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(12) **United States Patent**
Tahoun et al.

(10) **Patent No.: US 9,453,388 B2**
(45) **Date of Patent: Sep. 27, 2016**

(54) **APPARATUS AND METHOD TO REMOTELY CONTROL FLUID FLOW IN TUBULAR STRINGS AND WELLBORE ANNULUS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 426 days.

(21) Appl. No.: **13/846,946**

(22) Filed: **Mar. 18, 2013**

(65) **Prior Publication Data**

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Related U.S. Application Data

(60) Provisional application No. 61/622,572, filed on Apr. 11, 2012, provisional application No. 61/710,887, filed on Oct. 8, 2012, provisional application No. 61/710,823, filed on Oct. 8, 2012, provisional application No. 61/648,575, filed on May 17, 2012.

(51) **Int. Cl.**

E21B 47/18	(2012.01)
E21B 34/08	(2006.01)
E21B 34/12	(2006.01)
E21B 47/12	(2012.01)
E21B 21/10	(2006.01)
E21B 23/00	(2006.01)
E21B 34/06	(2006.01)
E21B 41/00	(2006.01)
E21B 34/00	(2006.01)

(52) **U.S. Cl.**

CPC ***E21B 34/08*** (2013.01); ***E21B 21/103*** (2013.01); ***E21B 23/006*** (2013.01); ***E21B 34/06*** (2013.01); ***E21B 34/066*** (2013.01); ***E21B 34/12*** (2013.01); ***E21B 41/0085*** (2013.01); ***E21B 47/12*** (2013.01); ***E21B 47/122*** (2013.01); ***E21B 47/18*** (2013.01); *E21B 2034/002* (2013.01); *E21B 2034/007* (2013.01)

(58) **Field of Classification Search**

CPC E21B 2034/002; E21B 21/103; E21B 23/006; E21B 34/066; E21B 34/12; E21B 34/05; E21B 41/0085; E21B 47/18; E21B 47/122; F16K 11/0876; F16K 11/0873; F16K 5/201

See application file for complete search history.

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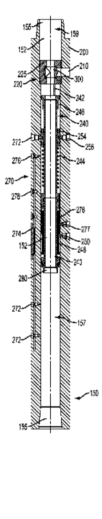
Primary Examiner — Jennifer H Gay

(57) **ABSTRACT**

A method and apparatus for remotely and selectively controlling and altering fluid flow through tubular string disposed within a wellbore and further control fluid flow between the tubular string inner flow passage and the annular flow passage, and a method for selectively and remotely receiving and interpreting a form of command or information at a particular apparatus within the wellbore caused by the operator on earth surface through a change of a physical property of the environment. The apparatus comprising a body, a valve operable in plurality of states, an actuator, and an activator responsive to a change of a physical property of the environment caused by the operator on earth surface.

