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(54) **Title**: VORTEX FLOW METER WITH VORTEX OSCILLATION SENSOR PLATE SUPPORTED BY STRUTS

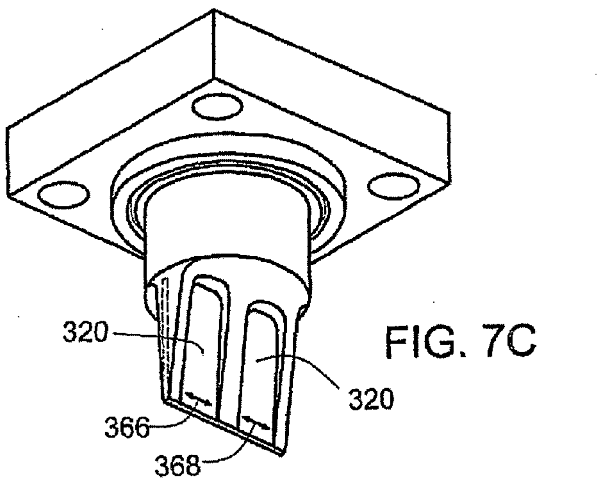

FIG. 7C

(57) **Abstract**: In a vortex flow meter 100, a sensor plate 220 is positioned downstream from a shedding bar 118. The sensor plate has a first rim 222 supported on the diaphragm 204 in a flow meter sidewall, and an opposite second rim that is unsupported. Upstream and downstream rims 226, 228 of the sensor plate are supported. A rotatable strut 230 extends along a central region of the sensor plate and extends through the diaphragm to transfer vortex oscillations to a sensor at a sensing location. An electronic transmitter circuit receives a sensor output and outputs a standardized transmission signal.

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VORTEX FLOW METER WITH VORTEX OSCILLATION SENSOR PLATE SUPPORTED BY STRUTS

BACKGROUND

This invention relates to flow meters, and in particular to flow meters which operate on the principle of measuring the frequency or period of vortices in a Karman vortex street set up in a moving fluid.

SUMMARY

A vortex flow meter comprises an assembly that includes a diaphragm. The diaphragm seals a base end of the assembly to form an isolation chamber. The assembly is adapted to seal an opening in a sidewall of a flow passage. Support struts protrude from the assembly into the flow passage. In one configuration, a vortex oscillation sensor plate has a first rim supported on the diaphragm. The vortex oscillation sensor plate has an opposite second rim that is unsupported. The vortex oscillation sensor plate has upstream and downstream rims. The upstream and downstream rims are supported by the support struts. A rotatable strut extends along a central region of the vortex oscillation sensor plate. The rotatable strut extends through the diaphragm. The rotatable strut transfers vortex oscillations to a sensor at a sensing location inside the isolation chamber. An electronic transmitter circuit receives a sensor output and provides an output related to flow of the fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a side sectional view of a vortex flow meter.

FIG. 2 illustrates an end view of the vortex flow meter of FIG. 1.

FIG. 3 illustrates a side sectional view of an apparatus that senses vortices.

FIG. 4 illustrates a front cross sectional view along line 4-4 in FIG. 3.

FIG. 5 illustrates a bottom view of the apparatus shown in FIGS. 3-4.

FIG. 6 illustrates an oblique view of the apparatus shown in FIGS. 3-5.

FIGS. 7A, 7B, 7C illustrate process steps in the manufacture of an apparatus.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

In the embodiments described below, an apparatus that senses vortices is positioned downstream of a vortex shedding bar in a vortex flow meter. The apparatus comprises a vortex oscillation sensor plate that senses vortices. The vortex oscillation sensor plate has upstream and downstream rims that are supported by upstream and downstream support struts. An upper rim of the vortex oscillation sensor plate is supported on a diaphragm. A lower rim of the vortex oscillation sensor plate is unsupported and free to move in response to the vortices. A rotatable strut is attached to the vortex oscillation sensor plate and passes through the diaphragm into an isolation chamber behind the diaphragm. The rotatable strut extends into the isolation chamber and transfers vortex oscillations to a position in the isolation chamber. A sensor in the isolation chamber senses the vortex oscillations. The sensor is connected to a transmitter circuit which proves an electrical output representative of the vortex oscillation frequency. The vortex oscillation frequency is representative of fluid flow velocity through the vortex flow meter.

The use of the support struts allows the vortex oscillation sensor plate to be thin and to have a low mass. The use of the support struts increases the stiffness of the vortex oscillation sensor plate. The decreased mass and increased stiffness increase the natural resonant frequency of the sensing, resulting in a wider frequency range of sensing and improved signal to noise ratio. The support struts limit undesired flapping of the upstream and downstream rims of the vortex oscillation sensor plate

FIG. 1 illustrates a side sectional view of a vortex flow meter 100. The vortex flow meter 100 comprises a flow tube 102 for carrying a fluid flow 104 of a fluid through the flow tube 102. The flow tube 102 comprises a round cylindrical sidewall 103. The fluid flow 104 can comprise a liquid or a gas. Pipe flanges 106, 108 are joined to the flow tube 102. The pipe flanges 106, 108 include bolt holes such as bolt holes 110, 112 for mounting to a fluid piping system with bolts (not illustrated). The pipe flanges 106, 108 include sealing faces 114, 116 for sealing to mating flanges of the fluid piping system.

The vortex flow meter 100 comprises a vortex shedder bar 118 inside the flow tube 102. The vortex shedder bar 118 comprises a bluff body shape. The vortex shedder bar 118 is attached to the flow tube 102 at an upstream position 120. As the fluid flow 104 flows past the shedder bar 118, vortices are generated in the fluid flow 104. The vortices are referred to as a von Karman vortex street. The vortices are present as the fluid flow 104 passes a downstream position 122. The downstream position 122 is positioned downstream of the upstream position 120.

