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McCormack

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- (54) **CRYOGENIC CAM BUTTERFLY VALVE**
- (71) Applicant: **The United States of America as
Represented by the Administrator of
the National Aeronautics and Space
Administration, Washington, DC (US)**
- (72) Inventor: **Kenneth J. McCormack, Slidell, LA
(US)**
- (73) Assignee: **The United States of America as
represented by the Administrator of
the National Aeronautics and Space
Administration, Washington, DC (US)**
- (*) Notice: Subject to any disclaimer, the term of this
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U.S.C. 154(b) by 112 days.

3,260,496 A	7/1966	Borcherdt	
3,587,631 A *	6/1971	Dern	F16K 15/03 137/527
3,902,694 A	9/1975	Friedell	
4,042,173 A *	8/1977	Boyer	F24F 11/04 137/486
4,204,408 A *	5/1980	Dawson	A21D 15/02 34/559
4,770,392 A *	9/1988	Schmidt	F16K 1/24 251/158
4,921,212 A	5/1990	deQuay	
5,330,157 A *	7/1994	Dern	F16K 1/24 251/162
2010/0206406 A1 *	8/2010	Nakamura	F02M 25/074 137/544
2011/0036408 A1 *	2/2011	Desai	F16K 15/063 137/1
2011/0042599 A1 *	2/2011	Arai	F16K 1/2263 251/251

OTHER PUBLICATIONS

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- (22) Filed: **Aug. 19, 2014**

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19, 2013.
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F16K 1/22 (2006.01)
F17C 13/04 (2006.01)
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CPC **F16K 1/221** (2013.01); **F16K 31/524**
(2013.01); **F17C 13/04** (2013.01)
- (58) **Field of Classification Search**
CPC F16K 31/524
USPC 251/160, 162, 163, 180, 192, 305
See application file for complete search history.

References Cited

U.S. PATENT DOCUMENTS

3,077,331 A	5/1959	Burtis
3,077,332 A	2/1960	Burtis
3,156,445 A	9/1964	Swain

“Post-Seal Type A431A Cryogenic High Performance Butterfly
Valve,” Feb. 2005, http://www.documentation.emersonprocess.com/groups/public/documents/instruction_manuals/d500242x012.pdf.

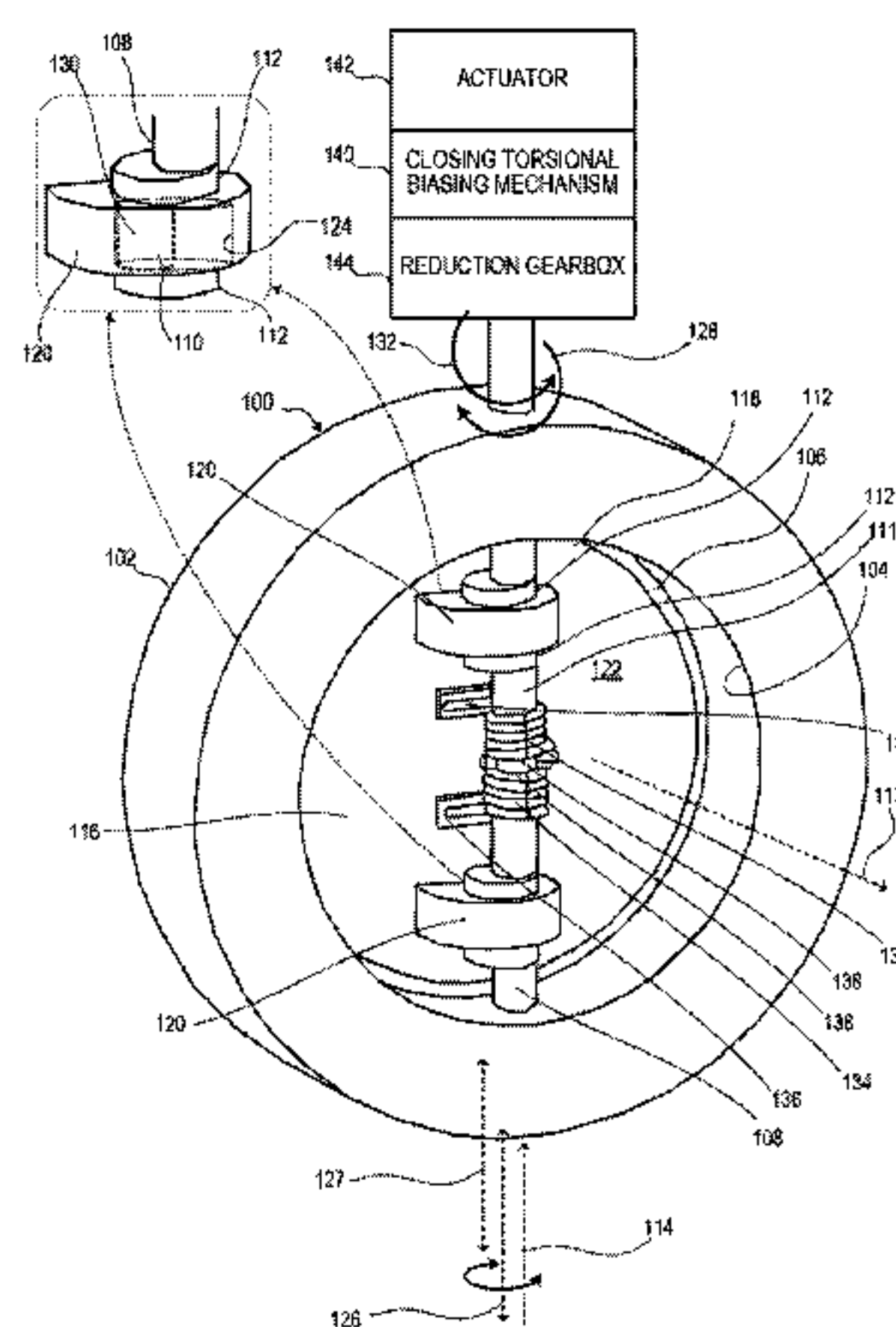
(Continued)

Primary Examiner — Kevin Murphy
Assistant Examiner — Paul J Gray

(57) **ABSTRACT**

A cryogenic cam butterfly valve has a body that includes an axially extending fluid conduit formed there through. A disc lug is connected to a back side of a valve disc and has a circular bore that receives and is larger than a cam of a cam shaft. The valve disc is rotatable for a quarter turn within the body about a lug axis that is offset from the shaft axis. Actuating the cam shaft in the closing rotational direction first causes the camming side of the cam of the cam shaft to rotate the disc lug and the valve disc a quarter turn from the open position to the closed position. Further actuating causes the camming side of the cam shaft to translate the valve disc into sealed contact with the valve seat. Opening rotational direction of the cam shaft reverses these motions.

19 Claims, 8 Drawing Sheets



(56)

References Cited

“Butterfly valve,” http://en.wikipedia.org/wiki/Butterfly_valve, accessed Jun. 23, 2014.

OTHER PUBLICATIONS

“Globe valve,” http://en.wikipedia.org/wiki/Globe_valve, accessed Jun. 23, 2014.

“Cryogenic Butterfly Valves,” <http://www.everestvalveusa.com/cryogenic-valves.html>, accessed Jun. 23, 2014.