6 Claims, 23 Drawing Sheets



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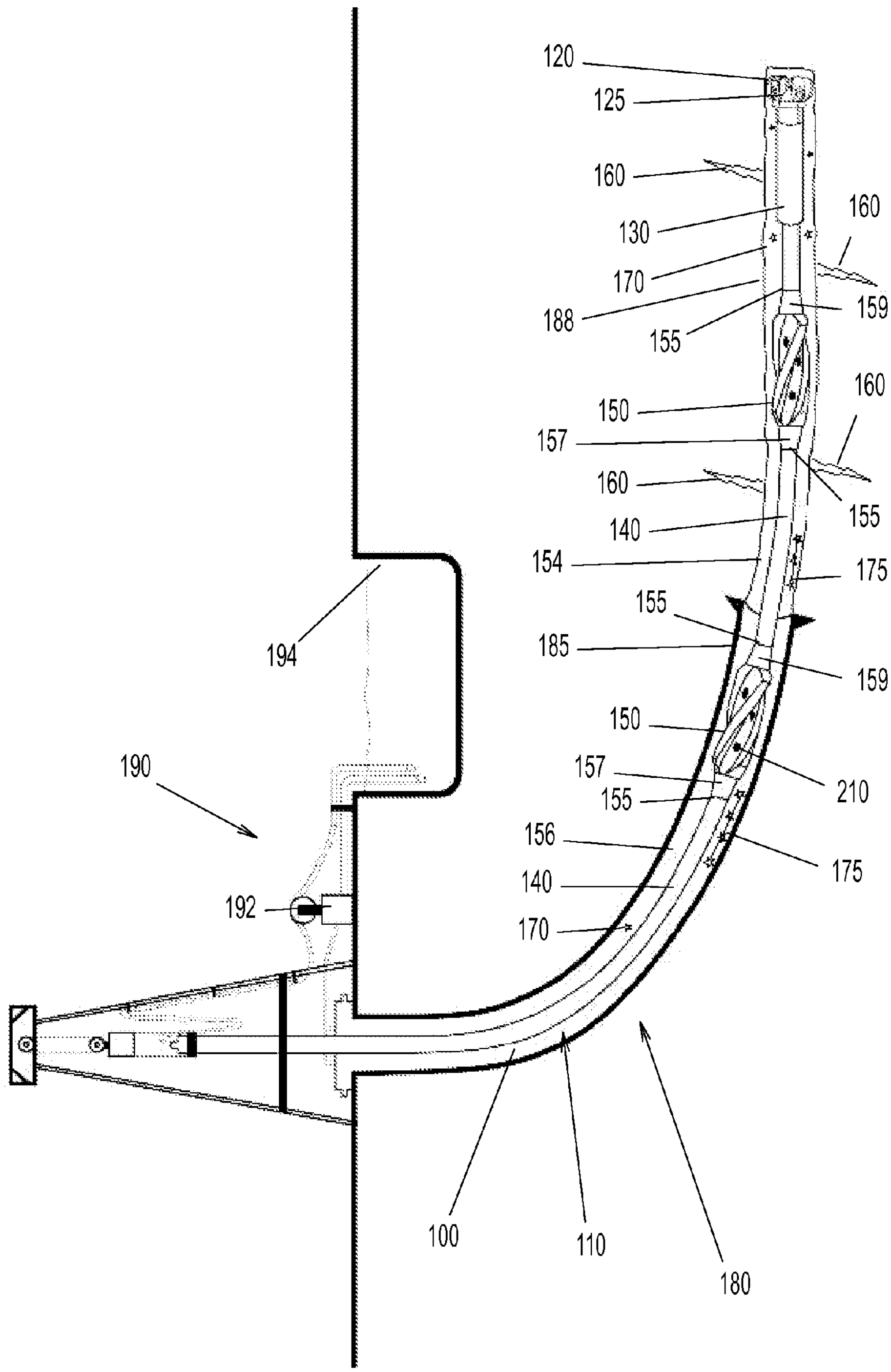
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FIG. 1

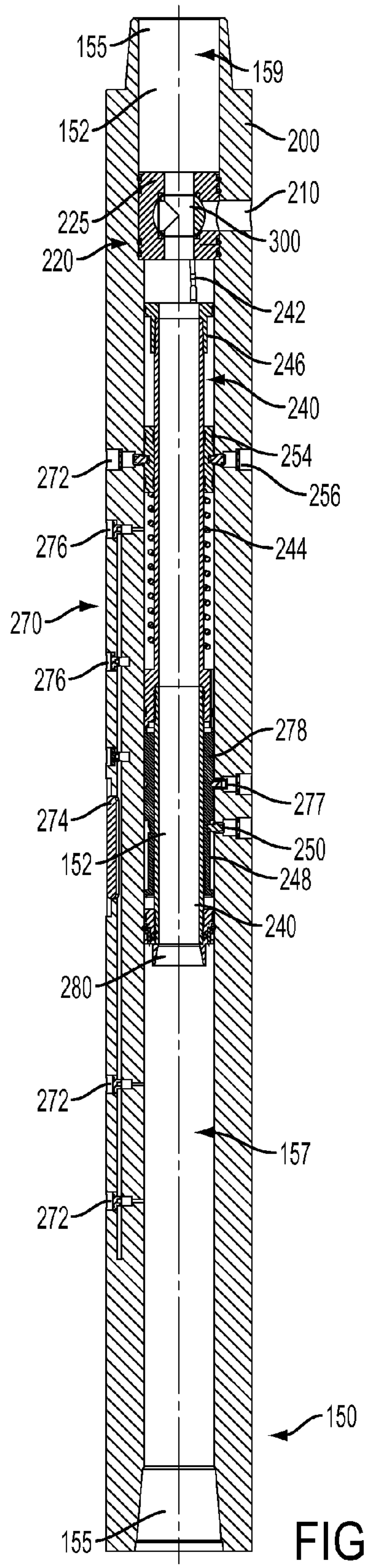
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FIG. 2

