionally include multiple

5 magnetic portions. Alternatively, the mixing member 108 can be formed of a magnetically responsive material, such as non-magnetized ferrous materials, for example.

The mixing member 108 in some embodiments is substantially elongate, as shown. However, the size and shape of the mixing member 108 can be varied as
10 needed.

The dual-action split electromagnetic coil 110 is divided between a first coil portion 121 and at least a second coil portion 122, wherein the dual-action split electromagnetic coil 110 includes two or more split coil portions. The first coil portion 121 is positioned to generate a first magnetic flux substantially in the first chamber
15 portion 101. The second coil portion 122 is positioned to generate a second magnetic flux substantially in the second chamber portion 102. The first and second fluxes can be substantially additive. The first and second magnetic fluxes can be substantially centered in the chamber 104 in some embodiments (see FIGS. 2-3 and 8-10). However, alternatively the first and second magnetic fluxes do not have to be centered
20 substantially with the chamber 104 (see FIG. 11).

The first coil portion 121 can be energized independently of the second coil portion 122. Alternatively, the first coil portion 121 and the second coil portion 122 can be substantially simultaneously or even commonly energized (such as where the two coil portions are connected in series, for example).

25 The first coil portion 121 is positioned around a first chamber portion 101. The second coil portion 122 is positioned around a second chamber portion 102. Any manner of insulating or containing layer may be disposed over the coil portions 121 and 122, such as to protect the coils and/or to retain heat generated by the coils. The second coil portion 122 is substantially spaced-apart from the first coil portion 121. The second
30 coil portion 122 can be spaced-apart from the first coil portion 121 by a predetermined distance. The predetermined distance can depend on the size of the chamber 104, the size of the mixing member 108, the size and number of instruments 106, etc.

The first chamber portion 101 and the second chamber portion 102 are substantially vertically arranged in the embodiment shown. However, it should be
35 understood that the two chamber portions 101 and 102 can be arranged in other orientations.

5 In one embodiment, the reaction vessel 100 comprises a colorimeter and includes a component(s) for detecting or measuring light passing through the fluid, for example (see FIGS. 5-6). A colorimeter is a device or instrument that measures the absorbance of light (or specific wavelengths of light) by a specific solution or material. However, other devices or instruments are contemplated and are within the scope of the
10 description and claims.

In operation, the first and second coil portions 121 and 122 can be energized in various manners. In the first energization, the first and second coil portions 121 and 122 can be energized by a direct current (DC) electrical signal in order to heat the fluid in the chamber 104. The DC energization may not move the mixing member 108 in some
15 embodiments. The DC signal comprises an essentially non-time-varying electrical current at a fixed polarity. Electrical resistance in the dual-action split electromagnetic coil 110 will generate heat in the dual-action split electromagnetic coil 110 when the DC electrical current flows. The chamber 104 transfers the heat to the fluid.

The DC signal can be of any desired current level. The DC signal can be greater
20 than the AC signal in order to achieve a desired level of heating. The DC signal can be varied as desired, including being ramped up or down over time.

FIG. 2 shows the reaction vessel 100 during a first cycle of an AC energization according to an embodiment of the invention. The first coil portion 121 is energized with a first electrical current I_1 flowing in a first direction and the second coil portion
25 122 is energized with a second electrical current I_2 also flowing in the first direction. As a result, the first magnetic field created by the first coil portion 121 will be of a substantially similar orientation to the second magnetic field created by the second coil portion 122 and the two fields will substantially add together.

The AC energization (*i.e.*, the second energization) is depicted by dashed lines
30 representing magnetic flux generated by the dual-action split electromagnetic coil 110. In the figure, the lines of magnetic flux travel upward through the chamber 104 (see arrows). Consequently, if the magnetic flux is strong enough, it will lift the mixing member 104. The height that the mixing member 108 is lifted, along with the rate of upward travel, will therefore depend on the magnitude of the AC signal.

35 The AC signal can comprise any manner of waveform, including sinusoids, square waves, etc. In one embodiment, the AC energization comprises a square wave of

5 approximately forty Hertz (Hz) and approximately fifty percent duty cycle. However, other AC signals are contemplated and are within the scope of the description and claims. It should be understood that the frequency, duty cycle, shape, and amplitude of the AC signal can be varied as needed, and the above square wave is given merely for illustration.

10 The first and second coil portions 121 and 122 can be energized similarly or differently. The first electrical current I_1 and the second electrical current I_2 can be of equal or different magnitudes. For example, the first magnetic field can be stronger or weaker than the second magnetic field. Further, the electrical currents or AC duty cycle can be ramped up or down in order to smoothly move and/or accelerate/decelerate the
15 mixing member 108.

The AC signal can attract the mixing member 108 back and forth between the first chamber portion 121 and the second chamber portion 122 in a substantially alternating fashion. Consequently, in a vertical chamber embodiment, as shown in the figure, the mixing member 108 will move substantially up and down in the fluid.

20 Consequently, the mixing member 108 may bounce off the bottom of the chamber 104 if moving fast enough. Further, the mixing member 108 may occasionally bounce off the sidewalls of the chamber 104. In addition, the mixing member 108 may have other motions, including rotational motion, for example. However, the motion of the mixing member 108 may be substantially erratic, wherein the mixing member 108 mixes and/or
25 agitates the fluid in the chamber 104 through substantially random motion, including vertical motion components and horizontal motion components in the chamber 104.

The magnetically induced movement/rotation of the mixing member 108 eliminates the need for any passage into the chamber 104. In addition, there is no need for any seals to seal the chamber 104. This reduces or eliminates the possibility of any
30 fluid leaking out of the chamber 104.

FIG. 3 shows the reaction vessel 100 during a second cycle of an AC energization according to an embodiment of the invention. In this figure, the electrical currents I_1 and I_2 are reversed, inverting the magnetic flux (see arrows). Consequently, the mixing member 108 may rotate and/or swap ends in order to maintain substantial
35 alignment with the magnetic flux. In addition, the mixing member 108 will be pulled

5 downward in the chamber 104, substantially opposite to the previous figure and the previous energization.

Depending on the dimensions and/or shape of the chamber 104 and the mixing member 108, and depending on the location of the coils, for example, the mixing member 108 may move in a manner more complex than merely up-and-down. The
10 substantially downward force created by the magnetic flux may cause the mixing member 108 to rebound. In addition, the shape of the mixing member 108 may cause erratic or random rebounding motion in some embodiments.