* cited by examiner

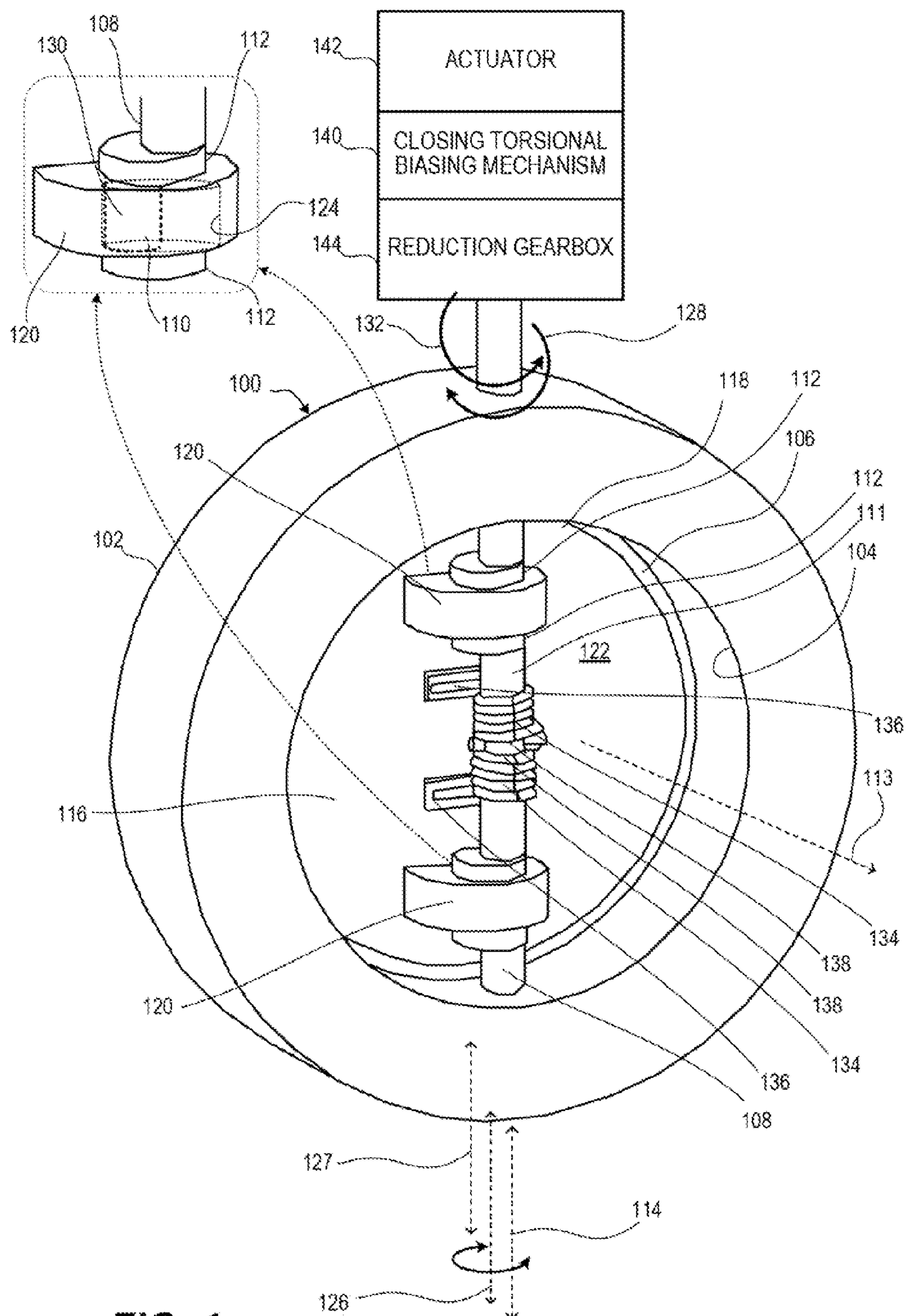


FIG. 1

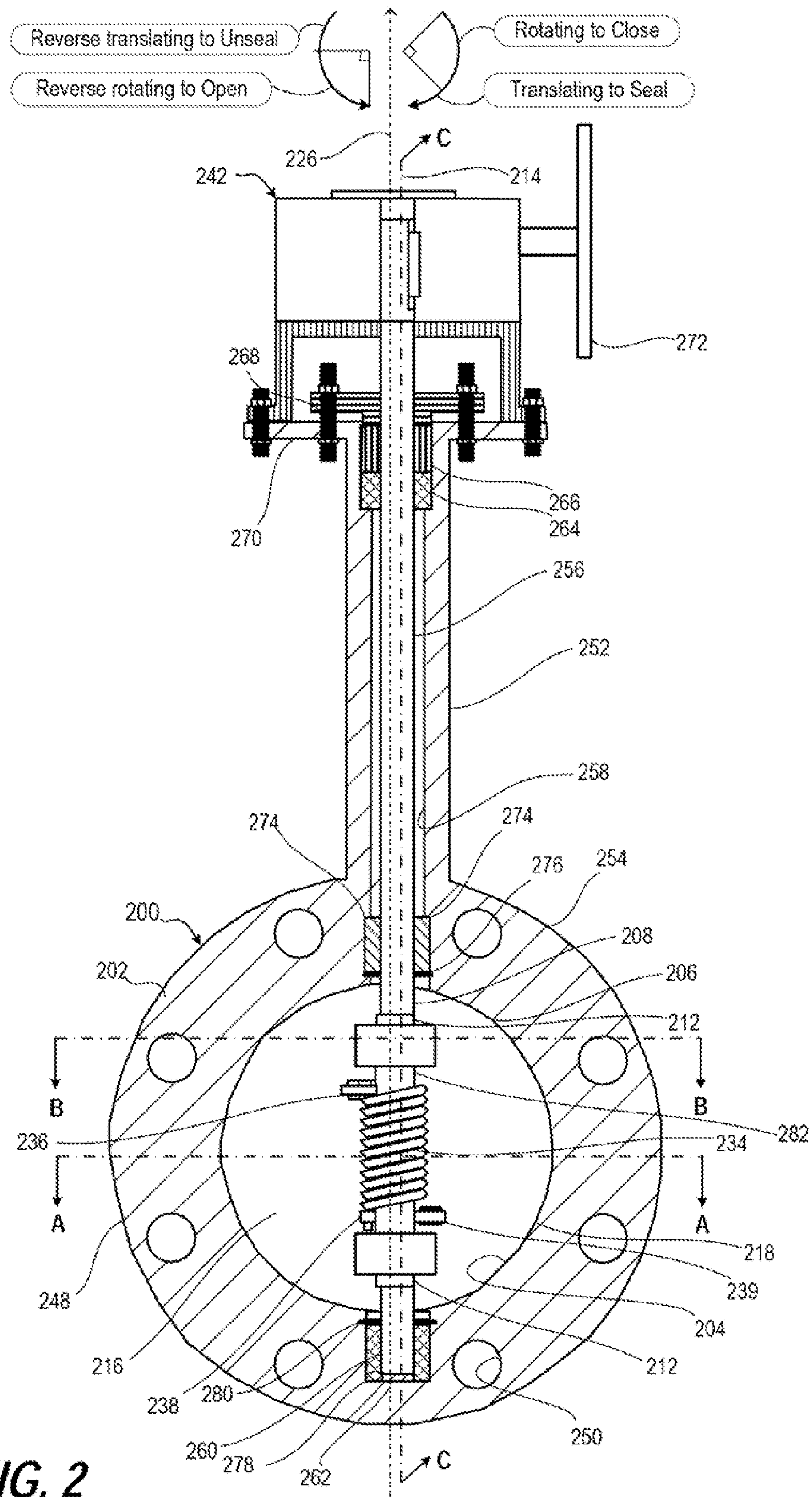


FIG. 2

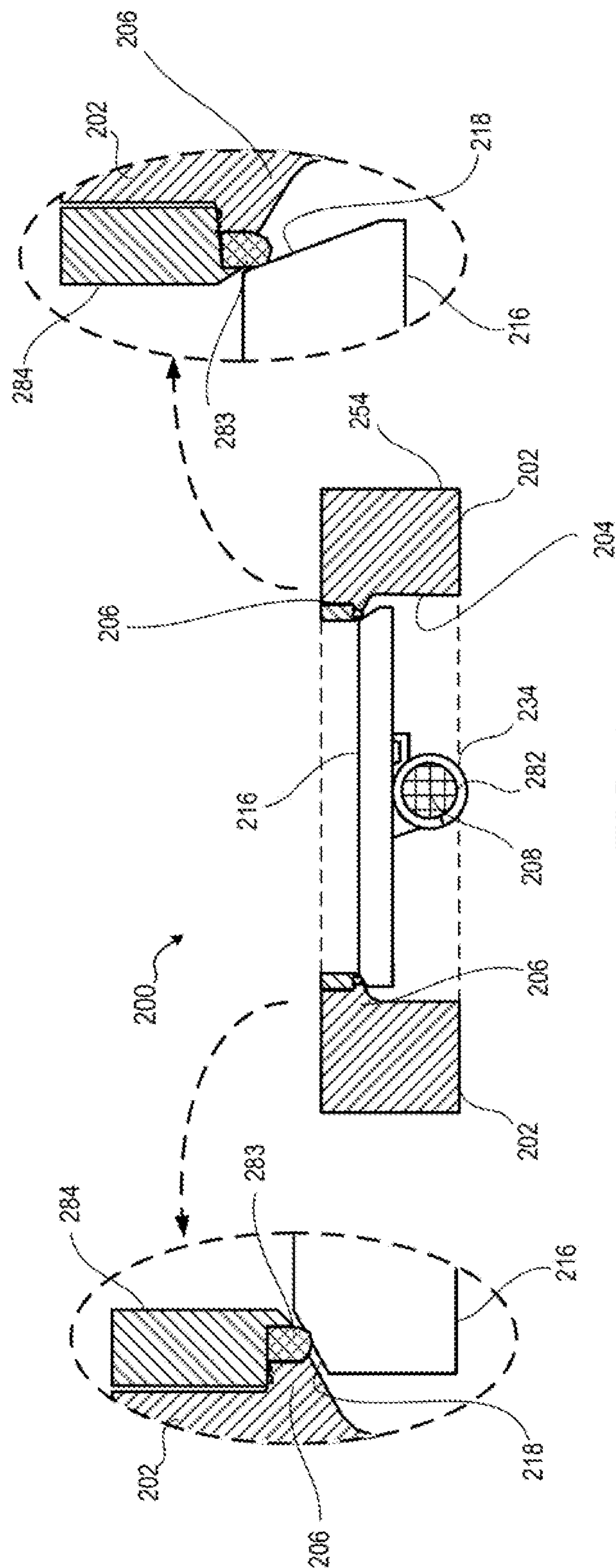