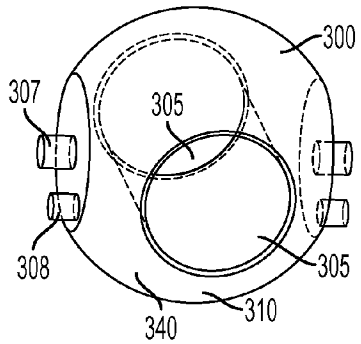


FIG. 3A

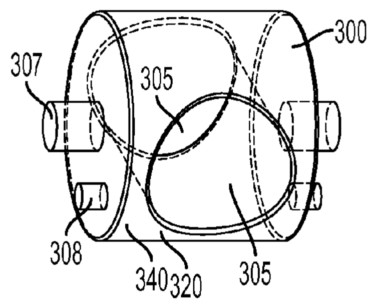


FIG. 3B

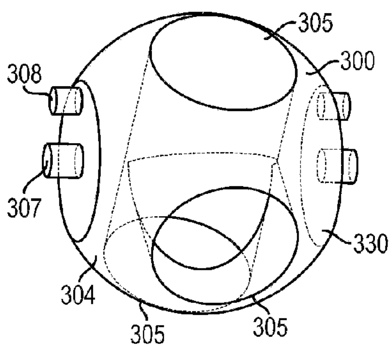


FIG. 3C

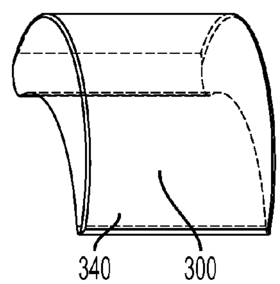


FIG. 3D