The flow tube 102 includes an opening 124 in the sidewall 103. The vortex flow meter 100 comprises an apparatus 126 that passes through the opening 124. The apparatus 126 seals the opening 124 such that fluid in flow tube 102 does not leak out through the opening 124. The apparatus 126 extends into the fluid flow 104 and senses vortices at the downstream location 122. The apparatus 126 senses the vortices in the fluid flow 104 and transfers mechanical motion of the vortices to a position 128 that is outside the fluid flow 104. The apparatus 126 is not a part of the shedder bar 118. The apparatus 126 is spaced a distance downstream from the shedder bar 118. The apparatus 126 is described in more detail below in connection with FIGS. 3-7.

The vortex flow meter 100 comprises a transmitter 140. The transmitter 140 comprises an electronic transmitter circuit 142. The transmitter 140 comprises a mechanical sensor 144 that senses the mechanical motion at the position 128 and that provides an electrical sensor signal representative of the mechanical motion. The mechanical sensor 144 is connected by leads 146 to provide the electrical sensor signal to the electronic transmitter circuit 142. The electronic transmitter circuit 142 converts the electrical sensor signal to a standardized transmission signal provided to output leads 148. The electronic transmitter circuit 142 provides an output related to the fluid flow 104 through the flow tube 102, based upon sensed oscillations of the von Karman vortex street. The mechanical sensor 144 senses vortex oscillations at the sensing location 128 and provides a sensor output on leads 146. The electronic transmitter circuit 142 receives the sensor output from the mechanical sensor 144 and outputs the standardized transmission signal on output leads 148. According to one embodiment, the standardized transmission signal comprises a 4-20 milliampere, two wire transmitter output signal. According to another embodiment, the 4-20 mA signal provides all of the energization for the electronic transmitter circuit 142 and the mechanical sensor 144. According to other embodiments, the standardized transmission signal on output leads 148 comprises a CAN, HART, PROFIBUS or other known standard industrial communication signal. Lead 148 can comprise a two-wire process control loop in which the same two wires power the device and carry data. In one configuration, the communication loop is a wireless process control loop in which data is transmitted wirelessly, for example using radio frequency (RF) communication.

FIG. 2 illustrates an end view of the vortex flow meter 100 of FIG. 1.

Reference numbers used in FIG. 2 are the same as reference numbers used in FIG. 1. As illustrated in FIG. 2, a portion of the apparatus 126 inside the flow tube 102 is aligned in a downstream direction behind the shedder bar 118. As described in more detail below in connection with FIGS. 3-6, the apparatus 126 in FIGS. 1-2 comprises a vortex oscillation sensor plate, support struts and a rotatable strut that transfers mechanical motion to the mechanical sensor 144.

FIG. 3 illustrates a side cross sectional view of an apparatus 200 (corresponding with the apparatus 126 shown in FIGS. 1-2). The apparatus 200 comprises an assembly 202. The assembly 202 includes a diaphragm 204 that seals a base end 206 of the assembly 202 to form an isolation chamber 208 in the assembly 202. The assembly 202 seals an opening 210 (corresponding with the opening 124 in FIG. 1) in a sidewall 212 (corresponding with the sidewall 103 in FIG. 1) of a flow passage 214. According to one embodiment, one or more O-rings 211 are compressed between the assembly 202 and the sidewall 212 to improve sealing. According to one aspect, the diaphragm 204 comprises diaphragm means for sealing an opening210 in a sidewall 212 to form an isolation region 208 at a downstream position 122.

The apparatus 200 comprises an upstream support strut 216 and a downstream support strut 218. The support struts 216, 218 protrude from the assembly 202 into the flow passage 214. According to one embodiment, the support struts 216, 218 include corner gussets 217, 219 which provide additional support to the support struts 216, 218.

The apparatus 200 comprises a vortex oscillation sensor plate 220 having a first rim 222 supported on the diaphragm 204. The vortex oscillation sensor plate 220 has a second rim 224, opposite the first rim, that is unsupported. The vortex oscillation sensor plate 220 has an upstream rim 226 and a downstream rim 228 that are supported by the support struts 216, 218. According to one embodiment, the support struts 216, 218 limit flapping of the upstream and downstream rims 226, 228 due to vortices passing by the sensor plate 220.

The apparatus 200 comprises a rotatable strut 230. The rotatable strut 230 extends along a central region of the vortex oscillation sensor plate 220. The rotatable strut 230 extends through the diaphragm 204. The rotatable strut 230 transfer vortex oscillations to a sensing location 232 inside the isolation chamber 208. According to one aspect, the rotatable strut 230 comprises rotatable strut means for transferring vortex oscillations 238 from the vortex oscillation sensor plate 220 to a sensor 242 at a sensing location 232 in the isolation chamber 208.

The rotatable strut 230 is coupled to a sensor 242 at the location 232.The sensor 242 can be of conventional design and can comprise a capacitive sensor, a magnetic sensor, an optical sensor, a piezoelectric sensor or other sensor used for sensing mechanical oscillation or mechanical oscillation frequency. The sensor 242 senses rotational oscillations of the rotatable strut 230. The sensor 242 is mounted to the assembly 202. According to one embodiment, the sensor 242 senses motion of the rotatable strut 230. According to another embodiment, the sensor 242 sensing forces exerted by the rotatable strut 230 on the sensor 242. According to yet another embodiment, the sensor 242 does not restrain the movement of the rotatable strut 230. According to yet another embodiment, the sensor 242 restrains the movement of the rotatable strut 230.

FIG. 4 illustrates a front cross sectional view (along line 4-4 in FIG. 3) of the apparatus 200 shown in FIG. 3. According to one embodiment, the rotatable strut 230 is inertially balanced around a rotational axis 234 adjacent the diaphragm 204. The inertial balancing has the advantage that the apparatus has reduced sensitivity to translational vibration noise.

According to another embodiment, an optional body 236 of viscous material is placed in contact with the rotatable strut 230 in the isolation chamber 208. The body 232 of viscous material damps rotational motion of the rotatable strut 230. According to another embodiment, an oscillation of a rotation motion 238 of the rotatable strut 230 has a damping ratio (zeta) of at least 0.4. Viscous damping has little effect on natural resonant frequency, but limits flapping. According to another embodiment, an oscillation of the rotation motion 238 of the rotatable strut 230 has a controlled natural resonant frequency of at least 20 % higher than an upper frequency limit of vortex oscillations to be sensed. The upper frequency to be sensed generally corresponds with characteristics of the flowing fluid, particularly whether the flowing fluid is a gas or a liquid. The frequency of the vortex oscillations is a known function of the velocity of the flowing fluid. A relationship between vortex oscillation frequency and fluid velocity is determined empirically by calibration testing of the flow meter.