FIG. 3
VIEW A-A

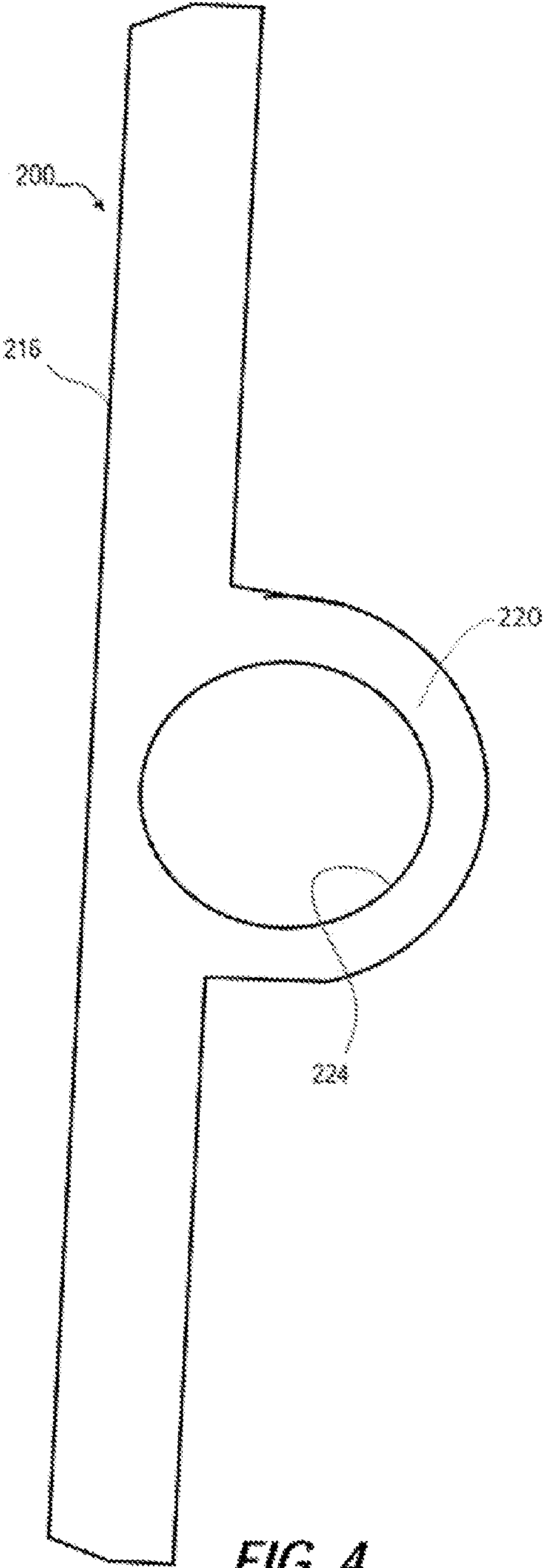


FIG. 4
VIEW B-B

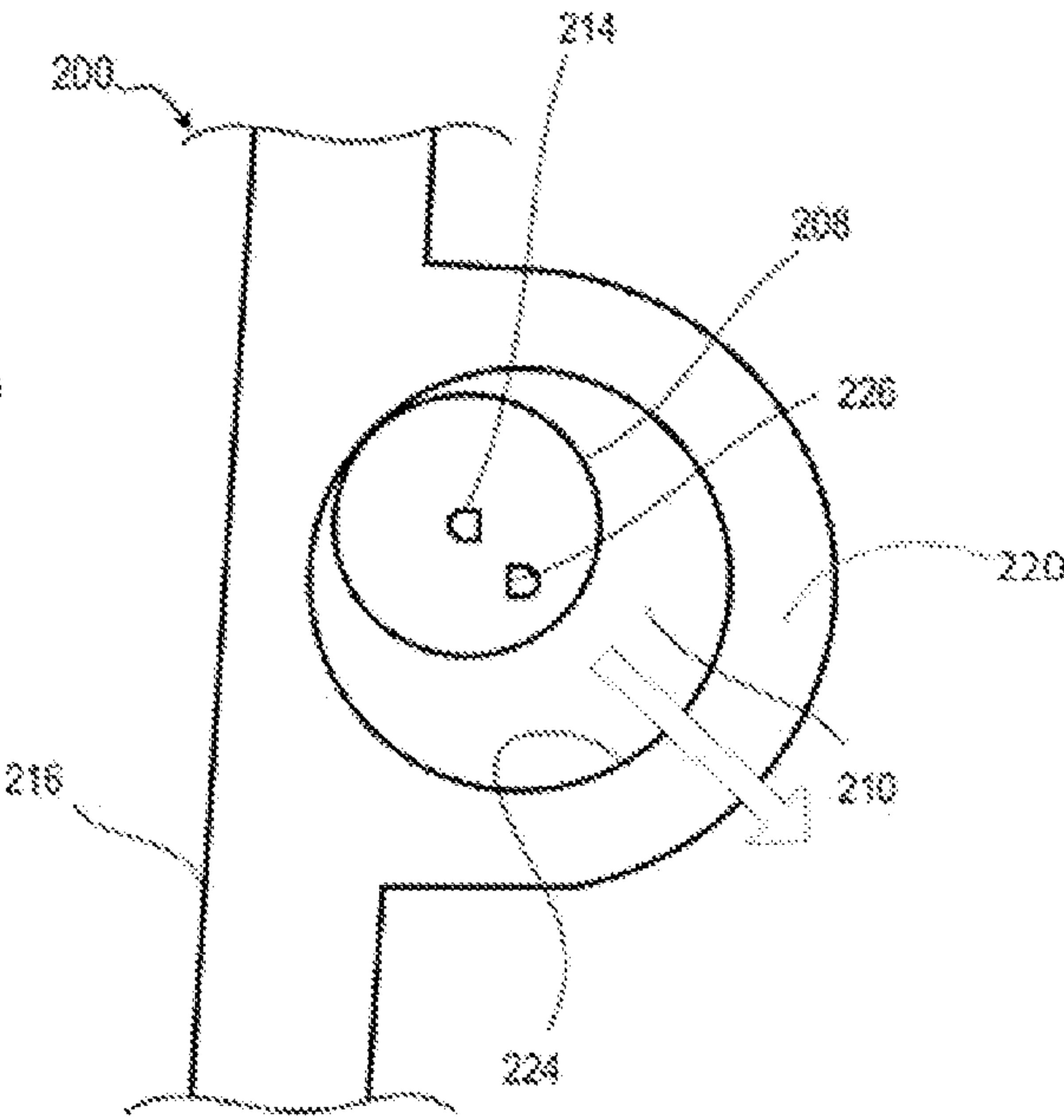


FIG. 5
VIEW B-B

