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(54) **Title**: MODULAR FLUID ACTUATOR

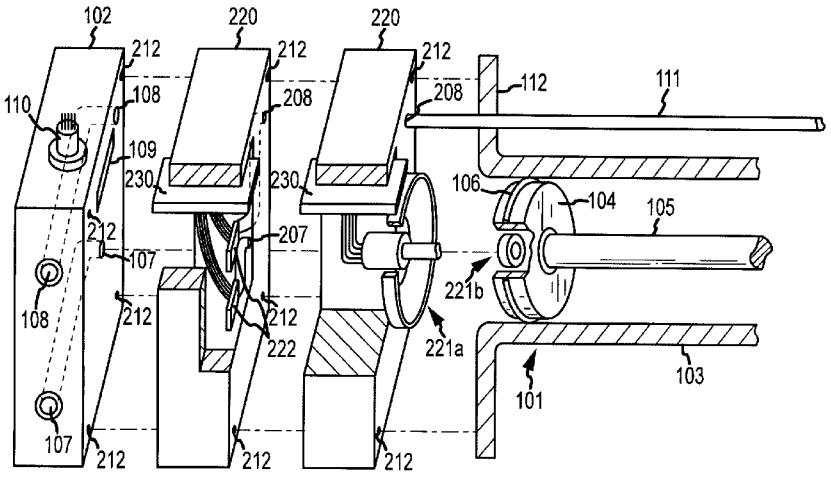

FIG. 2

(57) **Abstract**: A modular fluid actuator (100) is provided. The modular fluid actuator (100) includes a fluid operated cylinder (101) and a base unit (102). The modular fluid actuator (100) further includes one or more modular units (220). The modular units (220) are removably coupled to the fluid operated cylinder (101) on a first side (340) and removably coupled to the base unit (120) on a second side (341).

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MODULAR FLUID ACTUATOR

TECHNICAL FIELD

The present invention relates to a fluid actuator, and more particularly, to a fluid actuator assembly including modular units.

BACKGROUND OF THE INVENTION

Fluid operated actuators have received great success, in part, because of their wide range of applicability. One example of a fluid operated actuator is a piston positioned in a cylinder. The piston may be attached to a working carriage extending through a sealed portion of the cylinder that is attached to the piston. Another example comprises a rod attached to the piston and extending through one end of the cylinder. In both situations, fluid is introduced into a first side of the cylinder to move the piston in one direction while fluid on the second side of the piston is exhausted to the environment. To reverse directions of the piston, fluid is introduced on the second side of the piston and exhausted from the first side.

It is generally desired to measure various parameters of the fluid operated actuator, such as an operating pressure, a piston position, or a fluid temperature, for example. In addition, it may be advantageous to include various safety features such as a pilot operated stop valve, an emergency exhaust valve, etc. Prior art fluid operated actuators vary the actuator design depending on the specific features included. Therefore, the manufacturer is required to produce multiple actuator designs to accommodate the various actuator features offered. However, because of limited manufacturing space, the actuators are typically designed in a limited number of models, with each model including a different combination of sensors. The problem with this approach is that a user may require some capabilities included in a specific model, without requiring other sensing capabilities of that particular model. Custom ordering an actuator with only the sensors desired may outweigh the costs associated with paying for unused features. Therefore, the customer is required to pay for sensors that may not be used in the intended application. Many times, the sensors can be expensive and bulky. Thus, the customer pays for a sensor that will not be employed and may also have to expand the space available for the particular actuator. In contrast, if the customer is operating with a limited budget, the customer may sacrifice desired features

in exchange for down-grading to a lower cost model actuator that includes fewer sensing capabilities. In addition, the sensors typically operate using individual micro-controllers for each sensor. Therefore, each actuator requires excessive internal as well as external wiring.

In addition to added costs for the customer, this prior art approach also results in added costs to the manufacturer as the manufacturer is required to design, manufacture, and stock multiple models of an actuator, each of which includes a different combination of capabilities. This prior art approach therefore creates a needless waste of parts resulting in excess manufacturing time and cost.

The present invention solves this and other problems by providing a modular actuator adapted to accept modular units by coupling the units to an existing actuator. Therefore, only the features desired by a customer need to be provided. Furthermore, a universal actuator can be manufactured rather than a separate configuration for each combination of units. This allows a customer to purchase a universal actuator, which includes the most basic features available. The customer may then install additional desired sensors without having to install undesired sensors, thereby reducing the cost of the actuator.

ASPECTS

According to an aspect of the invention, a modular fluid actuator comprises:

a fluid operated cylinder;

a base unit; and

one or more modular units removably coupled to the fluid operated cylinder on a first side and removably coupled to the base unit on a second side.

Preferably, the one or more modular units comprises a printed circuit board adapted to provide electrical communication between a modular unit of the one or more modular units and the base unit.