According to one embodiment, radii (such as radius 223) at edges of the diaphragm 204 have an effect on stiffness and can be sized to control stiffness of the diaphragm 204. According to another the radii (such as radius 223) also affect sensitivity and can be sized to control sensitivity.

FIG. 5 illustrates a bottom view of the apparatus 200 shown in FIGS. 3-4 as installed in the sidewall 212. FIG. 5 illustrates a thickness T_{PLATE} of the vortex oscillation sensor plate 220. FIG. 5 illustrates a minimum thickness T_{STRUT} of the support struts 216, 218 at a lower end of the apparatus 200. According to one embodiment, the vortex oscillation sensor plate 220 has a controlled thickness T_{PLATE} that is less than 30 % of a controlled minimum thickness T_{STRUT} of the support struts 216, 218.

The use of support struts 216, 218 allows the vortex oscillation sensor plate 220 to be thin, resulting in a low moving mass during oscillations. The support struts 216, 218 support the upstream and downstream edges 226, 228 of the vortex oscillation sensor plate 220 so that the vortex oscillation sensor plate 220 is stiff. The resulting system has an increased natural resonant frequency that is controlled due to the low moving mass and high stiffness. Natural resonant frequency depends on system mass and system stiffness. System mass is reduced by use of at thin vortex oscillation plate in grooves between the support struts 226, 228 and the lower end of the rotatable strut 230.

FIG. 6 illustrates an oblique view of the apparatus 200 shown in FIG. 3. According to one embodiment, the support struts 216, 218 comprise a V-shaped cross-section 240. As best seen in FIG. 6, the apparatus 200 includes an O-ring groove 213 that is shaped to receive the O ring 211. The apparatus 200 comprises a rectangular mounting flange 250 that includes mounting holes such as holes 252, 254, 256 that are sized to receive bolts for mounting the apparatus 200 to a flow tube. The apparatus 200 is replaceable in a field working environment by removal of bolts.

FIGS. 7A, 7B, 7C illustrate process steps in the manufacture of an apparatus 300 (corresponding with the apparatus 126 shown in FIGS. 1-2). In a first process step shown in FIG. 7A, the apparatus 300 is completely formed except for a vortex oscillation sensor plate 320. The vortex oscillation sensor plate 320 is missing at the step shown in FIG. 7A. The apparatus in FIG.7A comprises a slot 350 that is cut into support struts 316, 318 and into a rotatable strut 330.

In a second process step shown in FIG. 7B, a metal plate 360 is inserted in the slot 350 as illustrated. The metal plate 360 is stretched by a stretching force so that the metal plate is in tension as illustrated by arrows 362, 364. While the metal plate 360 is stretched and in tension, the metal plate 360 is continuously welded or brazed to the support struts 316, 318 and the rotatable strut 330 on both sides. After the welding or brazing is complete, the stretching force is removed.

In a third step shown in FIG. 7B, waste portions of the metal plate 360 are trimmed away, leaving a central portion of the metal plate 360 as a vortex oscillation sensor plate 320. The vortex oscillation sensor plate 320 comprises stored tensional stress 366, 368 in central rest position when it is undeflected by vortices. The stored tensional stress increases the stiffness of the vortex oscillation sensor plate 320.

Although the present disclosure is made with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention. For example, the vortex flow meter can comprise a flangeless flow tube instead of a flanged flow tube. In another example, the sensor 242 can be constructed as an integral part of the assembly 202. In yet another example, the assembly 202 can be externally threaded and screw into an opening 210 that is threaded, eliminating a need for bolts.

WHAT IS CLAIMED IS:

1. A vortex flow meter, comprising:

a pipe having a sidewall around a flow passage adapted to carry a fluid flow in a downstream direction;

a vortex shedding bar mounted in the flow passage at an upstream position and producing vortex oscillations in the fluid flow;

a diaphragm sealing an opening in the sidewall to form an isolation region at a downstream position;

a vortex oscillation sensor plate having a first rim supported on the diaphragm, an opposite second rim that is unsupported, and upstream and downstream rims that are supported;

a rotatable strut that extends along a central region of the vortex oscillation sensor plate and that extends through the diaphragm to transfer vortex oscillations from the vortex oscillation sensor plate to a sensor at a sensing location in the isolation chamber; and

an electronic transmitter circuit that receives a sensor output from the sensor and that provides an output related to flow of the fluid.

2. The vortex flow meter of Claim 1 and further comprising:

viscous material in contact with the rotatable strut in the isolation chamber, the viscous material damping rotational motion of the rotatable strut.

3. The vortex flow meter of Claim 1 wherein the vortex oscillation sensor plate has thickness that is less than 30 % of a minimum thickness of the support struts.

4. The vortex flow meter of Claim 1 further comprising support struts that limit flapping of the upstream and downstream rims.

5. The vortex flow meter of Claim 4 wherein the support struts comprise a V-shaped cross-section.

6. The vortex flow meter of Claim 1 wherein the rotatable strut is inertially balanced around a rotational axis adjacent the diaphragm.

7. The vortex flow meter of Claim 1 wherein an oscillation of a rotation motion of the rotatable strut has a damping coefficient of at least 0.4.

8. The vortex flow meter of Claim 1 wherein the vortex oscillation sensor plate comprises stored tensional stress in central rest position.

9. The vortex flow meter of Claim 1 wherein an oscillation of a rotation motion of the rotatable strut has a natural resonant frequency of at least 20 % higher than an upper frequency limit of vortex oscillation.