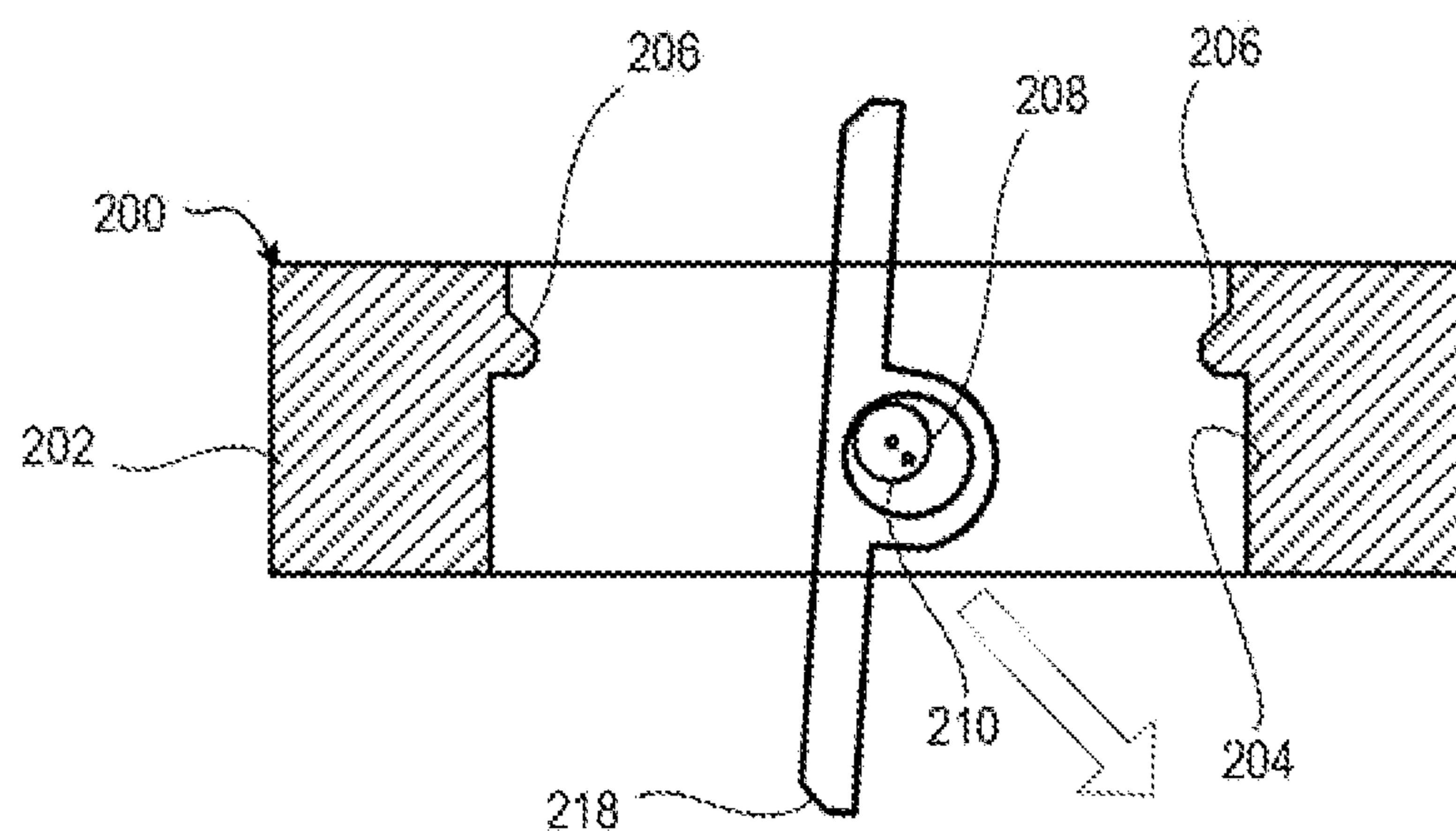


FIG. 6

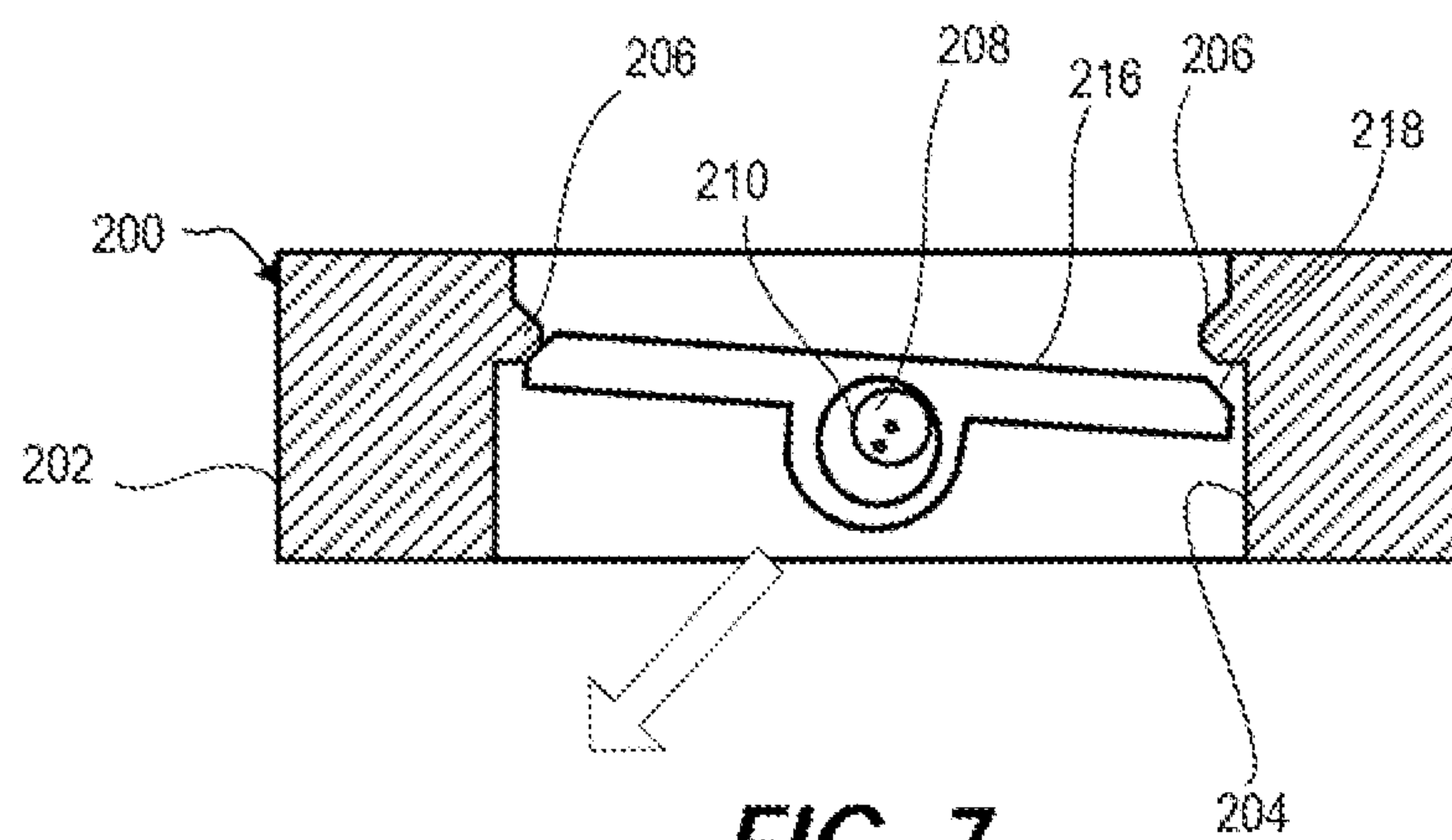


FIG. 7

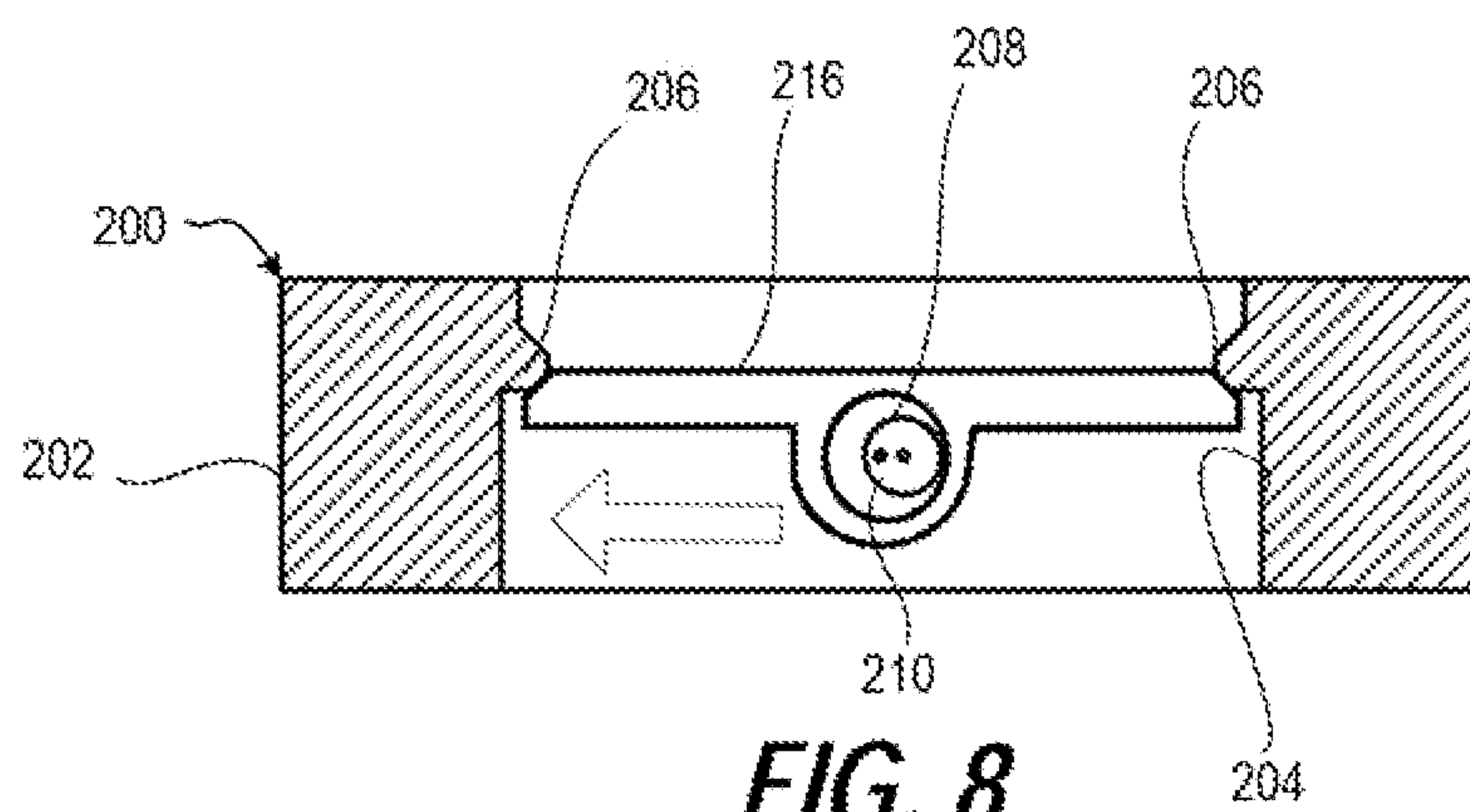


FIG. 8