Preferably, the base unit supplies electrical power to the one or more modular units.

Preferably, the one or more modular units provide electrical communication between the fluid operated cylinder and the base unit.

Preferably, the base unit is adapted to process signals received from the one or more modular units.

Preferably, the one or more modular units further comprise one or more fluid ports adapted to communicate fluid between the base unit and the fluid operated cylinder.

Preferably, the modular units further comprise an aligning feature adapted to ensure proper orientation of the one or more modular units with respect to one another.

According to an aspect of the invention, a modular fluid actuator comprises:

a fluid operated cylinder;

a base unit; and

one or more modular units coupled to the fluid operated cylinder on a first side and coupled to the base unit on a second side, wherein the one or more modular units is configured to communicate a fluid characteristic of the fluid operated cylinder with the base unit.

Preferably, the modular fluid actuator further comprises a printed circuit board adapted to provide electrical communication between a modular unit of the one or more modular units and the base unit.

Preferably, the one or more modular units provide electrical communication between the fluid operated cylinder and the base unit.

Preferably, the base unit is adapted to process signals received from the one or more modular units.

Preferably, the one or more modular units further comprise one or more fluid ports adapted to communicate fluid between the base unit and the fluid operated cylinder.

Preferably, the modular units further comprise an aligning feature adapted to ensure proper orientation of the one or more modular units with respect to one another.

According to another aspect of the invention, a modular unit for a modular fluid actuator comprises:

a first side adapted to couple a fluid operated cylinder;

a second side adapted to couple a base unit; and

one or more fluid ports adapted to communicate fluid between the fluid operated cylinder and the base unit;

wherein the modular unit is configured to measure a fluid characteristic of the fluid operated cylinder and communicate the fluid characteristic to the base unit.

Preferably, the modular unit further comprises a printed circuit board adapted to electrically communicate with the base unit.

Preferably, the modular unit is further configured to couple to one or more additional modular units.

Preferably, the modular unit further comprises an aligning feature adapted to ensure proper orientation of the one or more additional modular units with respect to one another.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a fluid operated actuator according to an embodiment of the invention.

FIG. 2 shows the fluid operated actuator with modular units according to an embodiment of the invention.

FIG. 3 shows the modular units according to an embodiment of the invention.

FIG. 4 shows the fluid operated actuator coupled to the modular units according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1 – 4 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 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 partial cross sectional view of a modular actuator 100 according to an embodiment of the invention. The modular actuator 100 comprises a linear fluid operated cylinder 101 and a base unit 102. Although FIG. 1 shows a fluid operated

cylinder 101, other types of actuators are generally known in the art and could be substituted for the cylinder 101. The particular actuator used is not important for purposes of the present invention and should not limit the scope of the invention. The fluid operated cylinder 101 shown includes a cylinder housing 103 and a piston 104. The piston 104 slides within the cylinder housing 103 in response to pressurized fluid introduced into the cylinder housing 103. The pressurized fluid could comprise a pneumatic or hydraulic fluid, for example. According to an embodiment of the invention, the piston 104 can be coupled to a rod 105. The rod 105 can transfer the movement of the piston 104 to perform work on an external device, for example. According to an embodiment of the invention, the piston 104 can include a sealing member 106. Although the sealing member 106 shown in FIG. 1 comprises an O-ring, it should be understood that in other embodiments, the sealing member 106 could comprise other types of sealing members. The sealing member 106 can slide within the cylinder housing 103 and provide a substantially fluid tight seal between the piston 104 and the cylinder housing 103. Therefore, fluid introduced on one side of the piston 104 does not leak to the other side of the piston 104.

According to an embodiment of the invention, the base unit 102 is adapted to couple to the fluid operated actuator 101 and enclose one end using a mounting plate 112. The mounting plate 112 may comprise a separate component, or may be formed integral to the cylinder housing 103. According to an embodiment of the invention, one or more fasteners 460 (not shown in FIG. 1) can be used to couple the mounting plate 112 to the base unit 102. The base unit 102 may include fastener apertures 113 adapted to engage the fasteners 460 so that a fluid tight seal is created between the fluid operated actuator 101 and the base unit 102. Although not shown, one or both of the fluid operated actuator 101 and the base unit 102 may comprise a sealing member on their sealing face in order to ensure that a fluid tight seal is formed once the fasteners 460 are fully engaged.

The base unit 102 can also include electronic circuitry (not shown) and an electronic port 109, which is discussed further below. The base unit 102 may be powered using an electrical interface 110. The electrical interface 110 may provide power to the base unit 102 as well as communicate information to/from the electronic circuitry.