10. A method, comprising:

providing a pipe sidewall around a flow passage;

mounting a vortex shedding bar in the flow passage at an upstream position;

sealing an opening in the pipe sidewall with a diaphragm to form an isolation region at a downstream position;

supporting a first rim of a vortex oscillation sensor plate on the diaphragm;

providing an unsupported opposite second rim of the sensor plate;

providing supported upstream and downstream rims of the sensor plate;

extending a rotatable strut along a central region of the vortex oscillation sensor plate and through the diaphragm to transfer vortex oscillations from the vortex oscillation sensor plate to a sensor at a sensing location in the isolation chamber and sensing oscillations of the rotatable strut due to flow of a process fluid through the flow passage; and

providing an electronic transmitter circuit that receives a sensor output measuring flow of the fluid based upon the sensed oscillations.

11. The method of Claim 10 and further comprising:

placing viscous material in contact with the rotatable strut in the isolation chamber.

12. The method of Claim 10 and further comprising:

controlling a thickness of the vortex oscillation sensor plate to be less than 30 % of a minimum thickness of the support struts.

13. The method of Claim 10 and further comprising:

inertially balancing the rotatable strut around a rotational axis adjacent the diaphragm.

14. The method of Claim 10 and further comprising:

storing tensional stress in the vortex oscillation sensor plate in central rest position.

15. The method of Claim 10 and further comprising:

controlling a natural resonant frequency of an oscillation of a rotational motion of the rotatable strut to have a natural resonant frequency of at least 20 % higher than upper frequency limit of vortex oscillation.

16. The method of Claim 10 and further comprising:

shaping the support struts to have a V-shaped cross-section.

17. The method of Claim 10 and further comprising:

providing a standardized transmission signal that comprises a two wire process control loop.

18. The method of Claim 10 and further comprising:

providing a standardized transmission signal that comprises a wireless signal.

19. The method of Claim 10 and further comprising:

providing a standardized transmission signal that is selected from the group of CAN, HART and PROFIBUS industrial communication signals.

20. A vortex flow meter, comprising:

a pipe having a sidewall around a flow passage adapted to carry a fluid flow in a downstream direction;

a vortex shedding bar mounted in the flow passage at an upstream position and producing vortex oscillations in the fluid flow;

diaphragm means for sealing an opening in the sidewall to form an isolation region at a downstream position;

a vortex oscillation sensor plate having a first rim supported on the diaphragm, an opposite second rim that is unsupported, and upstream and downstream rims that are supported;

rotatable strut means for transferring vortex oscillations from the vortex oscillation sensor plate to a sensor at a sensing location in the isolation chamber; and

an electronic transmitter circuit that receives a sensor output from the sensor and that outputs a standardized transmission signal.