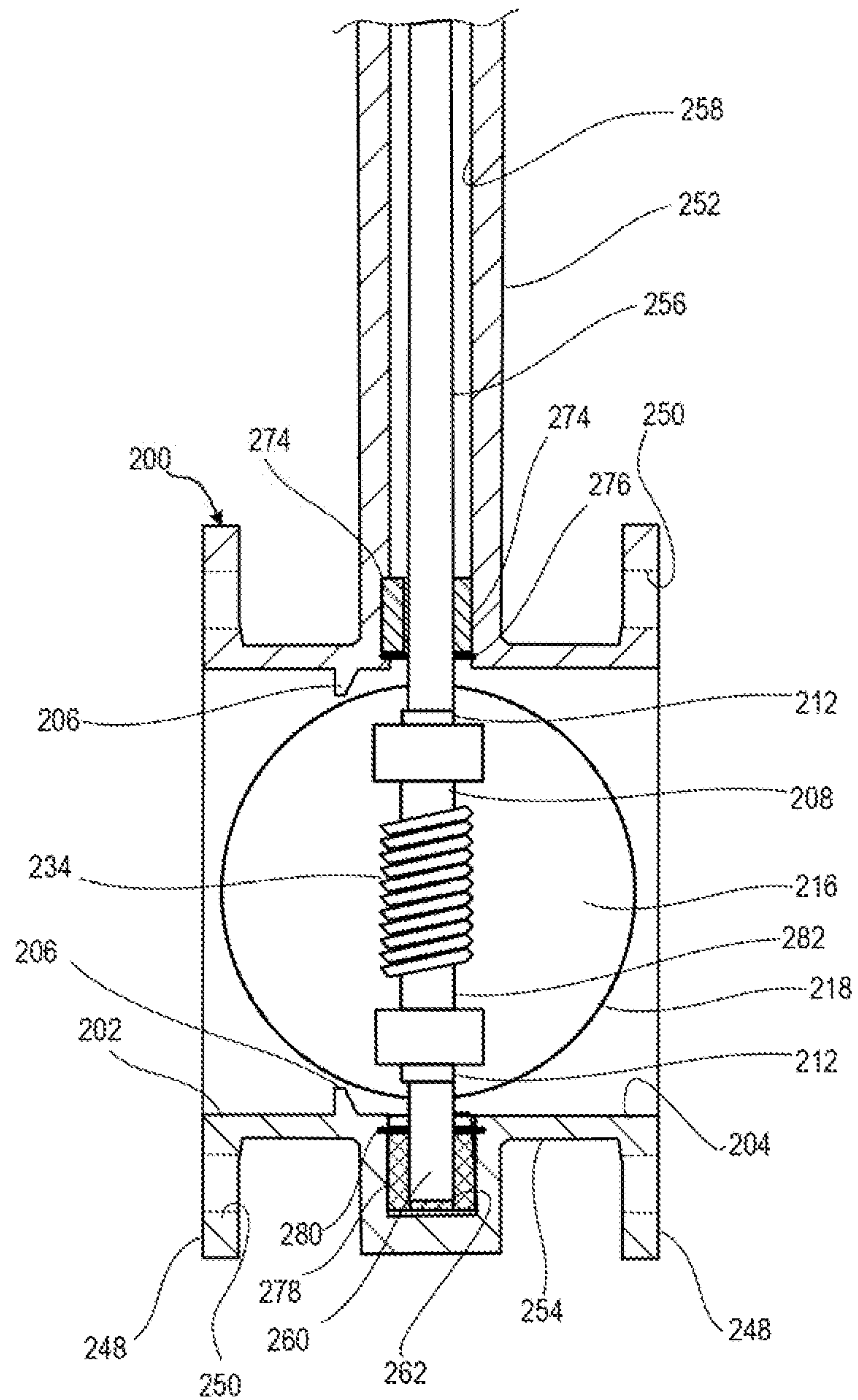


FIG. 9

VIEW C-C (Full Open)

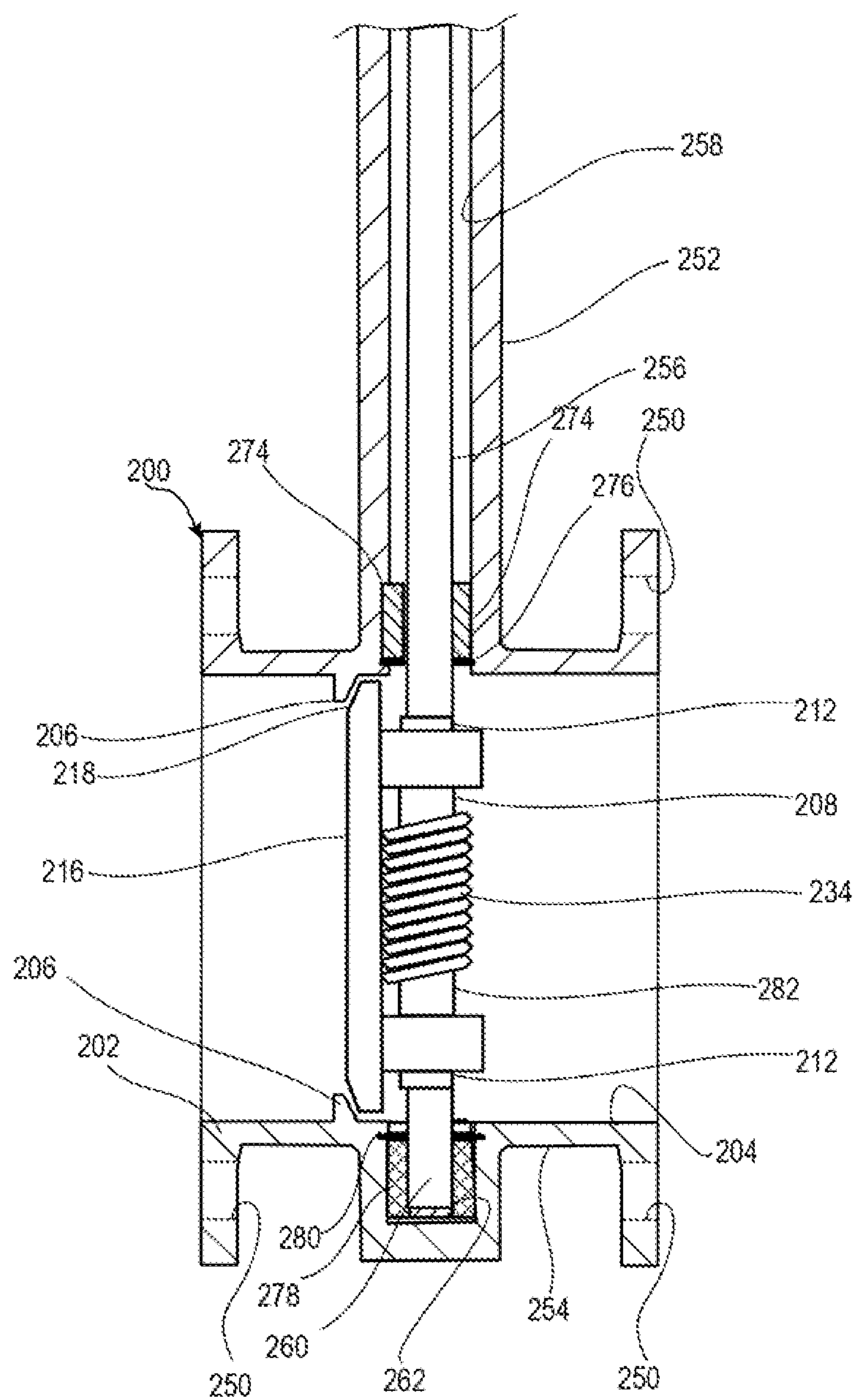


FIG. 10

VIEW C-C (Full Closed)