It should be understood that the AC signal can cause some heating in the first and second coil portions 121 and 122. The AC energization therefore can perform some
15 heating of the fluid.

It should be further understood that the heating and mixing operations can be alternated. The mixing/agitating can be halted during a measurement, for example, and the heating can be increased during such a period if needed.

FIG. 4 shows the mixing member 108 according to an embodiment of the
20 invention. The mixing member 108 in this embodiment has a substantially cylindrical shape and may be of a size and shape to prevent the mixing member 108 from rotating or moving out of position in the chamber 104. The mixing member 108 can therefore essentially comprise a rodless piston, for example, wherein the shape of the mixing member 108 constrains the motion to substantially up and down movements. However,
25 some space remains between the sides of the mixing member 108 and the sides of the chamber 104 in order to allow the fluid to pass around the mixing member 108 as it moves. Turbulence or eddy currents around the edges of the mixing member 108 can assist in the mixing of the fluid.

FIG. 5 shows an exterior elevation of an optical instrument 106 including the
30 reaction vessel 100 according to an embodiment of the invention. The optical instrument 106 can comprise a colorimeter device, for example. However, other instruments are contemplated and are within the scope of the description and claims. The optical instrument 106 includes a light source 4 (see FIG. 6), a light source retainer 5, the first coil portion 121, the second coil portion 122, an optical detector 10, a
35 detector retainer 12, and a drain outlet 16. In some embodiments, the first port 14 can comprise a reagent port and the second port 15 can comprise a sample inlet port. In

5 other embodiments additional ports may be added as required by the application. The light source 4 can comprise a light emitting diode (LED) in some embodiments, but can further comprise an incandescent light source, a fluorescent light source, or a coherent light source (*e.g.*, lasers), for example, as well as any other light source.

FIG. 6 is a cross-section AA of the optical instrument 106 of FIG. 5. It can be
10 seen from this figure that the optical instrument 106 further comprises an overflow weir 2, a first light pipe 3, the light source 4 that is held in the light source retainer 5, a temperature sensor 6, one or more instrument components 9 (including a filter, polarizer, lens, etc.), a second light pipe 11, and the mixing member 108. It can be seen that the first coil portion 121 is located at the first chamber portion 101 and the second
15 coil portion 122 is located at the second chamber portion 102.

The one or more instrument components 9 are optional. It should be understood that the one or more instrument components 9 can be located in various positions, including before or after the first light pipe 3 or before or after the second light pipe 11. The one or more instrument components 9 can comprise any manner of optical
20 components, such as filters, lenses, polarizers, shutters, etc. Alternatively, the one or more instrument components 9 can comprise any other manner of test device components, including non-optical components.

An interior volume 7 of the chamber 104 is substantially elongate. The mixing member 108 in some embodiments may not be able to lay flat in the bottom of the
25 interior volume 7. The mixing member 108 can travel a substantially vertical distance in the chamber 104. The mixing member 108 can move to a position that is substantially above the first coil portion 121 and to a position that is substantially below the second coil portion 122.

The light source 4 emits light into the first light pipe 3. The light is transmitted
30 into the interior of the chamber 104 by the first light pipe 3. Light that is not scattered or absorbed by a fluid in the chamber 104 is received in the second light pipe 11. The second light pipe 11 transmits the received impinging light to the optical detector 10. The optical detector 10 generates some manner of received light measurement or quantification.

35 The mixing member 108 can be moved by the dual-action split electromagnetic coil 110 in order to mix, agitate, or otherwise move the fluid in the chamber 104, as

5 previously discussed. In some embodiments, movement of the mixing member 108 is halted when a measurement or quantification is to be performed. The first and second coil portions 121 and 122 can be energized as in FIG. 3 in order to hold the mixing member 108 at the bottom of the chamber 104, below a light path between the first light pipe 3 and the second light pipe 11. Alternatively, the first and second coil portions 121
10 and 122 can be energized as in FIG. 2 in order to hold the mixing member 108 at a maximum upward position, again out of the light path between the first light pipe 3 and the second light pipe 11 and above the light path.

Additional capabilities are possible in the optical instrument 106. The optical components can be used to detect the presence of the mixing member 108. For
15 example, if the mixing member 108 is left out of the optical instrument 106 after a cleaning or servicing operation, the optical instrument 106 can be operated to move the mixing member 108 up and down. If the optical detector 10 does not detect any subsequent light interruption by the mixing member 108, the optical instrument 106 can determine that the mixing member 108 is absent and can perform any remedial
20 action/notification.

It should be noted that in any of the embodiments, the instrument 106 can include more than one detector or measurement device. For example, the optical instrument 106 can include a first optical detector 10, as shown, for receiving and quantifying light passing substantially through the interior volume 7. In addition, a
25 second detector (not shown) can be positioned out of the plane of the figure. This second light detector can receive light scattered in the interior volume 7, such as by particulate or suspension material in a fluid held in the interior volume 7, for example.

FIG. 7 shows a reaction vessel 100 including more than two coil portions according to an embodiment of the invention. The reaction vessel 100 in this
30 embodiment includes first, second, and third coil portions 121, 122, and 123. It should be understood that more than three coil portions can be included as needed. For example, the reaction vessel 100 can include more than one instrument 106, as shown in this figure. The number of coil portions in some embodiments can depend on the dimensions of the chamber 104, for example.

35 FIG. 8 shows the dual-action split electromagnetic coil 110 according to an embodiment of the invention. In this embodiment, the coil portions 121 and 122 are

5 located inside the chamber 104. Consequently, the heating action/efficiency of the coil portions 121 and 122 is improved, while retaining the mixing capability. It should be noted that the coil portions 121 and 122 may require some manner of insulation or coating in order to prevent electrical current from shorting across windings or through the fluid in the chamber 104.

10 FIG. 9 shows the dual-action split electromagnetic coil 110 according to an embodiment of the invention. In this embodiment, the coil portions 121 and 122 are formed inside a wall or walls of the chamber 104. The coil portions 121 and 122 can be a part of the structure of the chamber 104, such a sidewall or sidewalls. Where the chamber 104 is formed of a glass or non-ferrous metal, the heating action may be
15 improved.

FIG. 10 shows the dual-action split electromagnetic coil 110 according to an embodiment of the invention. In this embodiment, the coil portions 121 and 122 are outside the chamber 104 and do not contact the sidewalls of the chamber 104. This embodiment does not heat the chamber 104 or the fluid, but can still perform all of the
20 previously discussed mixing functions.