In addition to the electronic components of the base unit 102, the base unit 102 can also include fluid ports 107, 108. The fluid ports 107, 108 may be adapted to communicate a working fluid, such as pneumatic or hydraulic fluid, from a source (not shown) to the piston 104. According to an embodiment of the invention, the base unit 102 includes two fluid ports 107 and 108. However, in other embodiments, more or less than two fluid ports may be provided. According to the embodiment shown in FIG. 1, one fluid port 107 communicates fluid to/from a first side of the piston 104 while the other port 108 can communicate fluid to/from a second side of the piston 104 using a fluid conduit 111. The fluid conduit 111 may be provided to communicate fluid to/from the second side of the piston 104. Although the fluid conduit 111 is shown outside of the cylinder housing 103, it should be understood that in other embodiments the fluid conduit 111 can be within the cylinder housing 103. Additionally, the fluid conduit 111 may be formed as an integral member of the cylinder housing 103. Therefore, the scope of the present invention should not be limited to the position of the fluid conduit 111 as shown in FIG. 1. The electronic circuitry of the base unit 102 may be configured to control the flow of fluid in to and out of the fluid ports 107, 108 in order to control the piston movement.

According to an embodiment of the invention, the base unit 102 is adapted to provide essential capabilities. In other words, the base unit 102 provides the features required for the modular actuator 100 to function at a minimum number of measuring and controlling capabilities while optional features are included in the modular units 220.

FIG. 2 shows a partial cross sectional view of the modular actuator 100 according to an embodiment of the invention. The embodiment shown in FIG. 2 includes two modular units 220 adapted to couple to the base unit 102 as well as the fluid operated cylinder 101. The modular unit 220 shown closest to the cylinder 101 comprises a modular position sensor unit with a position sensor 221a with a corresponding magnet 221b coupled to the piston 104. The modular unit 220 shown closest to the base unit 102 comprises a modular pressure sensor unit with pressure sensors 222. The specific modular units 220 shown in FIG. 2 should not limit the scope of the invention as they are shown only to aid in the understanding of the modular units 220 generally. It should be understood that the modular units 220 may comprise any

manner of sensor or controller as is generally known in the art to be included in fluid operated actuators.

According to an embodiment of the invention, the modular units 220 are configured to communicate a fluid characteristic of the fluid operated cylinder 101 to the base unit 102. The fluid characteristic may be measured by the modular unit 220, for example. The fluid characteristic may comprise a wide variety of characteristics including temperature, pressure, density, mass, flow rate in to or out of the fluid operated cylinder 101, etc. The particular fluid characteristics listed above are merely examples and should not limit the scope of the present invention. Furthermore, the modular units 220 may be configured to control a specific feature of the modular fluid actuator 100, such as an emergency feature, for example. In addition, the modular units 220 may be configured to communicate controlling features from the base unit 102 to the fluid operated cylinder 101.

According to an embodiment of the invention, the modular units 220 are adapted to be removably coupled to one another rather than being substantially permanently attached. Although the modular units 220 may be substantially permanently coupled to one another as well as to the base unit 102 and the cylinder 101, by means of welding, brazing, bonding, etc., it is generally more advantageous to removably couple the modular units 220 so they can be replaced, added, or removed to the modular fluid operated actuator 100.

According to an embodiment of the invention, the modular units 220 are coupled to one another using fasteners (not shown), which engage fastening ports 212 included in each of the modular units 220 as well as the base unit 102. In addition, the fasteners can engage the mounting plate 112 of the cylinder body 103 in order to couple the cylinder 101 to the modular units 220. Thus, the modular units 220 couple to the cylinder 101 in substantially the same manner as the base unit 102 couples to the cylinder 101, as shown in FIG. 1. Therefore, a fastener, such as a bolt or screw, for example, may engage the fastening ports 212 in a removable manner (See FIG. 4). For example, in order to add a particular modular unit 220, the fastener can be removed and the modular unit 220 can be inserted. The fastener can then once again engage the fastener ports 212, including the fastener ports 212 of the newly added modular unit 220. Therefore, a new sensing or controlling capability can be added to an existing

modular actuator 100 without having to replace the entire actuator. Furthermore, if a particular modular unit 220 fails to operate, that particular modular unit 220 can be replaced without having to replace the entire actuator 100.

According to an embodiment of the invention, each modular unit 220 comprises substantially the same shape and size. This provides for an easier fit between modular units 220. In addition, the modular units 220 can be formed to comprise the same shape and size as the base unit 102. However, it should be understood that the modular units 220 do not have to comprise the same shape and size, nor do they have to substantially match the shape and size of the base unit 102.