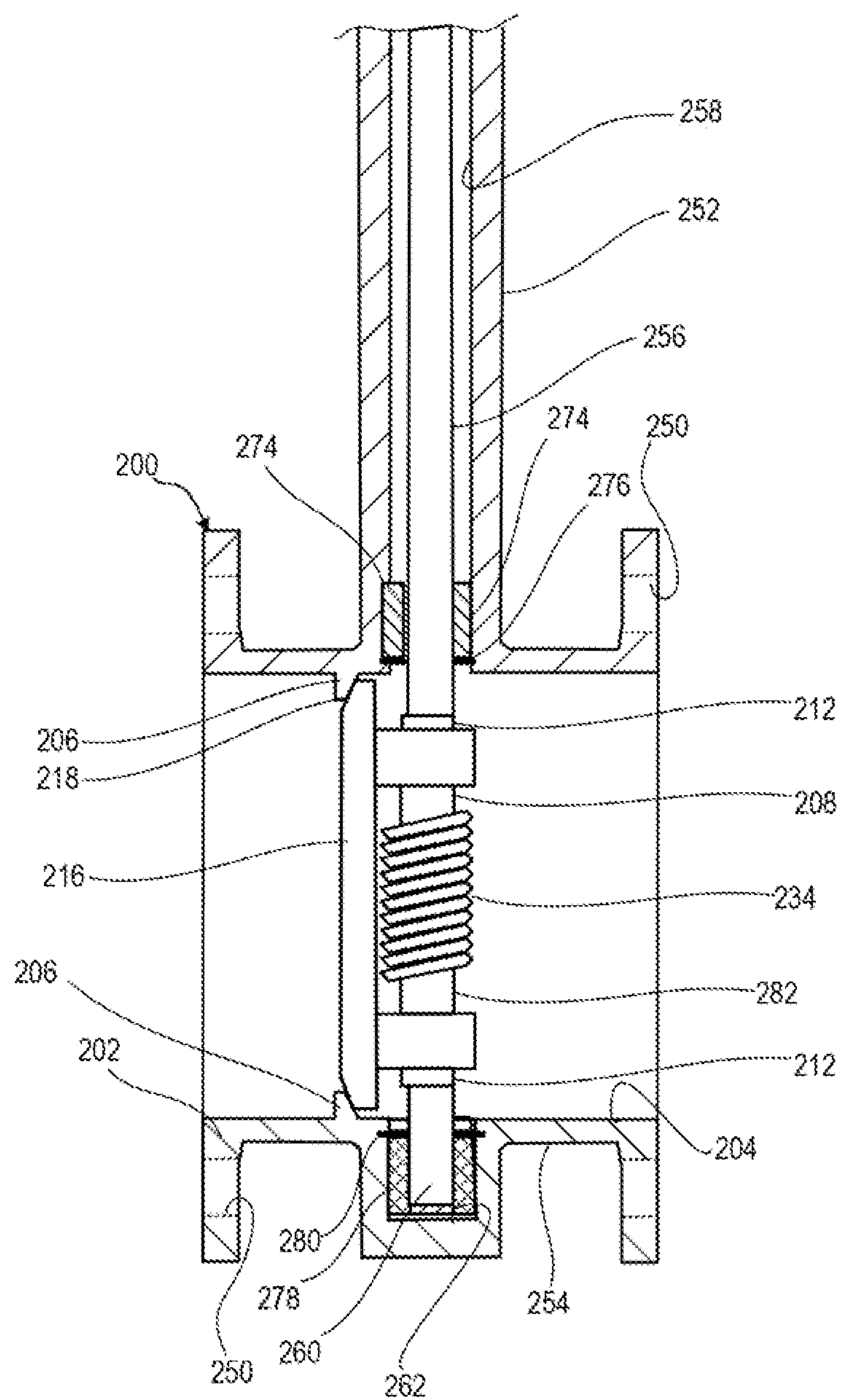


FIG. 11
VIEW C-C (Fully Sealed)

CRYOGENIC CAM BUTTERFLY VALVE**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims the benefit of priority under 35 U.S.C. §119(e) to U.S. Provisional Application Ser. No. 61/867,190 entitled "Cryogenic Cam Butterfly Valve," filed Aug. 19, 2013, the contents of which are incorporated herein by reference in its entirety.

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of 51 U.S.C. §20135.

BACKGROUND OF THE INVENTION**1. Technical Field**

The present invention generally relates to fluid stop valves, and more particularly to a butterfly valve that can effectively operate across a wide range of temperatures including cryogenic temperatures.

2. Description of the Related Art

A generally-known butterfly valve is a valve which can be used for isolating or regulating flow. The closing mechanism takes the form of a disc. Operation is similar to that of a ball valve, which allows for quick shut off. Butterfly valves are generally favored because they are lower in cost to other valve designs as well as being lighter in weight, meaning less support is required. The disc is positioned in the center of the pipe. Passing through the disc is a rod connected to an actuator on the outside of the valve. Rotating the actuator turns the disc either parallel or perpendicular to the flow. Unlike a ball valve, the disc is always present within the flow. Therefore a pressure drop is always induced in the flow, regardless of valve position. A butterfly valve is from a family of valves called quarter-turn valves. In operation, the valve is fully open or closed when the disc is rotated a quarter turn. The "butterfly" is a metal disc mounted on a rod. When the valve is closed, the disc is turned so that it completely blocks off the passageway. When the valve is fully open, the disc is rotated a quarter turn so that it allows an almost unrestricted passage of the fluid. The valve may also be opened incrementally to throttle flow.

The high flow rate and relatively low pressure drop at full flow are some of the advantages that butterfly valves have over other valves. Other advantages include simplicity of operation, compact valve body and relatively low cost. However, balanced against these advantages butterfly valves have high valve seat wear and inability to maintain a tight seal. Additionally, if the valve is used to throttle the fluid flow or to frequently cycle to open and closed positions, these disadvantages are amplified and additionally frequent repair is required. Therefore a need exists for a butterfly valve with improved sealing characteristics, and in particular for cryogenic applications.

BRIEF SUMMARY OF THE INVENTION

In one aspect, the present invention provides a cam butterfly valve that includes a body including an axially extending fluid conduit formed there through. A valve seat projects from the body annularly within the fluid conduit. A cam shaft has a cam of circular cross section, disposed transverse to an axis of the fluid conduit, and journally

mounted within the body to rotate about a shaft axis. A valve disc has a seating surface that corresponds in a closed position to the valve seat of the body. A disc lug is connected to a back side of the valve disc and has a circular bore that receives and is larger than the cam of the cam shaft. The valve disc is rotatable for a quarter turn within the body about a lug axis that is offset from the shaft axis. Actuating the shaft in the closing rotational direction first causes the camming side of the cam of the cam shaft to rotate the disc lug and the valve disc a quarter turn from the open position to the closed position. Further actuating causes the camming side of the shaft to translate the valve disc into sealed contact with the valve seat. Actuating the shaft in an opening rotational direction first causes the camming side of the cam of the cam shaft to reverse translate the valve disc to unseal from the valve seat. Continued actuating causes the camming side of the shaft to reverse rotate the disc lug and valve disc a quarter turn from the closed position to the open position.

In another aspect, the present invention provides a cryogenic cam butterfly valve having a body that includes an axially extending fluid conduit formed there through. A valve seat projects from the body annularly within the fluid conduit. A cam shaft has a cam of circular cross section, is disposed transverse to an axis of the fluid conduit, and is journally mounted within the body to rotate about a shaft axis. A valve disc has a seating surface that corresponds in a closed position to the valve seat of the body. A disc lug is connected to a back side of the valve disc and having a circular bore that receives and is larger than the cam of the cam shaft. The valve disc is rotatable for a quarter turn within the body about a lug axis that is offset from the shaft axis. At least one torsion spring is mounted concentrically on the cam shaft with one spring leg against the valve disc with a preloaded of sufficient torque to cause the valve disc to rigidly move with the cam shaft. A biasing mechanism is operatively coupled to the shaft. Actuating the shaft in the closing rotational direction first causes the camming side of the cam of the cam shaft to rotate the disc lug and the valve disc a quarter turn from the open position to the closed position. Further actuating causes the camming side of the shaft to translate the valve disc into sealed contact at an ambient temperature with the valve seat. The biasing mechanism asserts a closing bias rotation to the cam shaft to cause additional translation to maintain the sealed contact during cool down to a cryogenic temperature. Actuating the shaft in an opening rotational direction first causes the camming side of the cam of the cam shaft to reverse translate the valve disc to unseal from the valve seat and continued actuating causes the camming side of the shaft to reverse rotate the disc lug and valve disc a quarter turn from the closed position to the open position.

The above summary contains simplifications, generalizations, and omissions of detail and is not intended as a comprehensive description of the claimed subject matter but, rather, is intended to provide a brief overview of some of the functionality associated therewith. Other systems, methods, functionality, features, and advantages of the claimed subject matter will be, or will become, apparent to one with skill in the art upon examination of the following figures and detailed written description.

BRIEF DESCRIPTION OF THE DRAWINGS

The description of the illustrative embodiments can be read in conjunction with the accompanying figures. It will be appreciated that for simplicity and clarity of illustration,

elements illustrated in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements are exaggerated relative to other elements. Embodiments incorporating teachings of the present invention are shown and described with respect to the figures presented herein, in which:

FIG. 1 illustrates an isometric view of a cam butterfly valve, according to one embodiment;

FIG. 2 illustrates a side view of a cam butterfly valve having a valve housing particularly cutaway to expose a valve disc and cam shaft, according to one embodiment;

FIG. 3 illustrates a top view of the cam butterfly valve of FIG. 2 cut away along lines A-A and including left and right detail views of left and right sealed contacts between a valve seat and a valve disc, according to one embodiment;

FIG. 4 illustrates a top view of a valve disc taken in cross section through a disc lug along lines B-B of FIG. 2, according to one embodiment;

FIG. 5 illustrates a detail view of a circular bore of a disc lug and a cam taken in cross section along lines B-B of FIG. 2, according to one embodiment;

FIG. 6 illustrates a diagrammatic view of the cam butterfly valve of FIG. 2 in a full open (0°) position, according to one embodiment;

FIG. 7 illustrates a diagrammatic view of the cam butterfly valve of FIG. 2 in a closed (90°) position after a quarter turn, according to one embodiment;

FIG. 8 illustrates a diagrammatic view of the cam butterfly valve of FIG. 2 in a sealed ($\sim 135^\circ$) position after further closing actuation, according to one embodiment;

FIG. 9 illustrates a left side view of the cam butterfly valve in a full open (0°) position cut away along lines C-C of FIG. 2, according to one embodiment;

FIG. 10 illustrates a left side view of the cam butterfly valve in a full closed (90°) position cut away along lines C-C of FIG. 2, according to one embodiment; and

FIG. 11 illustrates a left side view of the cam butterfly valve in a sealed ($\sim 135^\circ$) position cut away along lines C-C of FIG. 2, according to one embodiment.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to valves and, more particularly, to a cam butterfly valve having a rotatable and slidable closure disk that provides the full flow advantages of a butterfly valve and the throttling and sealing advantages of globe and needle valves. The cam butterfly valve has particular application to cryogenic fluid transfer systems wherein the temperature range can vary between ambient temperatures and cryogenic temperatures. The ability of the cam butterfly valve to translate its valve disc into sealing contact with a valve seat overcomes dimensional changes within the valve due to a significant change in temperature. This ability to translate like globe and needle valves provides good sealing and throttling capability because the valve disc or plug position can be closely regulated. Furthermore, because of the linear movement of the valve disc and its ability to be closely positioned within the valve seat, good sealing can be obtained.