FIG. 11 shows the dual-action split electromagnetic coil 110 according to an embodiment of the invention. In this embodiment, the coil portions 121 and 122 do not surround the chamber 104, and instead are located off to a side. The magnetic field create by the coil portions 121 and 122 still passes somewhat through the chamber 104,
25 as shown by the dashed lines. Consequently, the first and second magnetic fluxes generated by the coil portions 121 and 122 are still additive and can still move the mixing member 108. As a result, this embodiment does not heat the chamber 104 or the fluid but can still perform all of the previously discussed mixing functions.

Advantageously, the reaction vessel according to embodiments of the invention
30 offers no leakage access. The reaction vessel offers a low drive friction, without the need for any gears, belts, etc. The reaction vessel offers a simple design that is robust and economical to manufacture. The reaction vessel offers a dual capability. The reaction vessel offers a flexible device that can be operated in a multitude of modes and can achieve mixing and heating, either separately or simultaneously.

5 We claim:

1. A reaction vessel (100) for heating and mixing a fluid, comprising:
a chamber (104) adapted for receiving the fluid;
a mixing member (108) located in the chamber (104); and
a dual-action split electromagnetic coil (110), comprising:

10 a first coil portion (121) positioned to generate a first magnetic flux
substantially in a first chamber portion (101); and
 at least a second coil portion (122) positioned to generate a second
magnetic flux substantially in a second chamber portion (102) and substantially spaced-
apart from the first coil portion (121), wherein the first coil portion (121) and the second
15 coil portion (122) can be energized substantially simultaneously or substantially
separately in order to move the mixing member (108) and/or to heat a fluid in the
chamber (104).

20 2. The reaction vessel (100) of claim 1, with the mixing member (108) being
substantially magnetic.

3. The reaction vessel (100) of claim 1, with the mixing member (108) being
substantially magnetically responsive.

25 4. The reaction vessel (100) of claim 1, with the second coil portion (122) being
independently energized from the first coil portion (121).

5. The reaction vessel (100) of claim 1, with the second coil portion (122) and the
first coil portion (121) being commonly energized.

30

6. The reaction vessel (100) of claim 1, further comprising one or more instruments
(106) adapted to perform one or more predetermined tests or measurements on the fluid.

5 7. The reaction vessel (100) of claim 1, further comprising one or more instruments (106) adapted to perform one or more predetermined tests or measurements on the fluid, wherein the first coil portion (121) is located on a first side of the one or more instruments (106) and the second coil portion (122) is located on a second side of the one or more instruments (106) and substantially opposite the first side.

10

8. The reaction vessel (100) of claim 1, with the first and second coil portions (121) and (122) being energized by a direct current (DC) electrical signal in order to heat the chamber (104) and the fluid.

15 9. The reaction vessel (100) of claim 1, with the first coil portion (121) and the second coil portion (122) being energized by an alternating current (AC) electrical signal in order to move the mixing member (108) within the chamber (104).

10 10. The reaction vessel (100) of claim 1, with the first coil portion (121) and the second coil portion (122) being substantially simultaneously energized by an alternating current (AC) electrical signal in order to move the mixing member (108) within the chamber (104).

11. A reaction vessel (100) for heating and mixing a fluid, comprising:
25 a chamber (104) adapted for receiving the fluid;
 a mixing member (108) located in the chamber (104);
 a dual-action split electromagnetic coil (110), comprising:
 a first coil portion (121) positioned to generate a first magnetic flux substantially in a first chamber portion (101); and
30 at least a second coil portion (122) positioned to generate a second magnetic flux substantially in a second chamber portion (102) and substantially spaced-apart from the first coil portion (121), wherein the first coil portion (121) and the second coil portion (122) can be energized substantially simultaneously or substantially separately in order to move the mixing member (108) and/or to heat a fluid in the
35 chamber (104); and

5 one or more instruments (106) adapted to perform one or more predetermined tests or measurements on the fluid, wherein the first coil portion (121) is located on a first side of the one or more instruments (106) and the second coil portion (122) is located on a second side of the one or more instruments (106) and substantially opposite the first side.

10

12. The reaction vessel (100) of claim 11, with the mixing member (108) being substantially magnetic.

15

13. The reaction vessel (100) of claim 11, with the mixing member (108) being substantially magnetically responsive.

14. The reaction vessel (100) of claim 11, with the second coil portion (122) being independently energized from the first coil portion (121).

20

15. The reaction vessel (100) of claim 11, with the second coil portion (122) and the first coil portion (121) being commonly energized.

25

16. The reaction vessel (100) of claim 11, with the first coil portion (121) and the second coil portion (122) being energized by a direct current (DC) electrical signal in order to heat the chamber (104) and the fluid.

30

17. The reaction vessel (100) of claim 11, with the first coil portion (121) and the second coil portion (122) being energized by an alternating current (AC) electrical signal in order to move the mixing member (108) within the chamber (104).

18. The reaction vessel (100) of claim 11, with the first coil portion (121) and the second coil portion (122) being substantially simultaneously energized by an alternating current (AC) electrical signal in order to move the mixing member (108) within the chamber (104).

35

5 19. A method of forming a reaction vessel for heating and mixing a fluid, comprising:

providing a chamber adapted for receiving the fluid;

providing a mixing member located in the chamber; and

providing a dual-action split electromagnetic coil, comprising:

10 a first coil portion positioned to generate a first magnetic flux substantially in a first chamber portion; and

at least a second coil portion positioned to generate a second magnetic flux substantially in a second chamber portion and substantially spaced-apart from the first coil portion, wherein the first coil portion and the second coil portion can be
15 energized substantially simultaneously or substantially separately in order to move the mixing member and/or to heat a fluid in the chamber.

20. The method of claim 19, with the mixing member being substantially magnetic.

20 21. The method of claim 19, with the mixing member being substantially magnetically responsive.

22. The method of claim 19, with the second coil portion being independently energized from the first coil portion.

25

23. The method of claim 19, with the second coil portion and the first coil portion being commonly energized.

24. The method of claim 19, further comprising providing one or more instruments
30 adapted to perform one or more predetermined tests or measurements on the fluid.