According to an embodiment of the invention, the modular units 220 include fluid ports 207, 208. The fluid ports 207, 208 are positioned such that they substantially align with the fluid ports 107, 108 of the base unit 102. Furthermore, the fluid ports 107, 108 can be positioned to align with the first side of the piston 104 and the fluid conduit 111, respectively. According to an embodiment of the invention, the fluid ports 207, 208 may comprise open apertures such as shown for the modular position sensing unit. In this embodiment, the fluid ports 207, 208 comprise an open port with substantially no interference. In other embodiments, such as shown in the modular pressure sensing unit, the fluid ports 207, 208 may comprise measuring devices, such as pressure sensors 222 adapted to measure a fluid characteristic. In either case, the modular unit 220 includes the fluid ports 207, 208 in order to communicate fluid from the cylinder 101 to the base unit 102.

Furthermore, according to an embodiment of the invention, the fluid ports 207, 208 are designed by a "pass through" configuration. In other words, the fluid ports of each modular unit 220 are subjected to substantially the same fluid pressure and temperature regardless of the modular unit's position with respect to other modular units 220. This design feature provides for greater flexibility as it does not matter which order the modular units 220 are arranged with respect to one another.

In addition to providing mechanical and fluid coupling between the modular units 220 as described above, the modular units 220 can also be electrically coupled together. According to an embodiment of the invention, the modular units 220 include an electronic communicator, such as a printed circuit board (PCB) 230. It should be understood that a PCB does not have to be used and some other electronic

communication medium, such as electrical leads could be used. Therefore, the present invention should not be limited to the use of a PCB.

According to an embodiment of the invention, each PCB 230 can include substantially identical connections such that when the modular units 220 are connected together, each PCB 230 can be connected to the PCB 230 of the adjoining modular unit 220. For example, as shown in FIG. 3, a first connection interface 231 may be provided on a first side 340 of the modular units 220 with a second connection interface 232 provided on a second side 341 of the modular units 220. Each PCB 230 can be provided to communicate measurements and/or commands to the base unit 102. As can be seen in FIG. 2, the PCB 230 of the modular unit 220 that adjoins the base unit 102 engages the electronic port 109 of the base unit 102. The PCBs can be provided with each modular unit 220 rather than requiring each modular unit 220 to include a microcontroller. According to an embodiment of the invention, the base unit 102 can be adapted to process signals received from the various modular units 220. Restricting processing to the base unit 102 can substantially reduce the amount of wiring required for each of the modular units 220 because processors and/or micro-controllers are not required for each modular unit 220. Furthermore, it can reduce the cost associated with each modular unit 220 as only one processing unit is required, rather than providing micro-processors and micro-controllers in each modular unit 220.

Although the modular actuator 100 has been shown in FIG. 2 as providing the modular units 220 as slices, which align in a single column, other configurations can be implemented. For example, the modular units 220 may be stacked in a vertical direction with fluid ports being formed on multiple sides of the modular unit 220. Therefore, the modular fluid actuator 100 should not be limited to the specific configuration shown.

FIG. 3 shows the modular units 220 according to an embodiment of the invention. The two modular units 220 shown in FIG. 3 are positioned such that a first side 340 of the modular unit 220 is seen in the modular unit 220 on the left while a second side 341 of the modular unit 220 is seen in the modular unit 220 on the right hand side. The first side 340 and the second side 341 are shown to aid in the understanding of how adjoining modular units 220 can be coupled together according to an embodiment of the invention.

As discussed above, the modular units 220 can include PCBs 230, or other electrical connectors, to communicate information from the modular units 220 to the base unit 102. According to an embodiment of the invention, a male portion 232 of the PCB 230 can extend from a second side 341 of the modular unit 220, while a corresponding female portion 231 of the PCB 230 can be positioned in the first side 340 of the modular unit 220. According to this embodiment, when two adjoining modular units 220 are coupled together, the male portion 232 of the PCB 230 can engage the female portion 231 of the PCB 230 of an adjoining modular unit 220. Once engaged, the adjoining PCBs 230 can communicate information and power from one modular unit 220 to the adjoining modular unit 220.

According to an embodiment of the invention, the modular units 220 also include an aligning feature 350 comprising an aligning tab 351 with a corresponding aligning aperture 352. The aligning tab 351 and corresponding aperture 352 prevent the modular units 220 from being coupled together in an incorrect orientation. According to an embodiment of the invention, in order for two adjoining modular units 220 to be coupled together, the aligning tab 351 should engage the aligning aperture 352. If engagement does not occur, a user/operator is alerted that at least one of the modular units 220 is improperly oriented. Therefore, the user/operator can reposition the modular units 220 until the aligning tab 351 engages the aligning aperture 352, thereby ensuring proper orientation of the modular units 220. The aligning feature 350 can prevent damage to the PCB 230 along with ensuring proper connections of the fluid ports 207, 208.