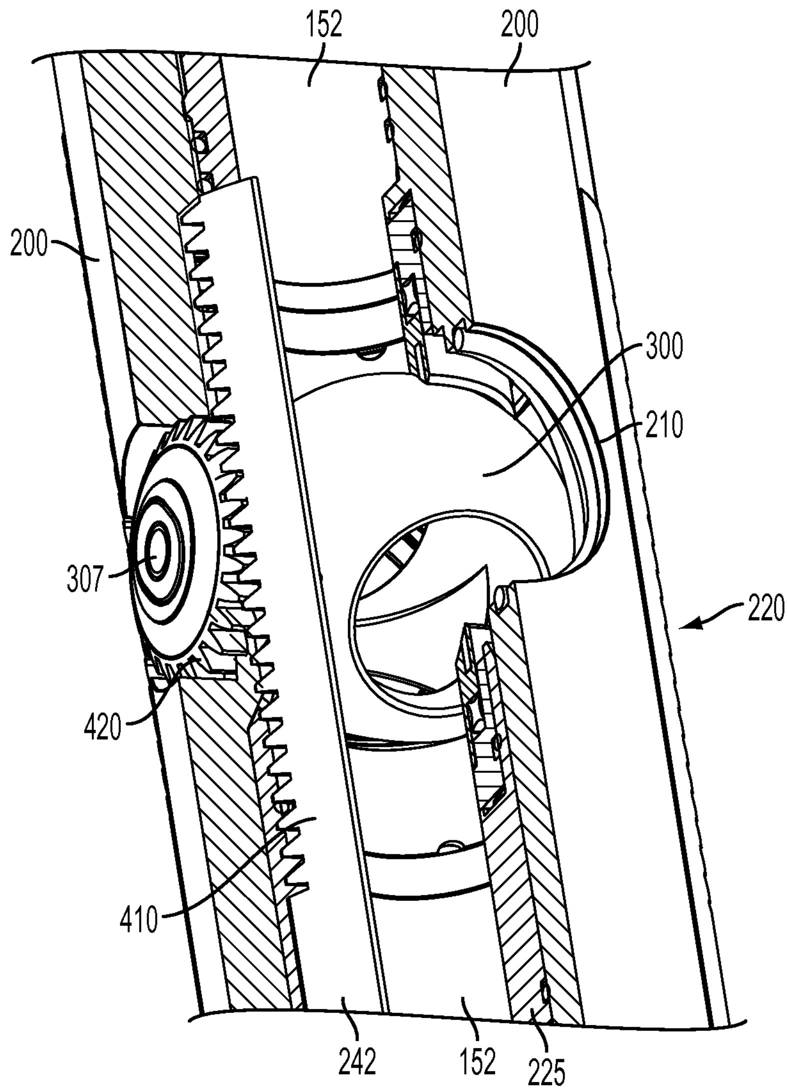


FIG. 4

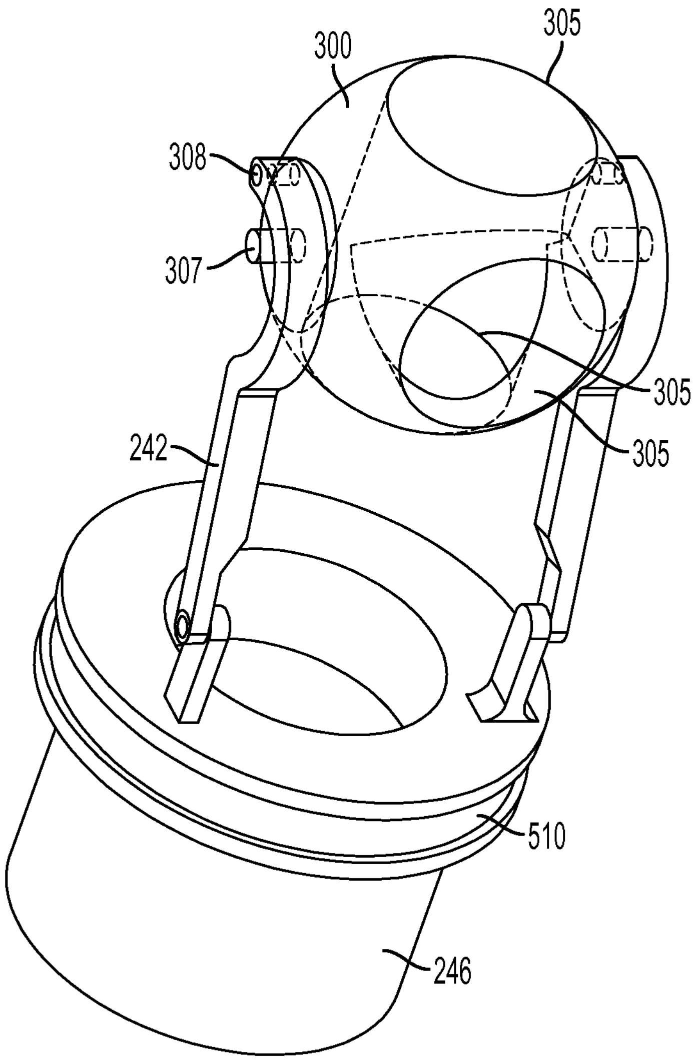


FIG. 5

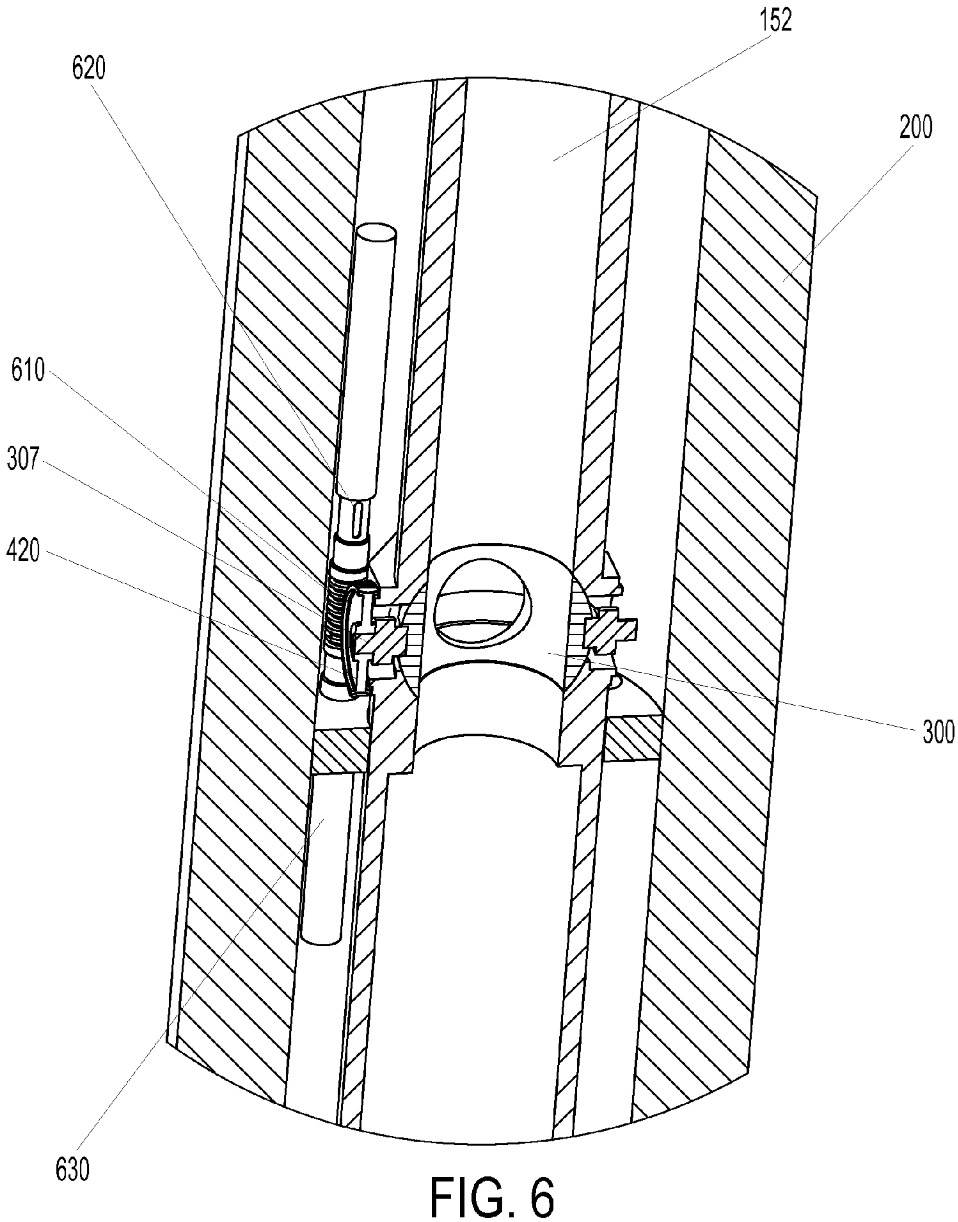


FIG. 6

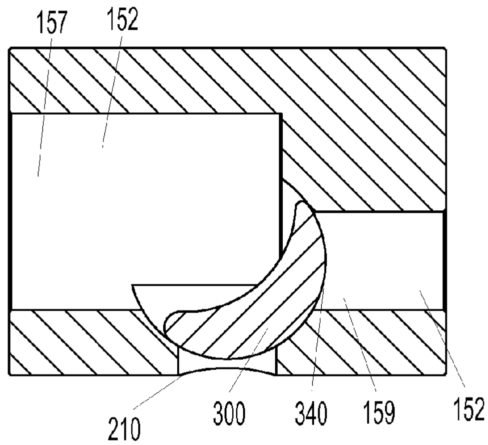


FIG. 7A1

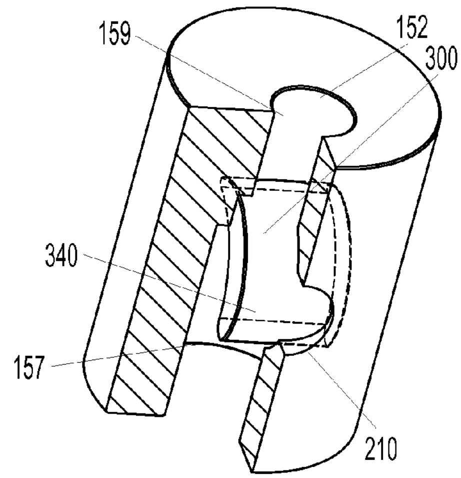