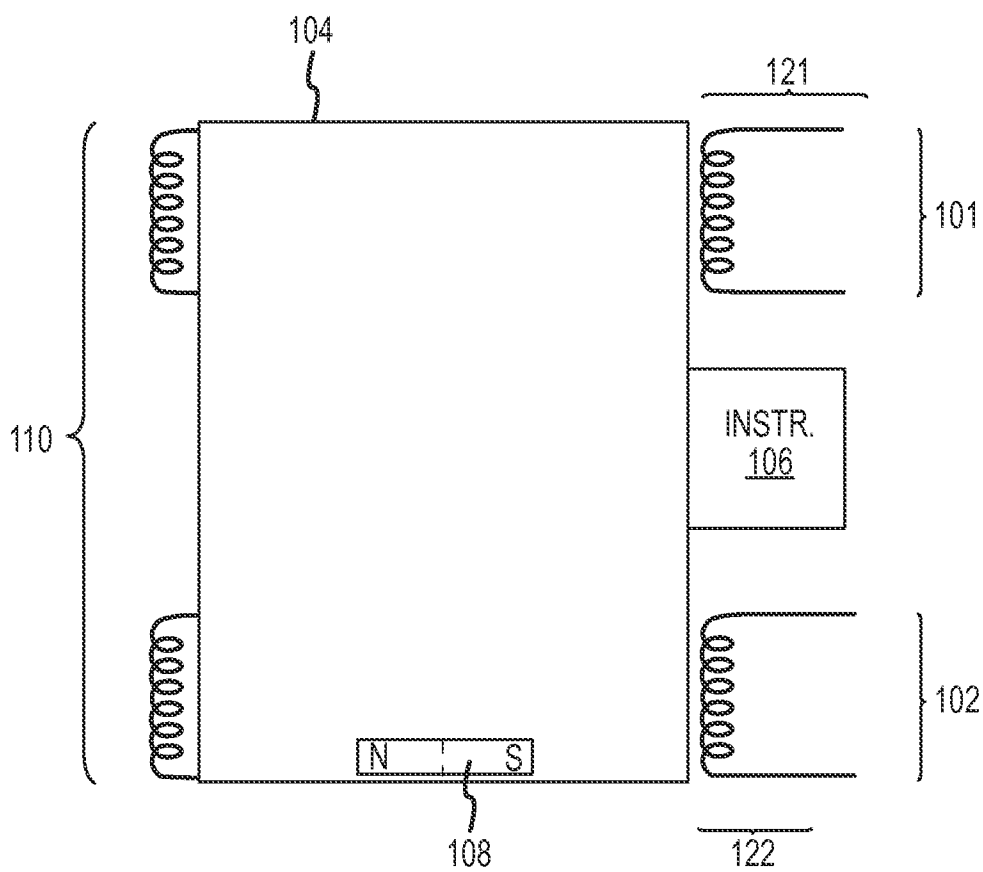
25. The method of claim 19, further comprising providing one or more instruments adapted to perform one or more predetermined tests or measurements on the fluid, wherein the first coil portion is located on a first side of the one or more instruments and
35 the second coil portion is located on a second side of the one or more instruments and substantially opposite the first side.

5

26. The method of claim 19, with the first and second coil portions being energized by a direct current (DC) electrical signal in order to heat the chamber and the fluid.

27. The method of claim 19, with the first coil portion and the second coil portion
10 being energized by an alternating current (AC) electrical signal in order to move the mixing member within the chamber.

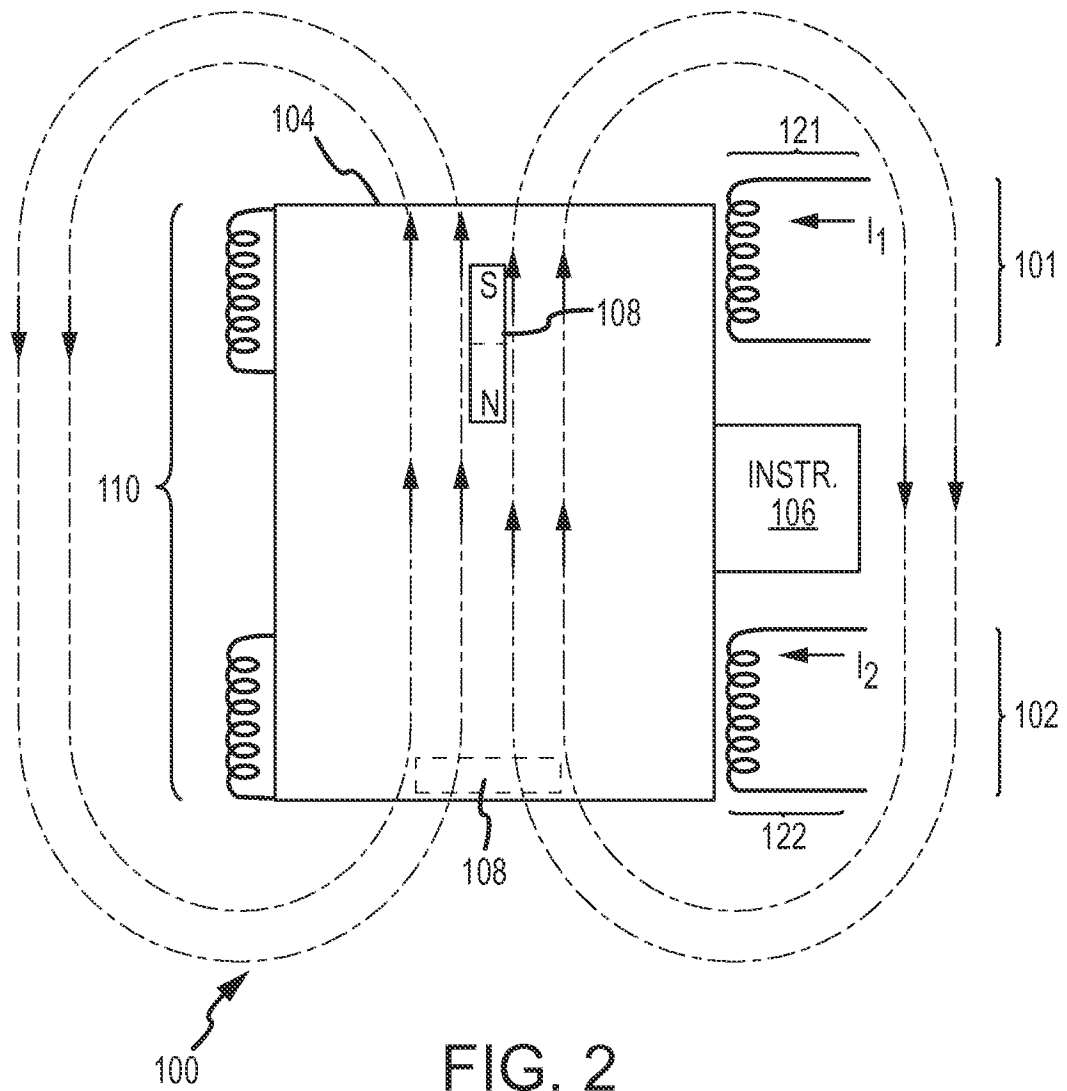
28. The method of claim 19, with the first coil portion and the second coil portion
15 being substantially simultaneously energized by an alternating current electrical signal in order to move the mixing member within the chamber.