FIG. 4 shows the modular fluid actuator 100 with modular units 220 fully coupled to the fluid operated actuator 101 and the base unit 102. As shown, the modular units 220 along with the base unit 102 are coupled to the fluid operated cylinder 101 with fasteners 460. The fasteners 460 engage the mounting plate 112 of the cylinder housing 103 along with the fastener apertures 212 of the modular units 220 and fastener apertures 113 of the base unit 102. As shown, once the modular units 220 are coupled together, the modular units 220 fit substantially evenly together to form a modular fluid actuator 100.

The modular fluid actuator 100 provided above is adapted to couple to modular units 220 in a removable and flexible manner. The modular units 220 can be easily

added, removed, or replaced without the need to replace the entire actuator 100. The modular fluid actuator 100 can be provided with only desired features by selecting the appropriate modular units 220 while omitting undesired sensing and controlling features. The modular fluid actuator 100 can therefore be provided to a customer cheaper and smaller than can be realized in the prior art.

The detailed descriptions of the above embodiments are not exhaustive descriptions of all embodiments contemplated by the inventors to be within the scope of the invention. Indeed, persons skilled in the art will recognize that certain elements of the above-described embodiments may variously be combined or eliminated to create further embodiments, and such further embodiments fall within the scope and teachings of the invention. It will also be apparent to those of ordinary skill in the art that the above-described embodiments may be combined in whole or in part to create additional embodiments within the scope and teachings of the invention.

Thus, although specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. The teachings provided herein can be applied to other fluid actuators, and not just to the embodiments described above and shown in the accompanying figures. Accordingly, the scope of the invention should be determined from the following claims.

CLAIMS

We claim:

1. A modular fluid actuator (100), comprising:

a fluid operated cylinder (101);

a base unit (102); and

one or more modular units (220) removably coupled to the fluid operated cylinder (101) on a first side (340) and removably coupled to the base unit (102) on a second side (341).

2. The modular fluid actuator (100) of claim 1, wherein the one or more modular units (220) comprises a printed circuit board (230) adapted to provide electrical communication between a modular unit (220) of the one or more modular units (220) and the base unit (102).

3. The modular fluid actuator (100) of claim 2, wherein the base unit (102) supplies electrical power to the one or more modular units (220).

4. The modular fluid actuator (100) of claim 1, wherein the one or more modular units (220) provide electrical communication between the fluid operated cylinder (101) and the base unit (102).

5. The modular fluid actuator (100) of claim 1, wherein the base unit (102) is adapted to process signals received from the one or more modular units (220).

6. The modular fluid actuator (100) of claim 1, wherein the one or more modular units (220) further comprise one or more fluid ports (207, 208) adapted to communicate fluid between the base unit (102) and the fluid operated cylinder (101).

7. The modular fluid actuator (100) of claim 1, wherein the modular units (220) further comprise an aligning feature (350) adapted to ensure proper orientation of the one or more modular units (220) with respect to one another.

8. A modular fluid actuator (100), comprising:

a fluid operated cylinder (101);

a base unit (102); and

one or more modular units (220) coupled to the fluid operated cylinder (101) on a first side (340) and coupled to the base unit (102) on a second side, wherein the one or more modular units (220) is configured to communicate a fluid characteristic of the fluid operated cylinder (101) with the base unit (102).

9. The modular fluid actuator (100) of claim 8, further comprising a printed circuit board (230) adapted to provide electrical communication between a modular unit (220) of the one or more modular units (220) and the base unit (102).

10. The modular fluid actuator (100) of claim 8, wherein the one or more modular units (220) provide electrical communication between the fluid operated cylinder (101) and the base unit (102).

11. The modular fluid actuator (100) of claim 8, wherein the base unit (102) is adapted to process signals received from the one or more modular units (220).

12. The modular fluid actuator (100) of claim 8, wherein the one or more modular units (220) further comprise one or more fluid ports (207, 208) adapted to communicate fluid between the base unit (102) and the fluid operated cylinder (101).

13. The modular fluid actuator (100) of claim 8, wherein the modular units (220) further comprise an aligning feature (350) adapted to ensure proper orientation of the one or more modular units (220) with respect to one another.

14. A modular unit (220) for a modular fluid actuator (100), comprising:

a first side (340) adapted to couple a fluid operated cylinder (101);

a second side (341) adapted to couple a base unit (102); and

one or more fluid ports (207, 208) adapted to communicate fluid between the fluid operated cylinder (101) and the base unit (102);

wherein the modular unit (220) is configured to measure a fluid characteristic of the fluid operated cylinder (101) and communicate the fluid characteristic to the base unit (102).

15. The modular unit (220) of claim 14, further comprising a printed circuit board (230) adapted to electrically communicate with the base unit (102).

16. The modular unit (220) of claim 14, further configured to couple to one or more additional modular units (220).

17. The modular unit (220) of claim 14, further comprising an aligning feature (350) adapted to ensure proper orientation of the one or more additional modular units (220) with respect to one another.