A typical configuration for a butterfly valve consists of a 'butterfly' disc mounted to a shaft, which is then mounted in the valve body. The shaft is rotated by an actuator, which can be operated manually by a hand wheel, or by other mechanical means, such as an electric motor or hydraulic/pneumatic cylinders. The butterfly disc rotates 90° to control the flow of fluid through the valve. Thus, a generally-known butterfly

fly has a quarter turn (90°) actuator wherein a valve disk can only rotate. The valve disk is pinned rigidly to a plain shaft.

The main problem with most typical butterfly valves is that they cannot seal at both ambient and cryogenic temperatures. The vast temperature differences that a cryogenic valve encounters makes the valve grow and shrink, which changes critical valve dimensions, such as the distance between the disc and seat. The valve must be able to compensate for these changing dimensions or it will not be able to hold tight seat leakage (i.e., will not prevent leaks when closed) throughout the temperature range. In order to address wear and dimensional changes due to temperature, some generally-known butterfly valves attempt to compensate for this challenge by including dynamic and complex seals for cryogenic applications.

The lack of a reliable cryogenic butterfly valve resulted in the need for a new, novel valve design which provides a better seal in cryogenic environments. The Cryogenic Cam Butterfly Valve (hereinafter "CCBV") met this need. The CCBV can hold tight seat leakage no matter how drastic the dimensional changes are due to changing operating temperatures because the valve disc can translate in addition to rotating.

In the following detailed description of exemplary embodiments of the invention, specific exemplary embodiments in which the invention may be practiced are described in sufficient detail to enable those skilled in the art to practice the disclosed embodiments. For example, specific details such as specific method orders, structures, elements, and connections have been presented herein. However, it is to be understood that the specific details presented need not be utilized to practice embodiments of the present invention. It is also to be understood that other embodiments may be utilized and that logical, architectural, programmatic, mechanical, electrical and other changes may be made without departing from general scope of the invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims and equivalents thereof.

References within the specification to "one embodiment," "an embodiment," "embodiments," or "one or more embodiments" are intended to indicate that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. The appearance of such phrases in various places within the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments. Further, various features are described which may be exhibited by some embodiments and not by others. Similarly, various requirements are described which may be requirements for some embodiments but not other embodiments.

It is understood that the use of specific component, device and/or parameter names and/or corresponding acronyms thereof, such as those of the executing utility, logic, and/or firmware described herein, are for example only and not meant to imply any limitations to the described embodiments. The embodiments may thus be described with different nomenclature and/or terminology utilized to describe the components, devices, parameters, methods, and/or functions herein, without limitation. References to any specific protocol or proprietary name in describing one or more elements, features, or concepts of the embodiments are provided solely as examples of one implementation, and such references do not limit the extension of the claimed embodiments to embodiments in which different element, feature, protocol, or concept names are utilized. Thus, each

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term utilized herein is to be given its broadest interpretation given the context in which that terms is utilized.

In FIG. 1, a cam butterfly valve **100** according to aspects of the present invention provides a quarter turn for closing with additional translation for tight sealing even in cryogenic applications. In one embodiment, a cam butterfly valve **100** has a body **102** that includes an axially extending fluid conduit **104** formed there through. A valve seat **106** projecting from the body annularly within the fluid conduit **104**. A cam shaft **108** has a cam **110** of circular cross section attached to a central stem **111** between a pair of shaft lobes **112**. The cam shaft **108** is disposed transverse to a flow axis **113** of the fluid conduit, and journaled within the body **102** to rotate about a shaft axis **114**. A valve disc **116** has a seating surface **118** that corresponds in a closed position to the valve seat **106** of the body **102**. A disc lug **120** is connected to a back side **122** of the valve disc **116** and has a circular bore **124** that receives and is larger than the cam **110** of the cam shaft **108**. The valve disc **116** is rotatable for a quarter turn within the body **102** about a lug axis **126** that is offset from the shaft axis **114**.

In one embodiment, the valve disc **116** is a triple offset design with the cam shaft **108** offset from a plane made from the seating surface **118**. The shaft axis **114** is offset from a body centerline **127** of the body **102**. The seating surface **118** on the valve disc **116** has a slanted cone shape.

Actuating the cam shaft **108** in the closing rotational direction **128** first causes the camming side **130** of the cam **110** of the cam shaft **108** to rotate the disc lug **120** and the valve disc **116** a quarter turn from the open position to the closed position. Further actuating of the cam shaft **108** causes the camming side **130** of the cam shaft **108** to translate the valve disc **116** into sealed contact with the valve seat **106**.

Actuating the cam shaft **108** in an opening rotational direction **132** first causes the camming side **130** of the cam **110** of the cam shaft **108** to reverse translate the valve disc **116** to unseal from the valve seat **106**. Continued actuating of the cam shaft **108** causes the camming side **130** of the cam shaft **108** to reverse rotate the disc lug **120** and the valve disc **116** a quarter turn from the closed position to the open position. In one embodiment, the cam butterfly valve **100** has a second disc lug **120** that contains a second cam **110** of the cam shaft **108** that is identical to and operates in unison with the cam **110**.

At least one torsion spring **134** is mounted concentrically on the cam shaft **108** with one spring leg **136** against the valve disc **116** and another spring leg **138** attached to the cam shaft **108**. Each torsion spring **134** is preloaded with sufficient torque to cause the valve disc **116** to rigidly move with the cam shaft **108**. For cryogenic applications, each torsion spring **134** can be formed from an austenitic nickel-chromium-based superalloy (e.g., INCONEL).

In one embodiment, the cam butterfly valve **100** is for transferring a cryogenic fluid. Further actuating of the cam shaft **108** after the quarter turn causes the camming side **130** of the cam **110** to translate the valve disc **116** a first amount into sealed contact with the valve seat **106** at an ambient temperature and to translate the valve disc **116** a second amount into sealed contact with the valve seat **106** at a cryogenic temperature.

In one or more embodiments, a closing torsional biasing mechanism **140** is operatively coupled to the cam shaft **108** to assert a closing bias rotation to the cam shaft **108** to cause additional translation to maintain the sealed contact during cool down to a cryogenic temperature. In one embodiment, the biasing mechanism **140** can include or wholly comprise

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an additional torsion spring (not shown) that urges the cam shaft **108** to rotate toward closing. In a particular embodiment, the biasing mechanism **140** is a torsion spring that is utilized in an actuator **142** between a worm gear (not shown) and the cam shaft **108** upstream of a reduction gearbox **144** to maintain a sufficient torque on the cam shaft **108** during cryogenic chill down. The reduction gearbox **144** is connected to the actuator **142** (e.g., a manual hand wheel or motorized actuator). The reduction gearbox **144** provides significant mechanical advantage to an operator (e.g., ten (10) full rotations of the hand wheel equals 90° of rotation of the cam shaft **108**). The biasing mechanism **140** can receive the benefit of this mechanical advantage to eliminate, or at least significantly reduce, the need to continually apply torque to the actuator **142**, such as a hand wheel, during temperature changes to maintain a leak tight seat.

FIGS. 2-7 illustrate an exemplary embodiment of a cryogenic cam butterfly valve (CCBV) **200** that includes a valve body **202**, valve disc **216**, cam shaft **208**, torsion spring **234**, and 180° operation manual actuator **242**. A valve seat **206** is a simple static valve seat. In an exemplary embodiment, a valve body **202**, valve disc **216**, and cam shaft **208** are fabricated from 304 or 316 stainless steel while the torsion spring **234** is made of austenitic nickel-chromium-based superalloy. The operating temperatures of the CCBV **200** can be from -320° F. to +200° F. The CCBV **200** can be assembled similar to a typical butterfly valve. In the full open position, disc rotation is "0 degrees" and the valve disc **216** is approximately perpendicular to the valve body **202** to allow maximum fluid flow through the CCBV **200**. Unlike a typical butterfly valve where the valve disc is pinned to the shaft, the CCBV **200** has a preloaded torsion spring **234** mounted concentrically on the cam shaft **208** with one spring leg **236** against the valve disc **216** and another spring leg **238** attached to the cam shaft **208** by a pin **239**. The torsion spring **234** is preloaded with sufficient torque to cause the assembly of the valve disc **216** and cam shaft **208** to act like the valve disc **216** is rigidly pinned to the cam shaft **208**.

With particular reference to FIGS. 2 and 9-11, CCBV **200** including mounting flanges **248** having radially spaced through holes **250**. The valve body **202** includes an extended neck **252** from a main body **254** that defines a fluid conduit **204**. With particular reference to FIG. 2, an upper shaft portion **256** of the cam shaft **208** is received for rotation within an upward bore **258**. A shorter lower shaft portion **260** of the cam shaft **208** is received into a downward bore **262** formed in the main body **254**. The upper shaft portion **256** is dynamically sealed and supported in the upward bore **258** by an upper guide **264**. The upper guide **264** is held from above by packing assembly **266** that is in turn retained by a top hat collar **268** fastened to a top horizontal flange **270** of the extended neck **252**. The upper shaft portion **256** extends upwardly out of the top hat collar **268** to be received in a operation manual actuator **242** that is also fastened to the top horizontal flange **270** and that is manually operated by a hand wheel **272**. The upper shaft portion **256** is supported at a lower end of the upward bore **258** by a middle guide **274** kept up by a retaining ring **276**. The shorter lower shaft portion **260** is dynamically guided for rotation by a lower guide **278** held in the downward bore **262** by a retaining ring **280**.