FIG. 1

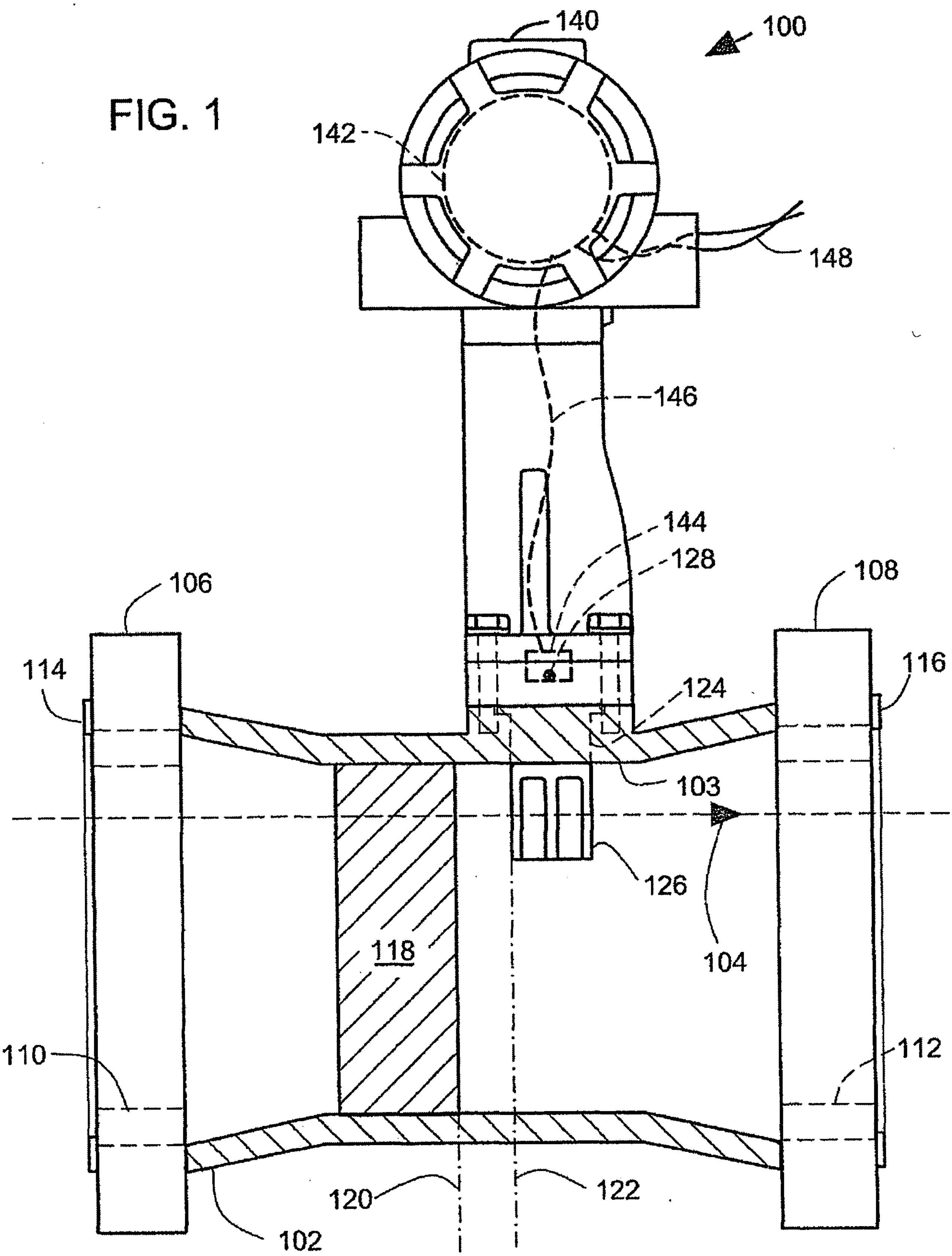
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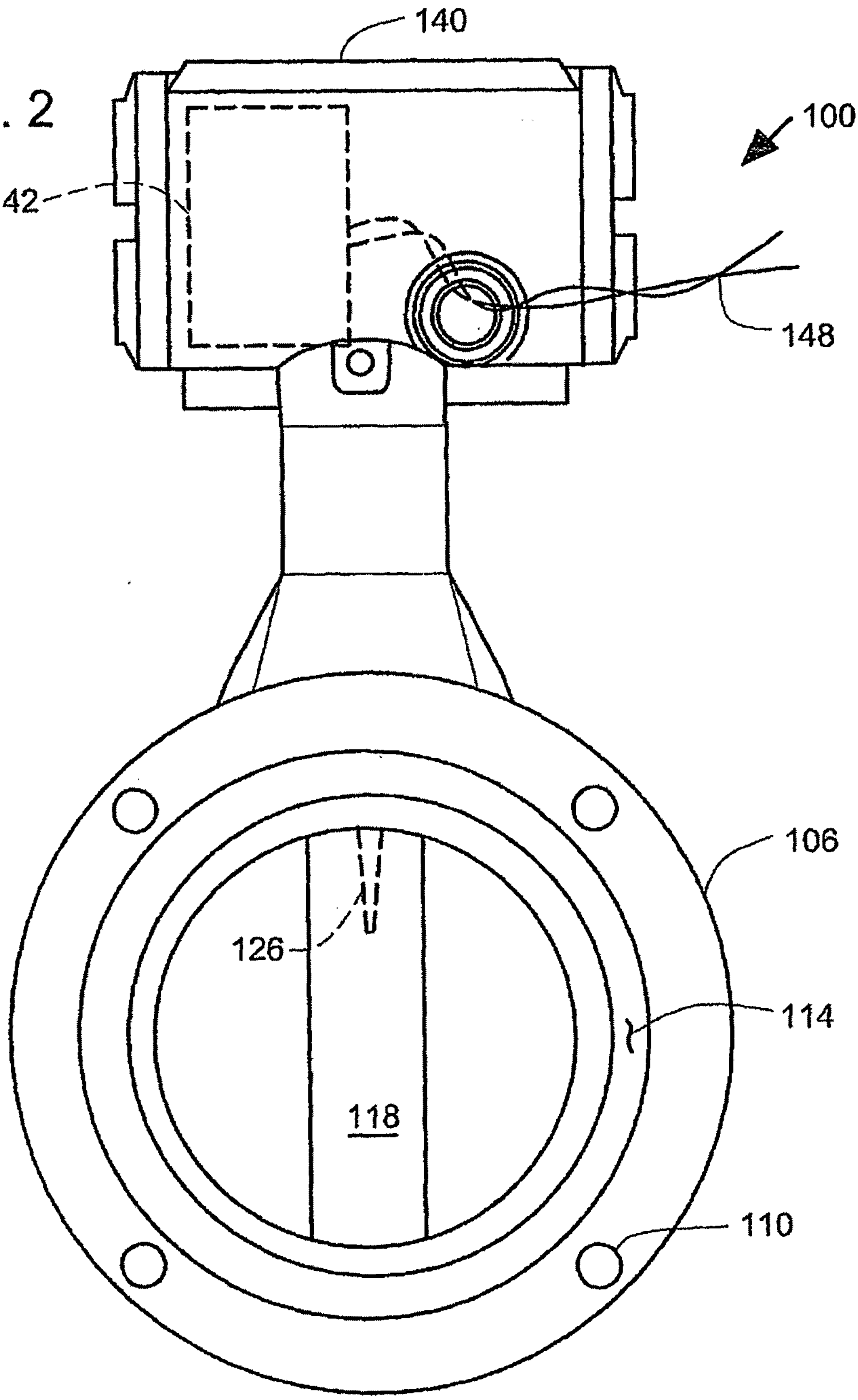
FIG. 2