FIG. 7A2

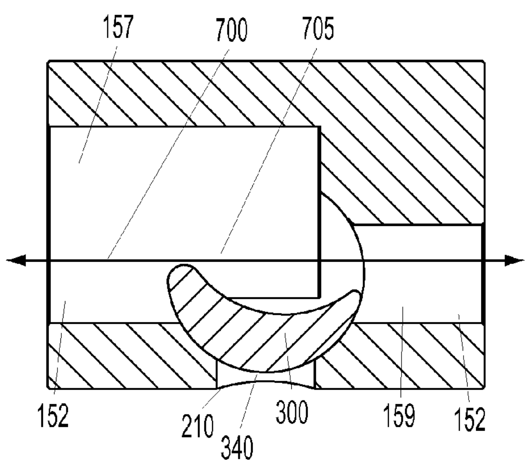
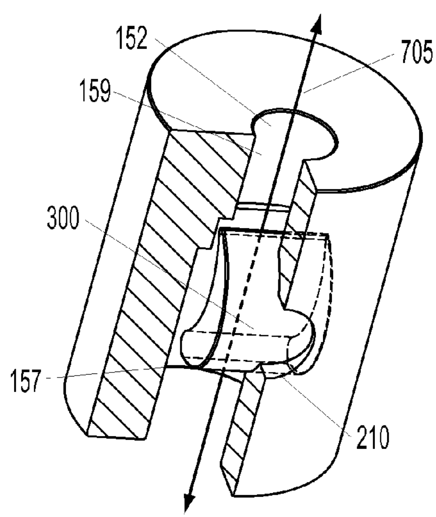


FIG. 7B1



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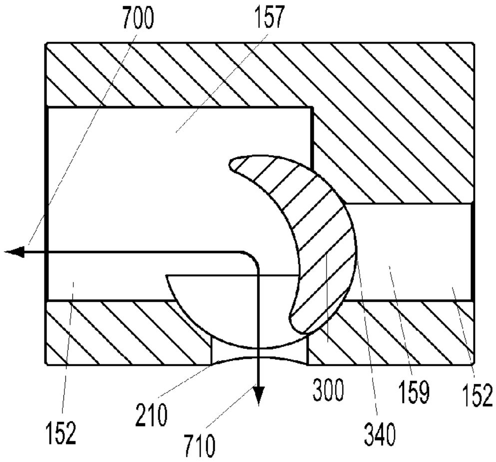