100 ↗

FIG. 1

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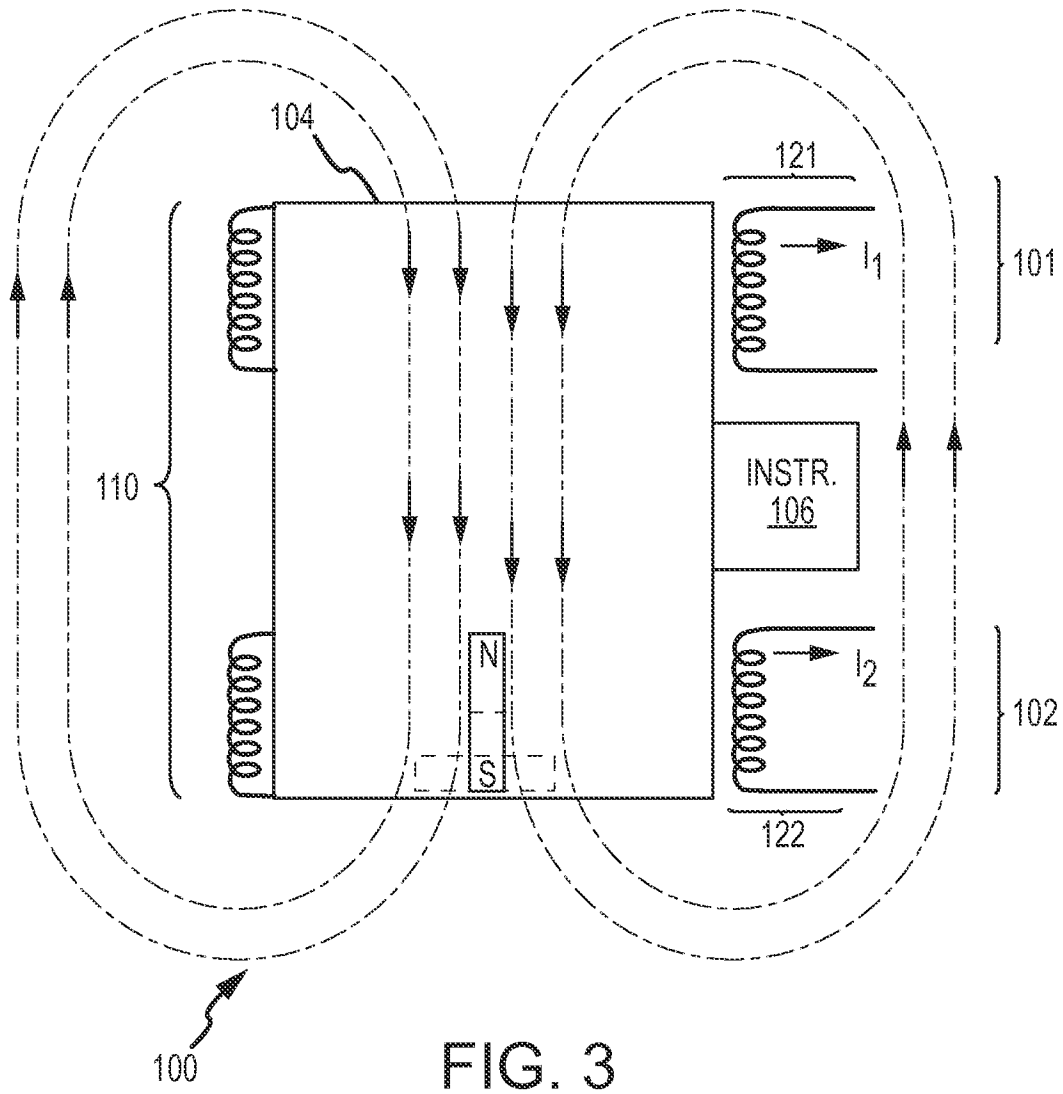
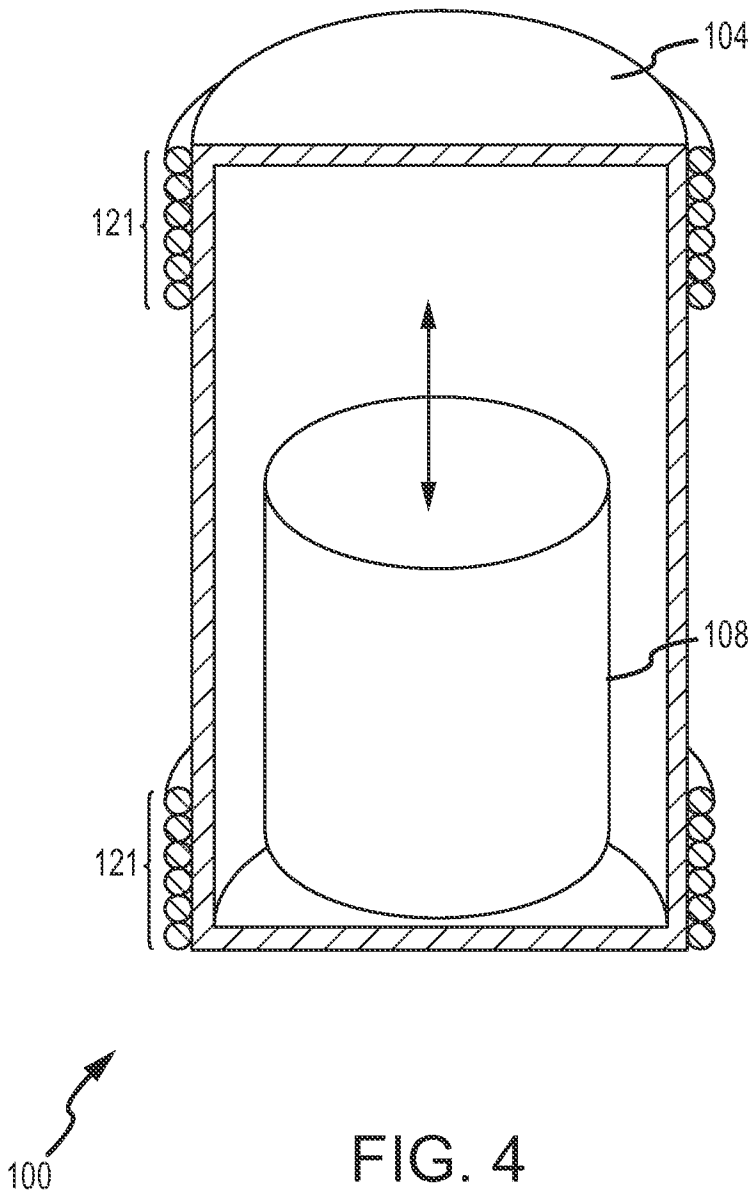
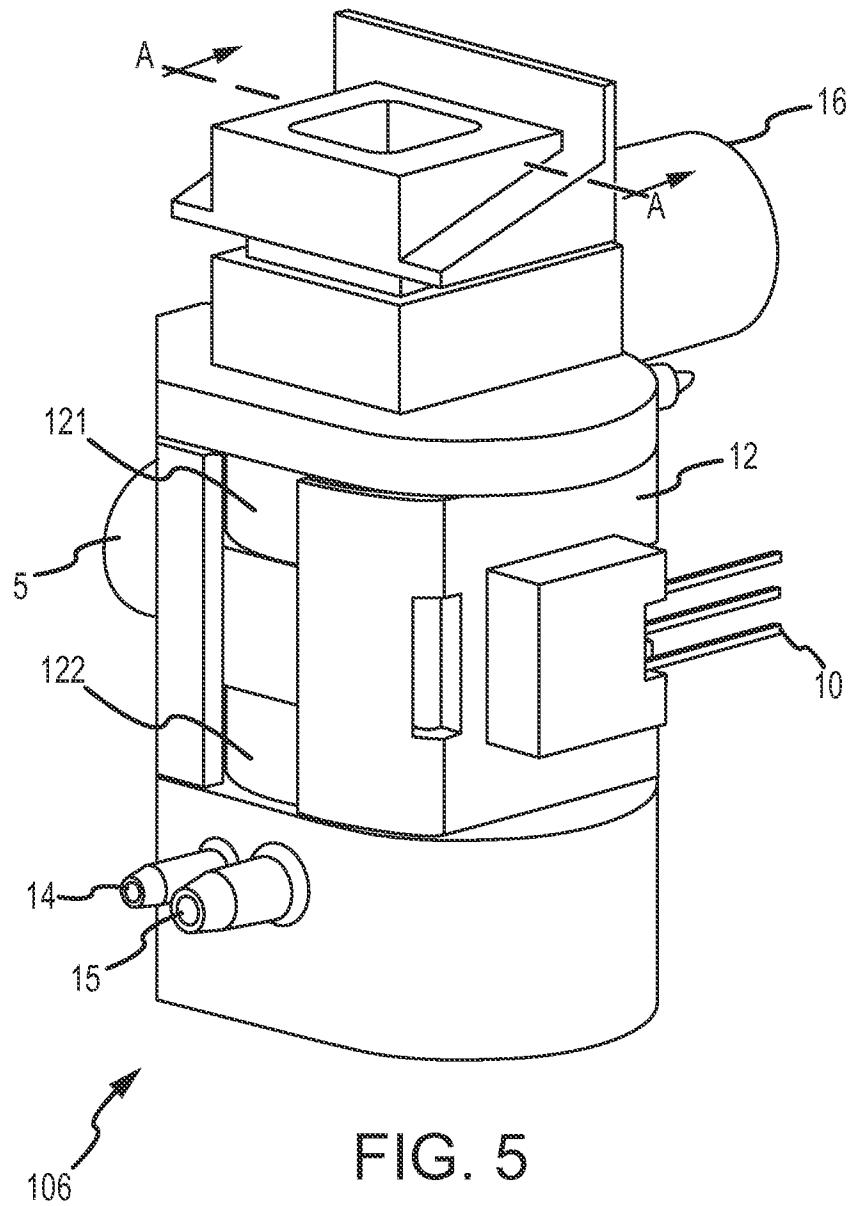