With particular reference to FIG. 3, a central stem portion **282** of the cam shaft **208** concentrically receives the torsion spring **234**. The valve disc **216** presents a chamfered edge as a seating surface **218** to a valve seat **206**, which is a simple, static valve seat of a conical ring attached to the valve body.

To ensure a tight seal, a downstream sealing ring **283** is positioned to contact the seating surface **218** and is attached by a retaining collar **284**. The valve seat **206** can be a static “chunk” design. The valve seat **206** can be asymmetrical with one side seating first with an angle more in opposition to the sealing ring **283** and the other side of the seating surface **218** more tangentially contacting for sliding along during translation of the valve disc **216**.

FIG. **4** illustrates a circular bore **224** of a disc lug **220** attached to the valve disc **216**. FIG. **5** illustrates a cam **210** of the cam shaft **208** having a shaft axis **214** that is offset from a lug axis **226**. FIG. **6** illustrates the CCBV **200** in a full open (0°) position. FIG. **7** illustrates the CCBV **200** in a closed (90°) position after a quarter turn. The first 90° of the actuator and shaft rotation rotates the valve disc **216**, just like a typical butterfly valve. The valve disc **216** can be a lug type, similar to a Royal valve disc, so that the cam shaft **208** is accessible between the disc lugs **220**. FIG. **8** illustrates the CCBV **200** in a sealed ($\sim 135^\circ$) position after further closing actuation. All actuator and shaft rotation beyond 90° translates the valve disc **216** towards the valve seat **206** to create a tighter seal, in a similar manner as a globe valve. Seat leakage when the CCBV **200** is in this position will be reduced and most likely stopped by additional actuator rotation. In particular, in FIG. **7** the edge of the valve disc **216** initially contacts the valve seat **206** at the “9 o’clock” point, continually making a tight seal all around the valve disc **216** to the “3 o’clock” point as the cam shaft **208** is increasingly rotated past the “90 degree” position. The valve disc **216** can be a triple offset design with the shaft offset from the plane made from the seating surface **218**, the shaft axis offset from the body centerline, and the seating surface on the disc having a slanted cone shape. The cam shaft lobes **212** are circular and are supported by bushings (not shown) inside the disc lugs **220**.

FIGS. **9-11** correspond respectively to FIGS. **6-8** illustrating respectively the CCBV **200** in a full open (0°) position, in a full closed (90°) position, and in a sealed ($\sim 135^\circ$) position.

While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular system, device or component thereof to the teachings of the specification without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims. Moreover, the use of the terms first, second, etc. does not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

The description of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the disclosure in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope of the invention. The described embodiments were chosen and described in order to best explain the principles of the invention and the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

I claim:

1. A cam butterfly valve, comprising:

a body including an axially extending fluid conduit formed there through;

a valve seat projecting from the body annularly within the fluid conduit;

a cam shaft having a cam of circular cross section, disposed transverse to an axis of the fluid conduit, and mounted within the body to rotate about a shaft axis;

a valve disc having a seating surface that corresponds in a closed position to the valve seat of the body;

a disc lug connected to a back side of the valve disc and having a circular bore that receives and is larger than the cam of the cam shaft, the valve disc rotatable for a quarter turn within the body about a lug axis that is offset from the shaft axis; and

at least one torsion spring mounted concentrically on the cam shaft with one spring leg against the valve disc having a preload of sufficient torque to cause the valve disc to rigidly move with the cam shaft;

wherein actuating the cam shaft in the closing rotational direction first causes the camming side of the cam of the cam shaft to rotate the disc lug and the valve disc a quarter turn from the open position to the closed position and further actuating causes the camming side of the cam shaft to translate the valve disc into sealed contact with the valve seat, said valve disc being translated by the force of the valve disc against the valve seat; and

Wherein actuating the cam shaft in an opening rotational direction first causes the camming side of the cam of the cam shaft to reverse translate the valve disc to unseal from the valve seat and continued actuating causes the camming side of the cam shaft to reverse rotate the disc lug and valve disc a quarter turn from the closed position to the open position.

2. The cam butterfly valve of claim 1, wherein the at least one torsion spring comprises an austenitic nickel-chromium-based superalloy.

3. The cam butterfly valve of claim 1, wherein the cam shaft has a second cam of circular cross section that moves in unison with the first cam, the cam butterfly valve further comprising a second disc lug connected to a back side of the valve disc and having a circular bore that receives and is larger than the second cam of the cam shaft, the valve disc rotatable for a quarter turn within the body about the lug axis that is offset from the shaft axis.

4. The cam butterfly valve of claim 1, wherein the valve disc comprises a triple offset design with the cam shaft offset from a plane made from the seating surface, wherein the shaft axis is offset from a body centerline of the body, and wherein the seating surface on disc has a slanted cone shape.

5. The cam butterfly valve of claim 1, wherein the valve seat comprises a static valve seat.

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6. The cam butterfly valve of claim 5, wherein the static valve seat comprises a conical ring attached to the valve body.

7. The cam butterfly valve of claim 1, wherein the fluid conduit contains a cryogenic fluid, wherein further actuating of the cam shaft causes the camming side of the cam shaft to translate the valve disc a first amount into sealed contact with the valve seat at an ambient temperature and to translate the valve disc a second amount into sealed contact with the valve seat at a cryogenic temperature.

8. The cam butterfly valve of claim 1, wherein the body, the valve disc and the cam shaft comprise stainless steel.

9. The cam butterfly valve of claim 1, wherein actuating the cam shaft comprises a rotation of 0-90° and further actuating the cam shaft comprises an additional rotation of 90° to approximately 135° to thereby translate the valve disc towards the valve seat thereby creating a tight seal.

10. The cam butterfly valve of claim 1, further comprising:

an actuator operably connected to the cam shaft to cause rotation; and

a reduction gearbox operatively coupled to the actuator gear reduce a rotational actuation and to assert a closing bias during cryogenic cool down.

11. The cam butterfly valve of claim 1, further comprising:

an actuator operably connected to the cam shaft to cause rotation; and

a closing torsional biasing mechanism coupled to the actuator to assert a closing bias during cryogenic cool down.

12. A cryogenic cam butterfly valve, comprising:

a body including an axially extending fluid conduit formed there through;

a valve seat projecting from the body annularly within the fluid conduit;

a cam shaft having a cam of circular cross section, disposed transverse to an axis of the fluid conduit, and mounted within the body to rotate about a shaft axis;

a valve disc having a seating surface that corresponds in a closed position to the valve seat of the body;

a disc lug connected to a back side of the valve disc and having a circular bore that receives and is larger than the cam of the cam shaft, the valve disc rotatable for a quarter turn within the body about a lug axis that is offset from the shaft axis; and

at least one torsion spring mounted concentrically on the cam shaft with one spring leg against the valve disc having a preload of sufficient torque to cause the valve disc to rigidly move with the cam shaft;

a biasing mechanism operatively coupled to the cam shaft, wherein actuating the cam shaft in the closing rotational direction first causes the camming side of the cam of the cam shaft to rotate the disc lug and the valve

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disc a quarter turn from the open position to the closed position and further actuating causes the camming side of the cam shaft to translate the valve disc into sealed contact at an ambient temperature with the valve seat, said valve disc being translated by the force of the valve disc against the valve seat,

wherein the biasing mechanism asserts a closing bias rotation to the cam shaft to cause additional translation to maintain the sealed contact during cool down to a cryogenic temperature, and

wherein actuating the cam shall in an opening rotational direction first causes the camming side of the cam of the cam shaft to reverse translate the valve disc to unseal from the valve seat and continued actuating causes the camming side of the cam shaft to reverse rotate the disc lug and valve disc a quarter turn from the closed position to the open position.

13. The cryogenic cam butterfly valve of claim 12, wherein the at least one torsion spring comprises an austenitic nickel-chromium-based superalloy.

14. The cryogenic cam butterfly valve of claim 12, wherein the cam shaft has a second cam of circular cross section that moves in unison with the first cam, the cam butterfly valve further comprising a second disc lug connected to a back side of the valve disc and having a circular bore that receives and is larger than the second cam of the cam shaft, the valve disc rotatable for a quarter turn within the body about the lug axis that is offset from the shaft axis.

15. The cryogenic cam butterfly valve of claim 12, wherein the valve disc comprises a triple offset design with the cam shaft offset from a plane made from the seating surface, wherein the shaft axis is offset from a body centerline of the body, and wherein the seating surface on disc has a slanted cone shape.

16. The cryogenic cam butterfly valve of claim 12, wherein the valve seat comprises a static valve seat.

17. The cryogenic cam butterfly valve of claim 16, wherein the static valve seat comprises a conical ring attached to the valve body.

18. The cryogenic cam butterfly valve of claim 12, wherein the fluid conduit contains a cryogenic fluid, the wherein further actuating of causes the camming side of the cam shaft to translate the valve disc a first amount into sealed contact with the valve seat at an ambient temperature and to translate the valve disc a second amount into sealed contact with the valve seat at a cryogenic temperature.

19. The cryogenic cam butterfly valve of claim 12, wherein actuating the cam shaft comprises a rotation of 0-90° and further actuating the cam shaft comprises an additional rotation of 90° to approximately 135° to thereby translate the valve disc towards the valve seat thereby creating a tight seal.

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