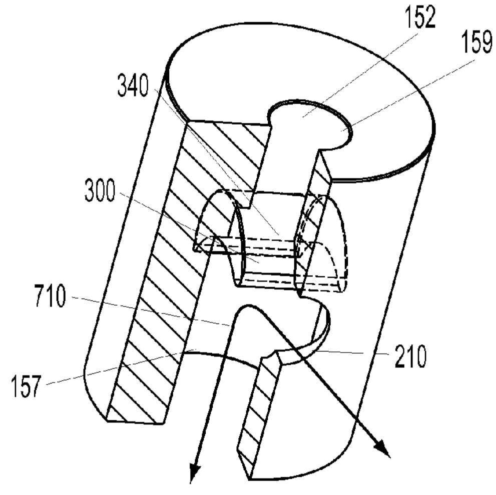


FIG. 7C1



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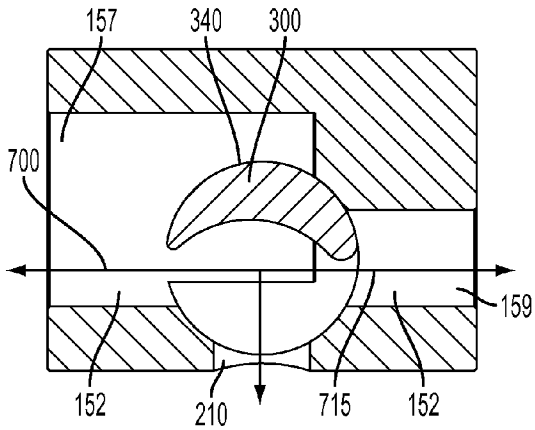

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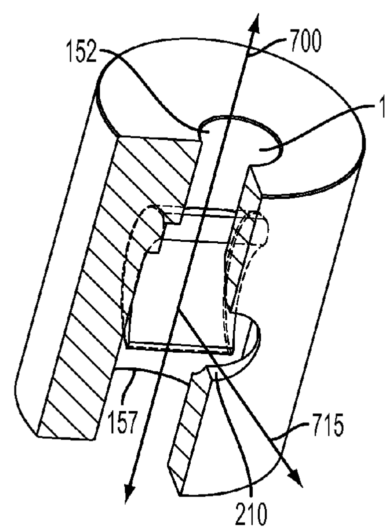