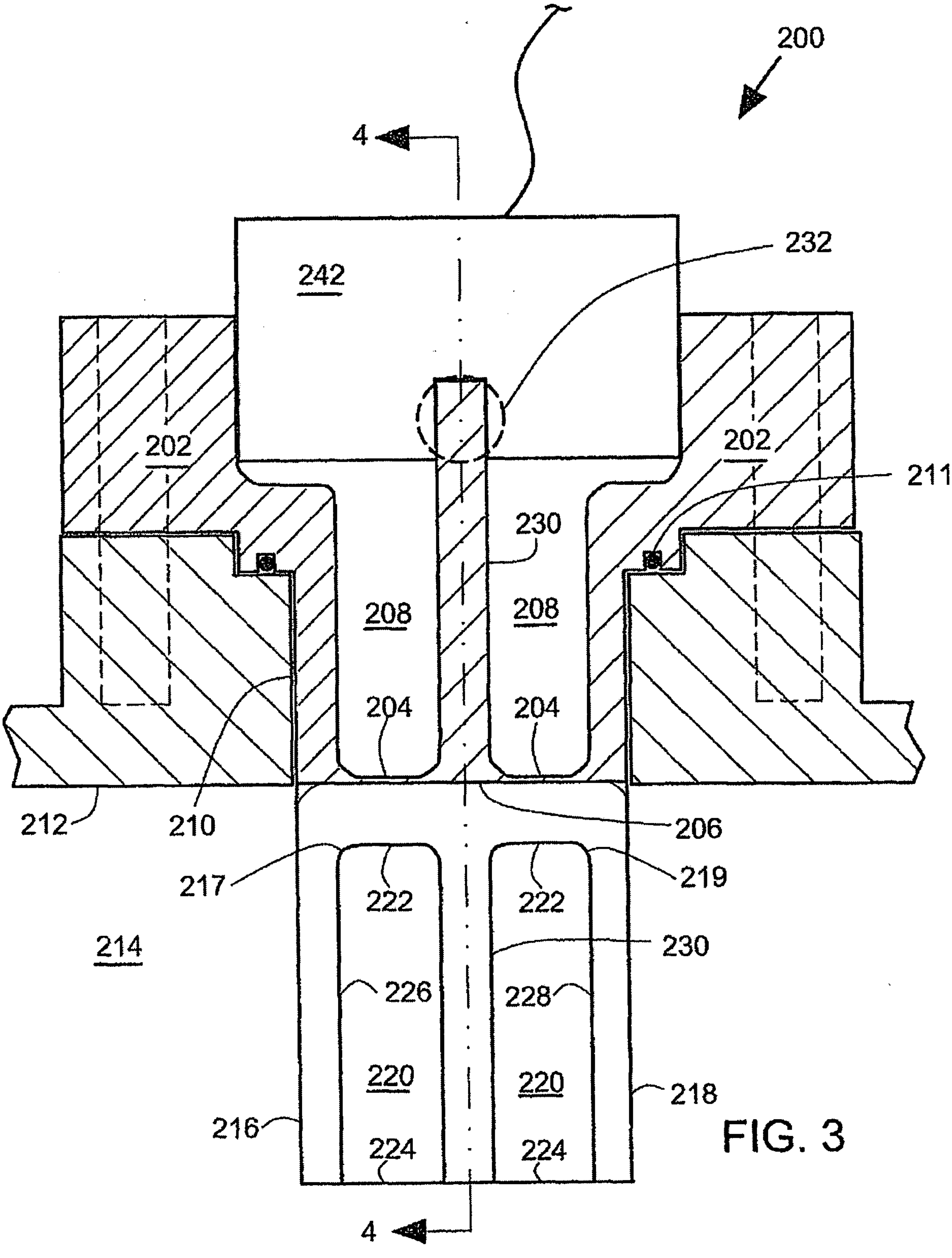

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FIG. 3

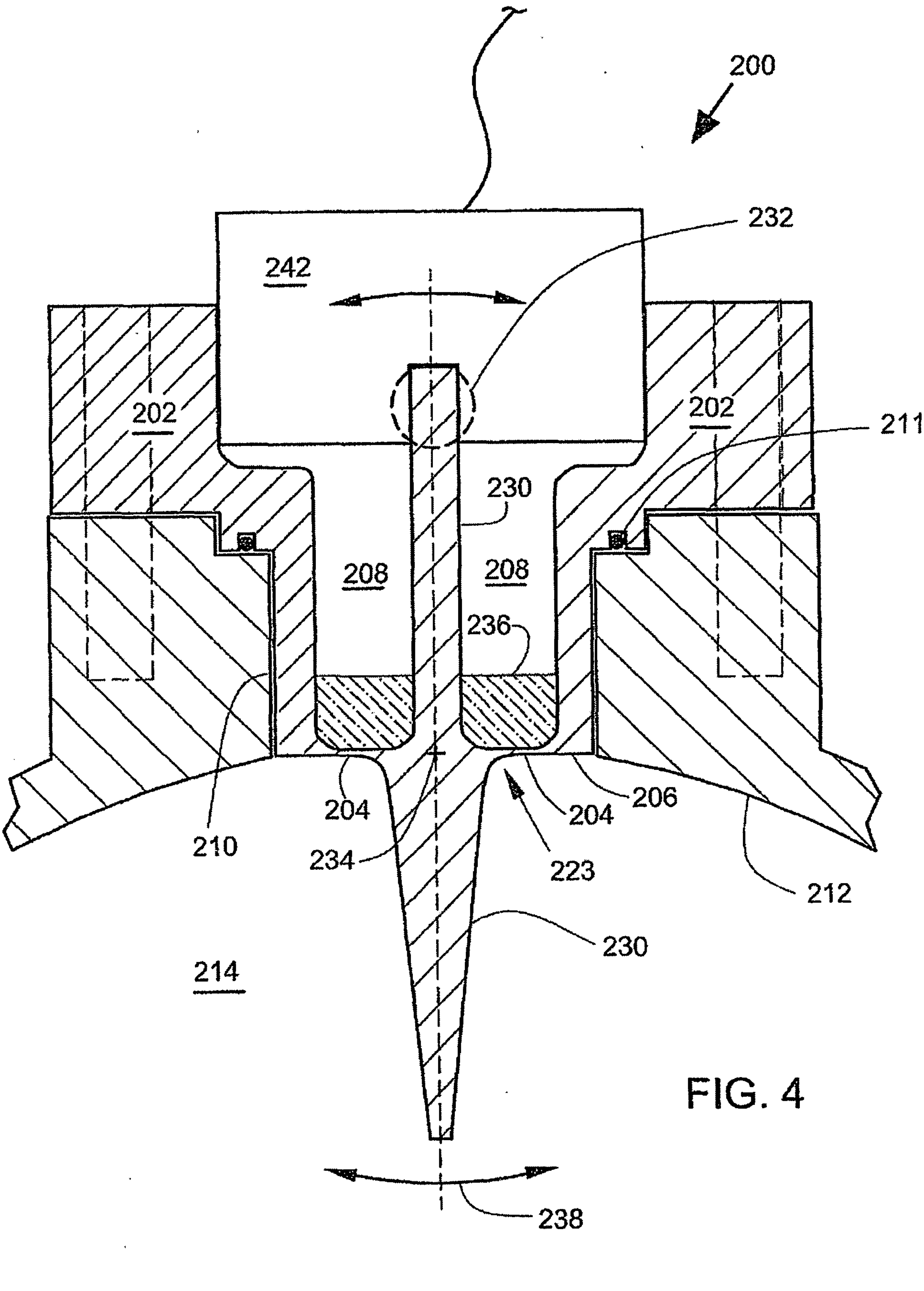
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FIG. 4