FIG. 3

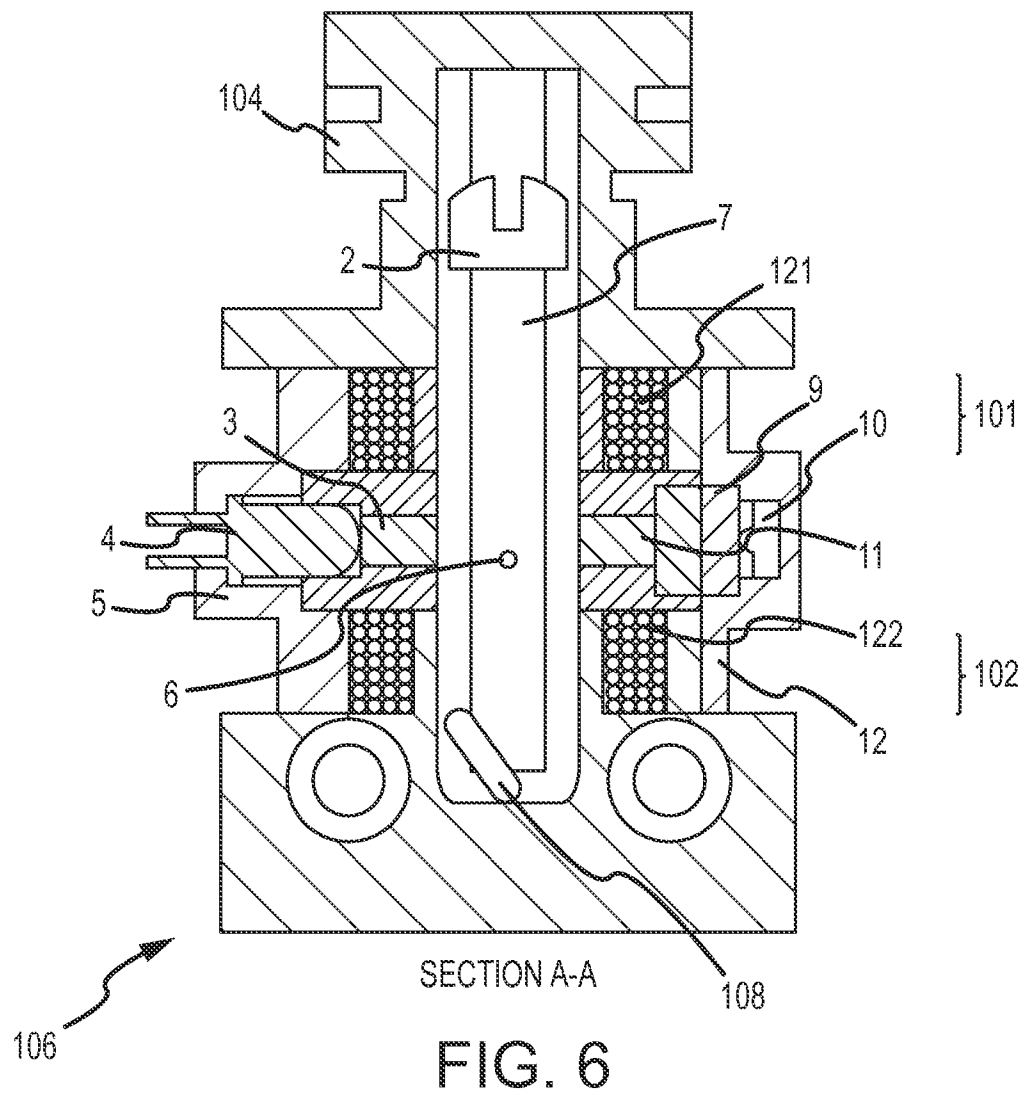
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