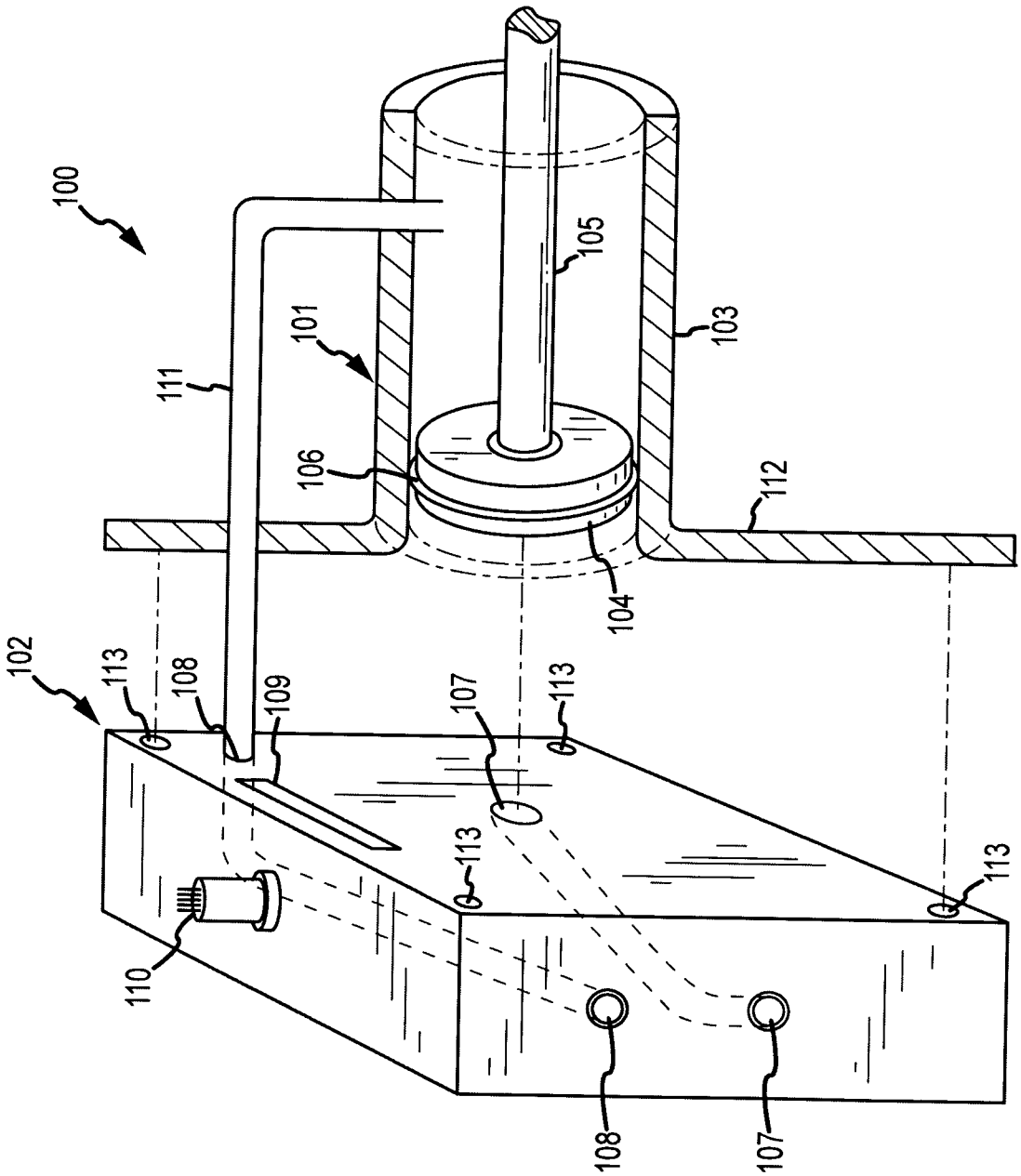

FIG. 1

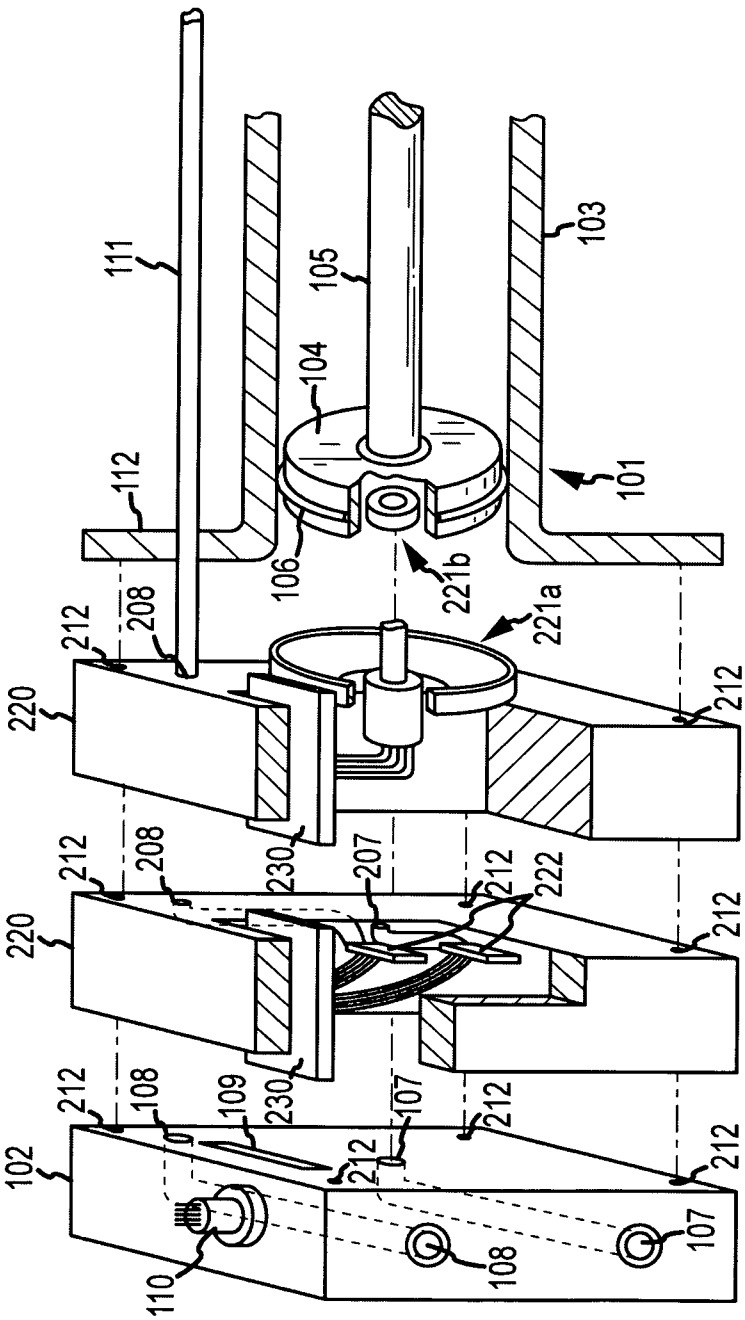
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