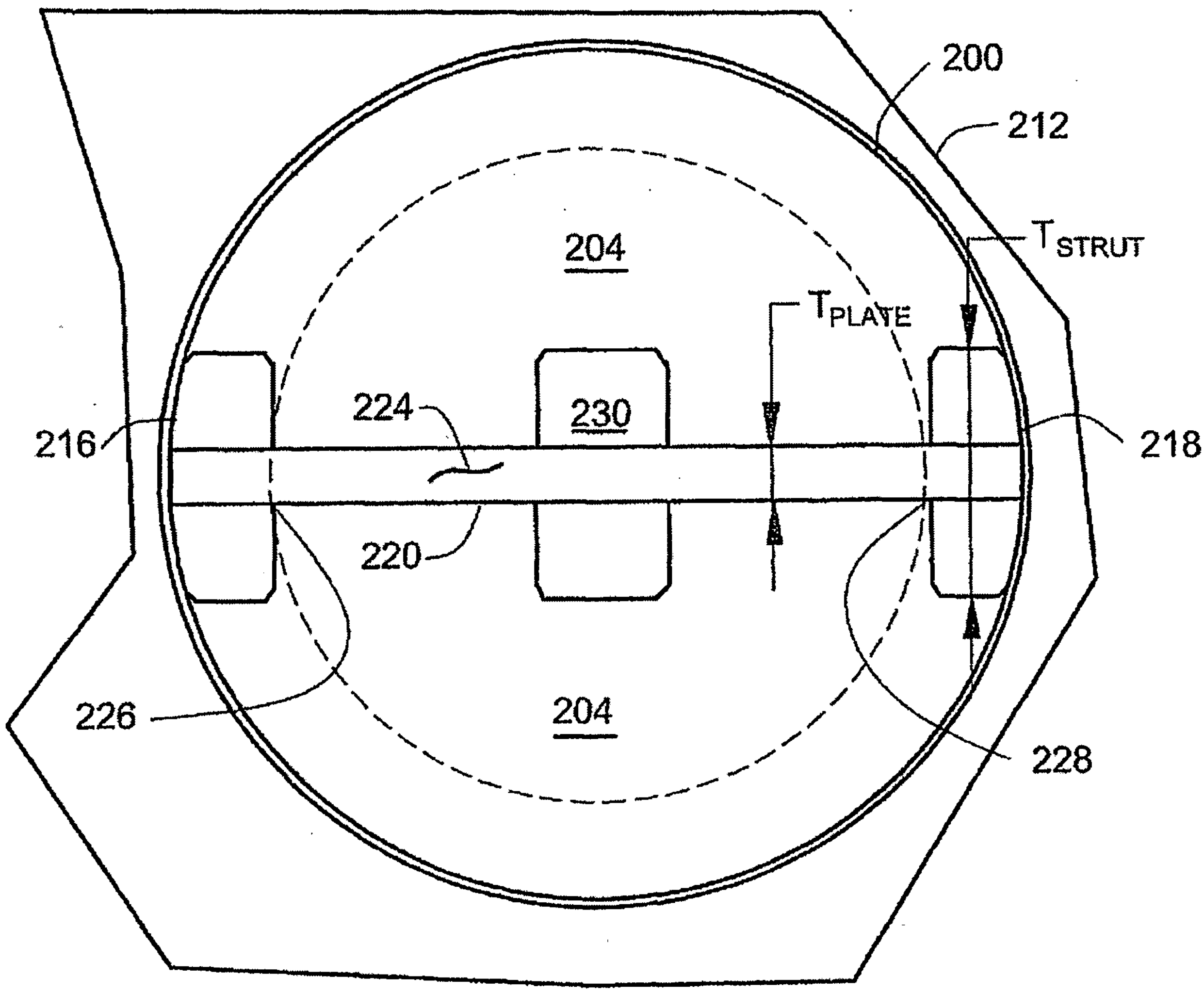


FIG. 5

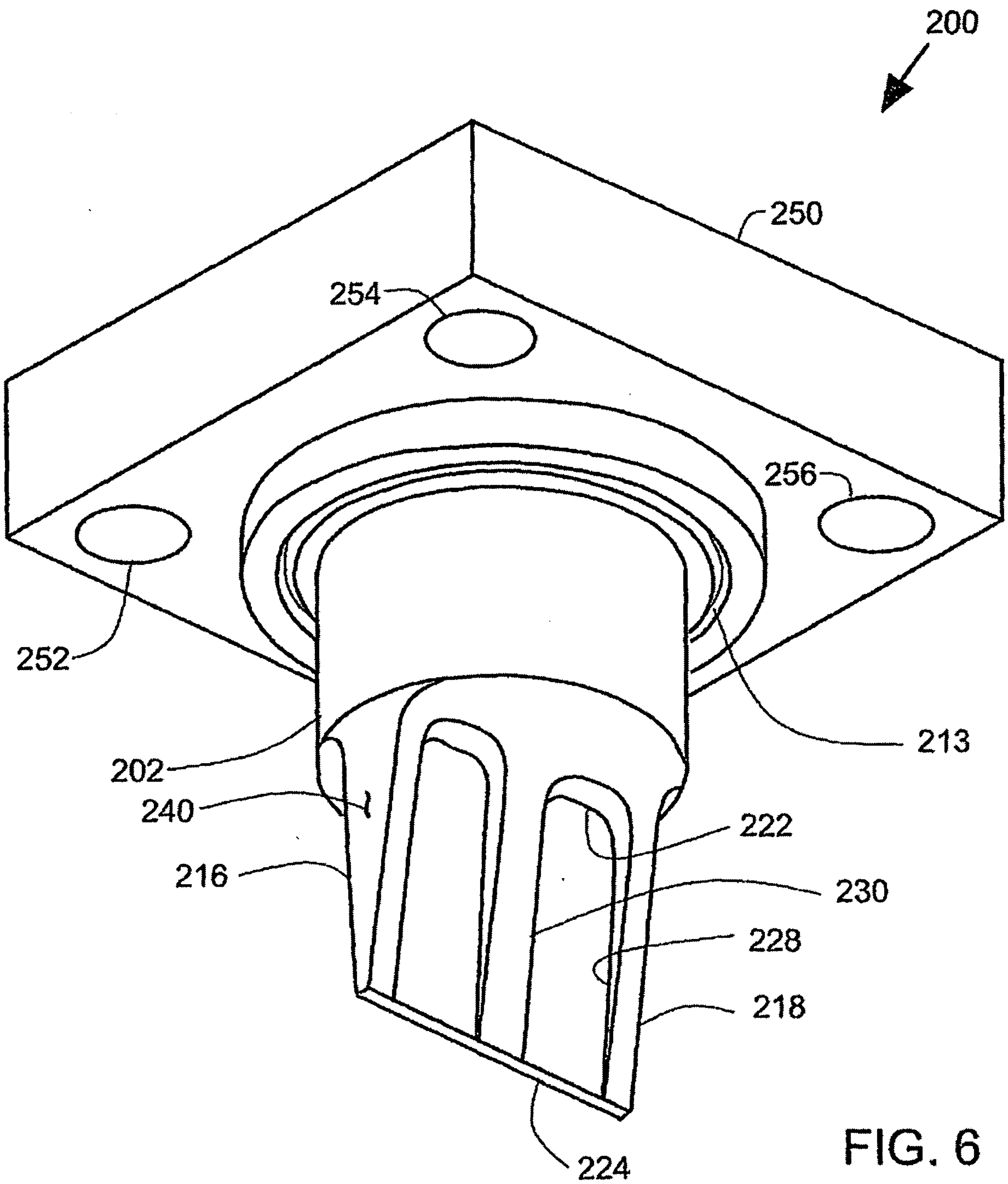


FIG. 6

FIG. 7B

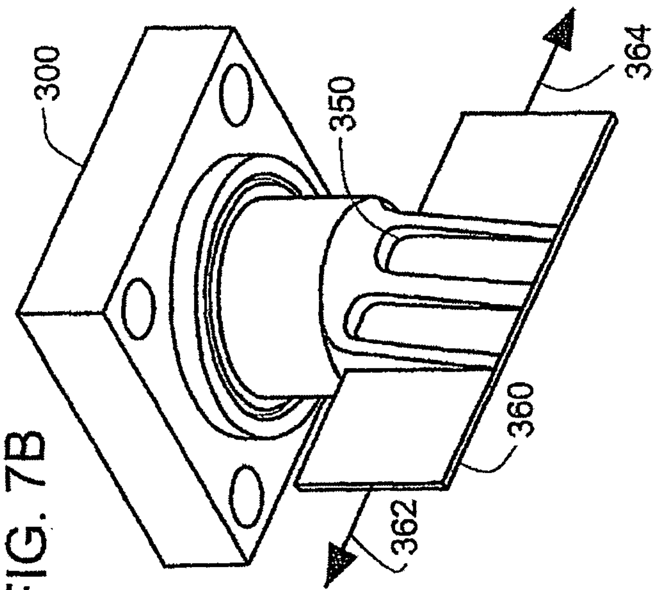


FIG. 7C

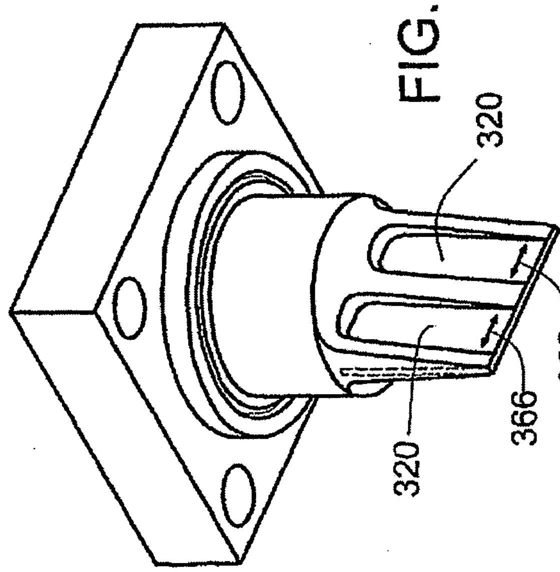
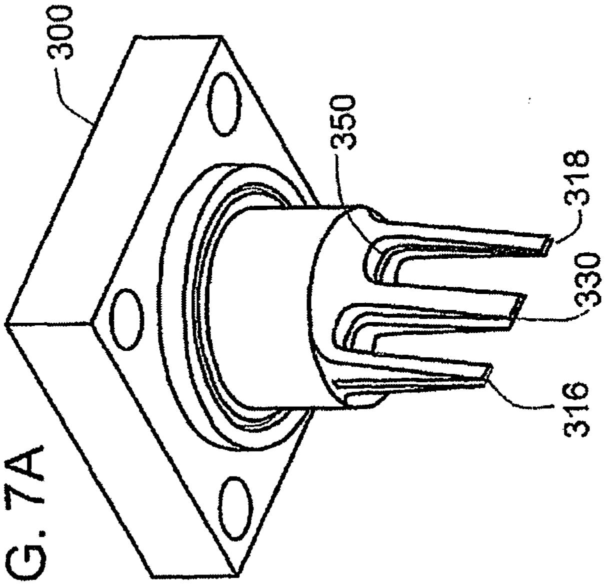


FIG. 7A



INTERNATIONAL SEARCH REPORT

International application No
PCT/RU2009/000722

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01F1/32
ADD.

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)
G01F

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 2005/210998 A1 (DIMARCO STEVEN J [US] ET AL) 29 September 2005 (2005-09-29)	1,4,10, 20
A	paragraph [0057] - paragraph [0059]; figures 7,9A,9B,9C	2,3,5-9, 11-19
X	US 2004/216532 A1 (KOUDAL OLE [CH] ET AL KOUDAL OLE [CH] ET AL) 4 November 2004 (2004-11-04)	1,10,20
A	paragraph [0043] - paragraph [0046]; figures 3,4	2-9, 11-19
A	US 6 237 425 B1 (WATANOBE AKIKO [JP]) 29 May 2001 (2001-05-29) the whole document	1-20

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

☒ See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
24 August 2010	22/09/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Fenzl, Birgit

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/RU2009/000722

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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