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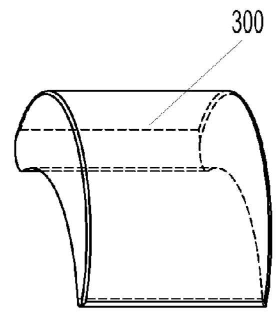
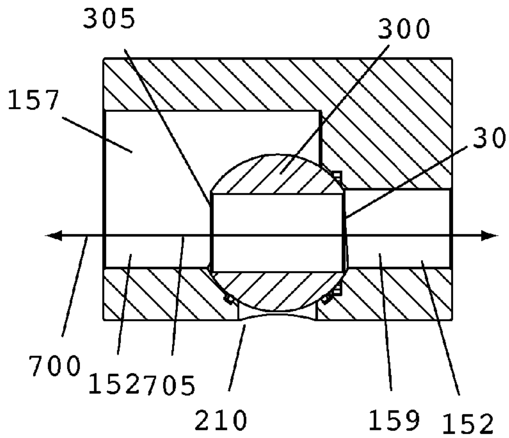


FIG. 7E



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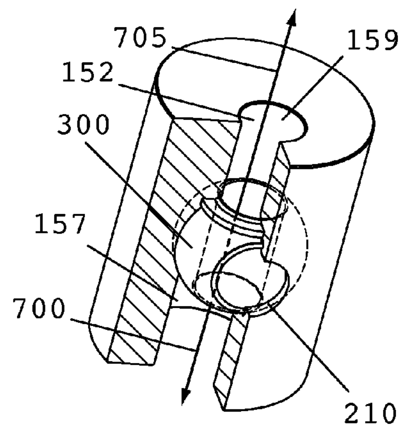

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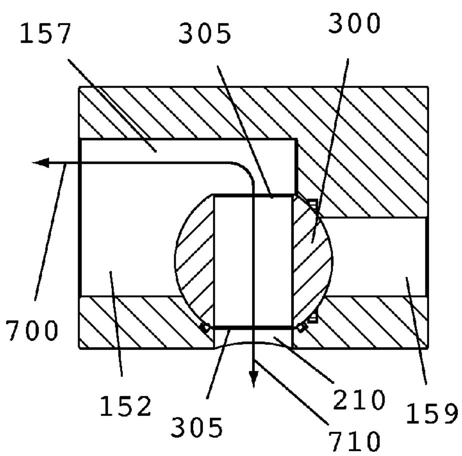

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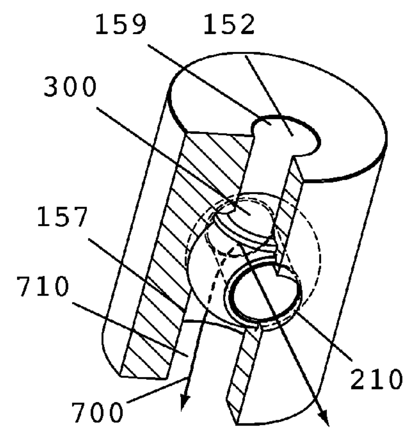

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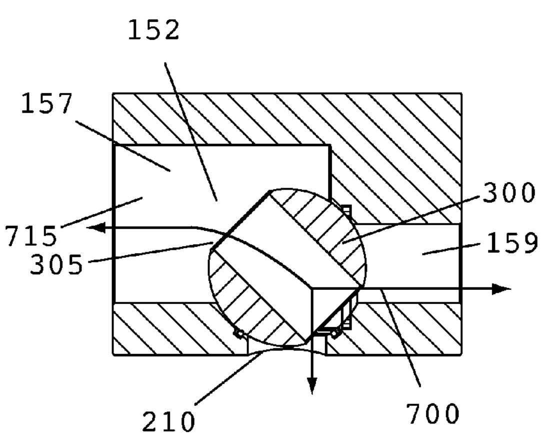

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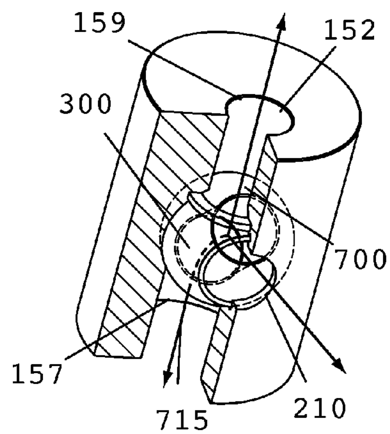