FIG. 2

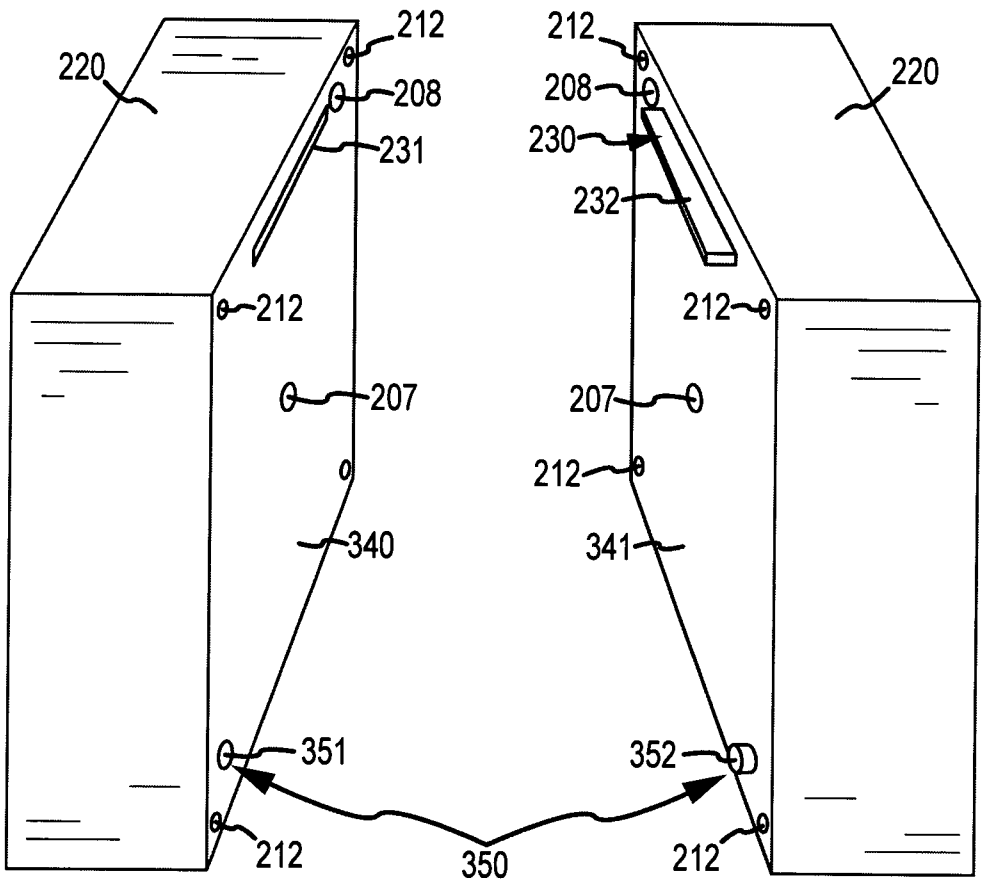
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FIG. 3