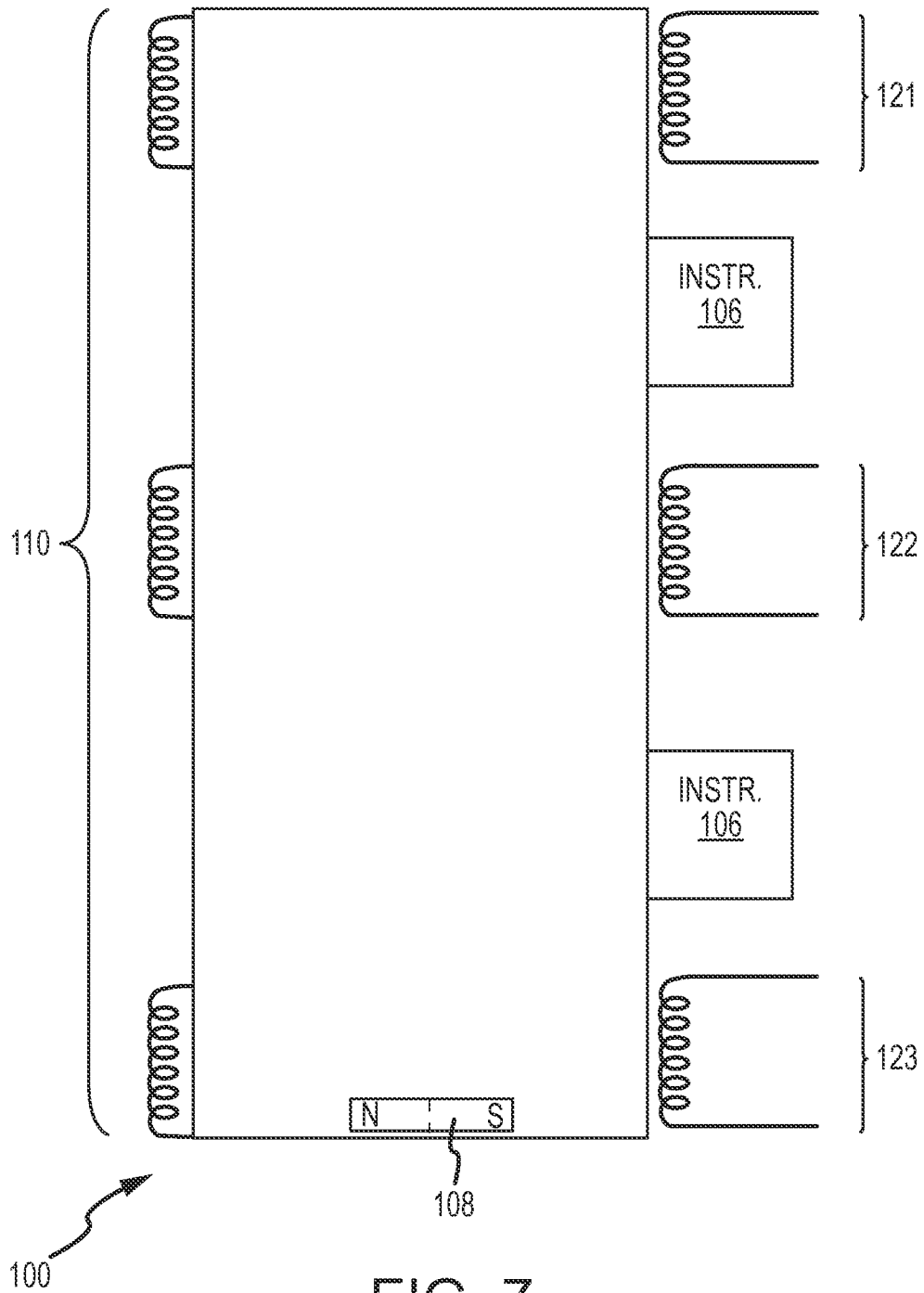
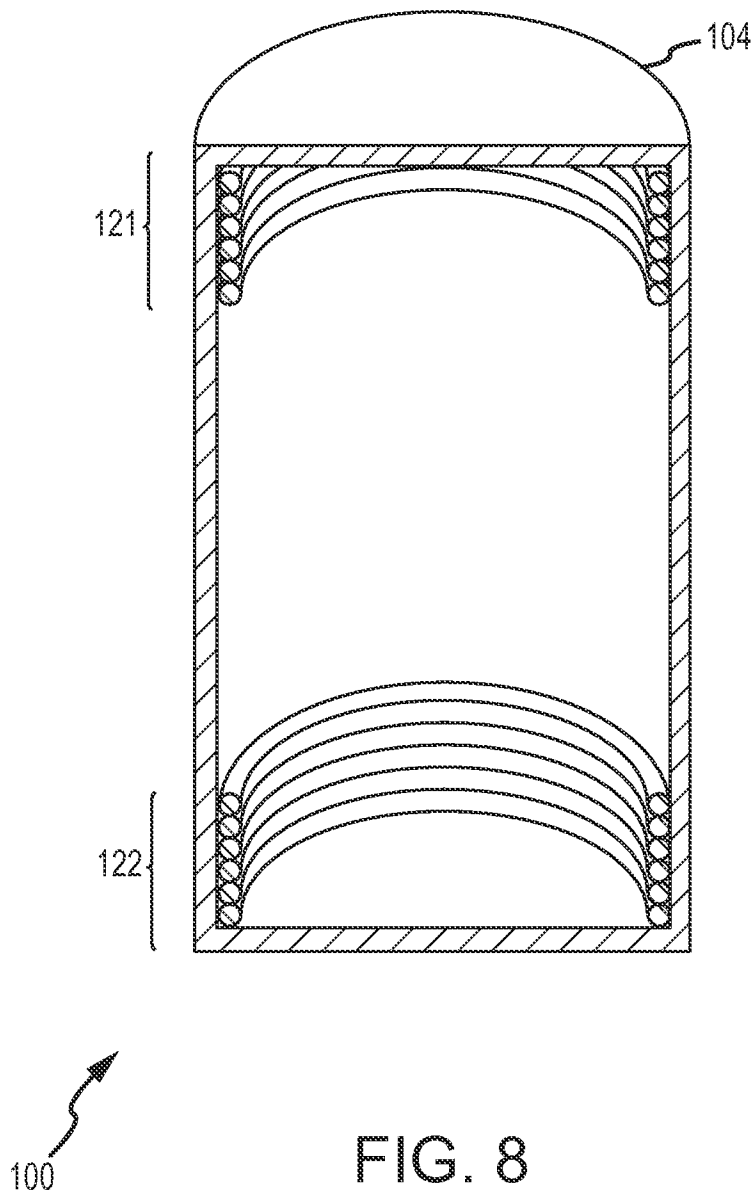