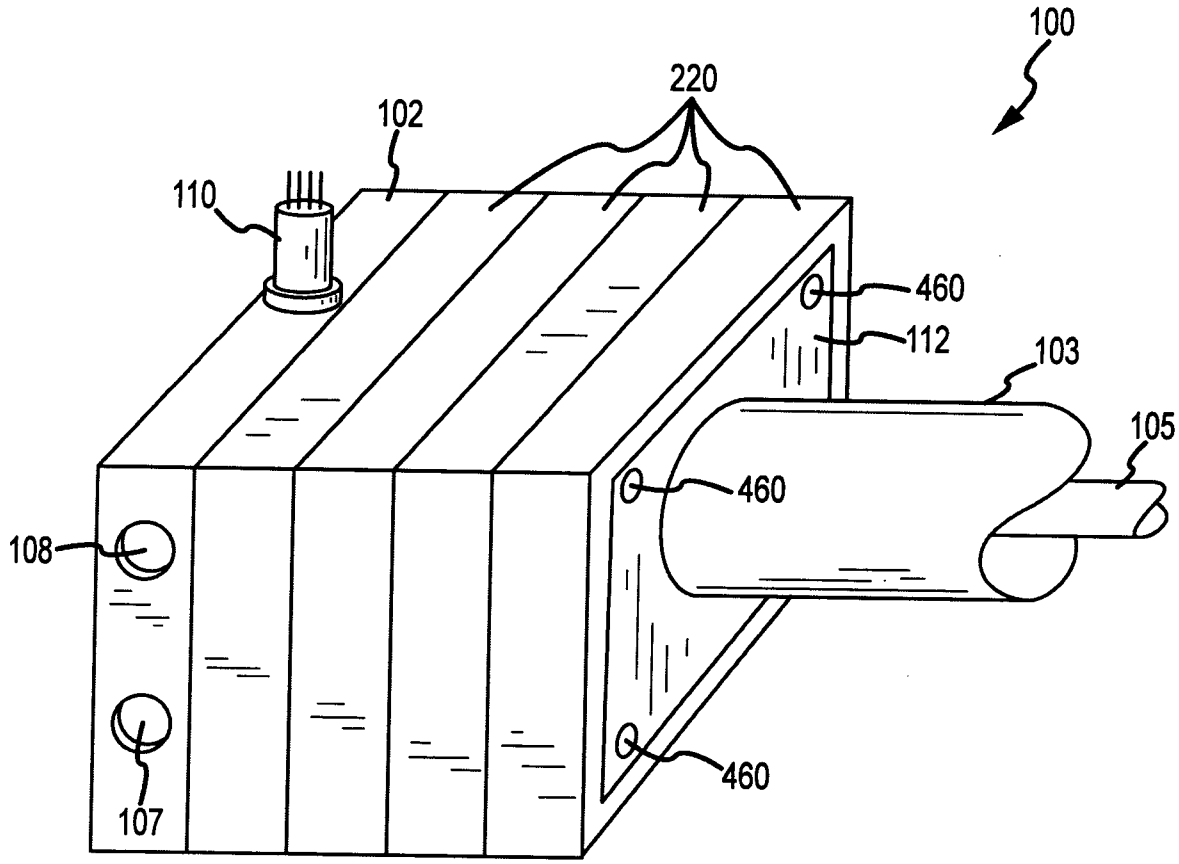

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/007772

A. CLASSIFICATION OF SUBJECT MATTER
INV. F15B21/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F15B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/051381 A1 (GARNER JENS [DE] ET AL) 18 March 2004 (2004-03-18) paragraphs [0002], [0017], [0020] - [0024], [0027]	1-17
X	US 2004/011194 A1 (LEDERER THOMAS [DE] ET AL) 22 January 2004 (2004-01-22) claims 1-3,5; figures 1,2	1-5, 8-11, 14-16
X	US 2002/186666 A1 (HASSEL JOERG [DE] ET AL) 12 December 2002 (2002-12-12) paragraphs [0025] - [0029]; figures 1,2	1-17
A	US 6 169 338 B1 (STOLL KURT [DE] ET AL) 2 January 2001 (2001-01-02) figure 1	1,8,14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 June 2009	06/07/2009

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Information on patent family members

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