FIG. 7



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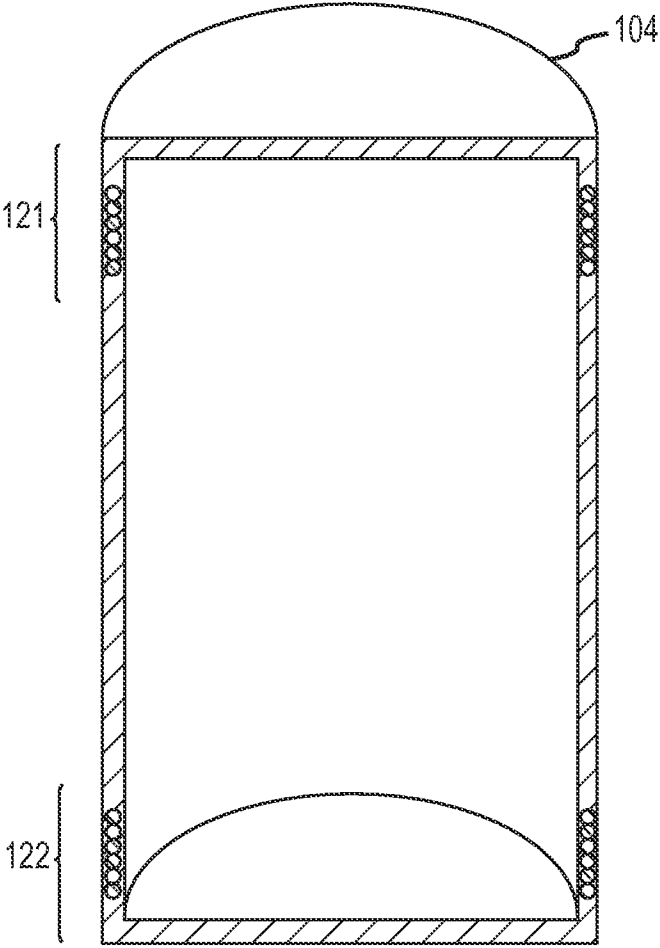
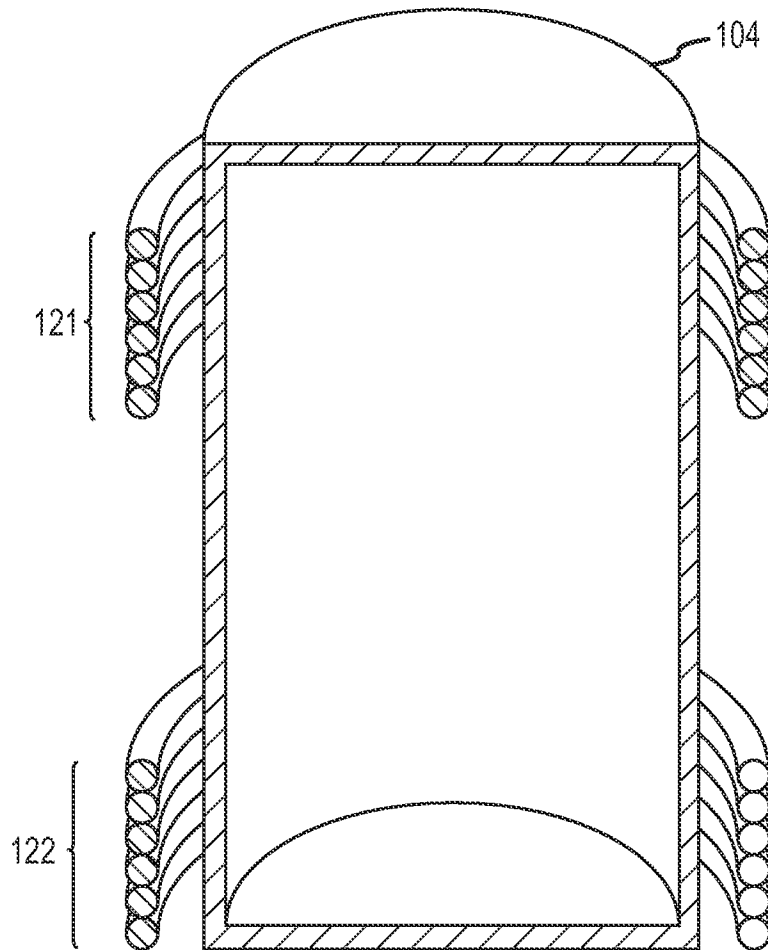


FIG. 9

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100

FIG. 10