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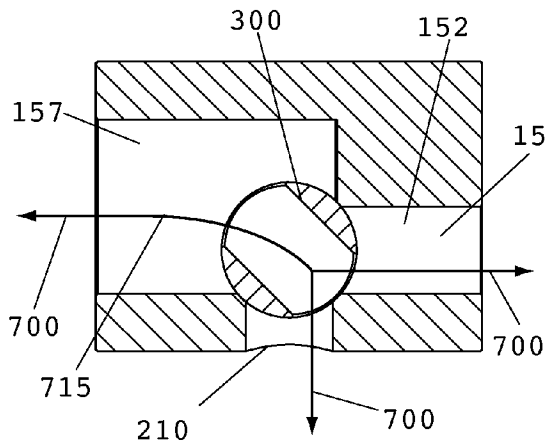

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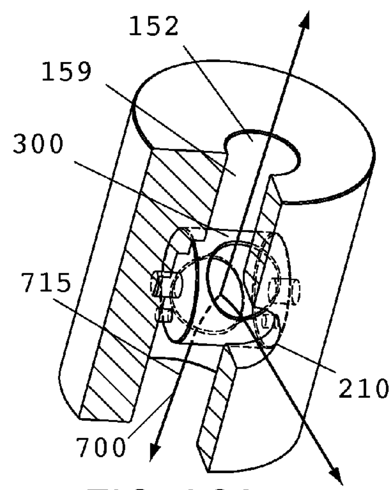

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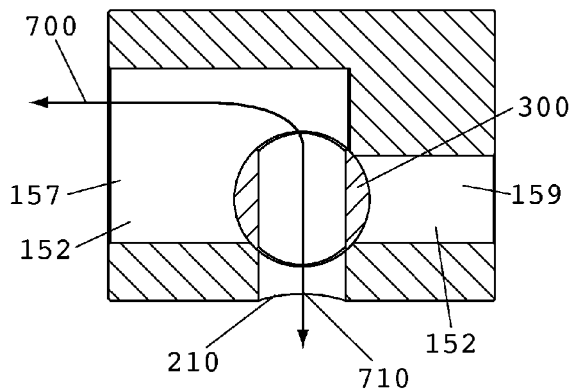

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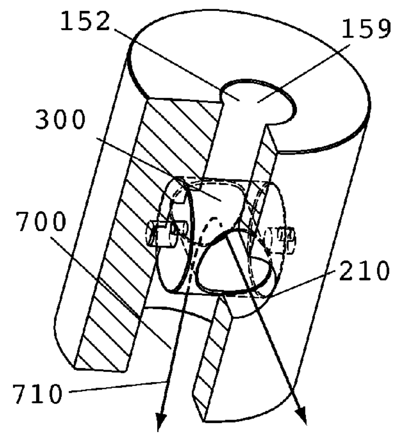

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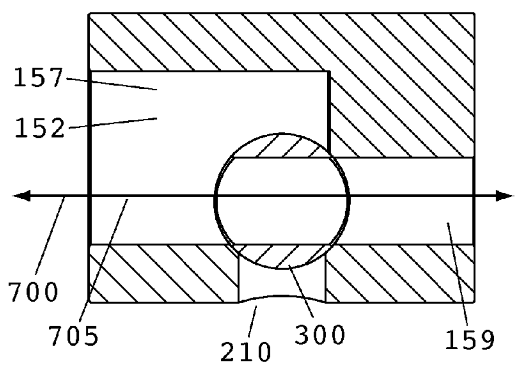


FIG. 9A1

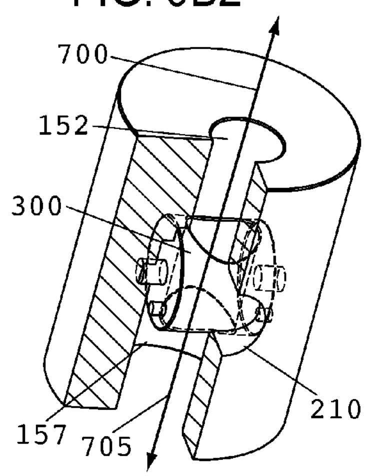


FIG. 9A2

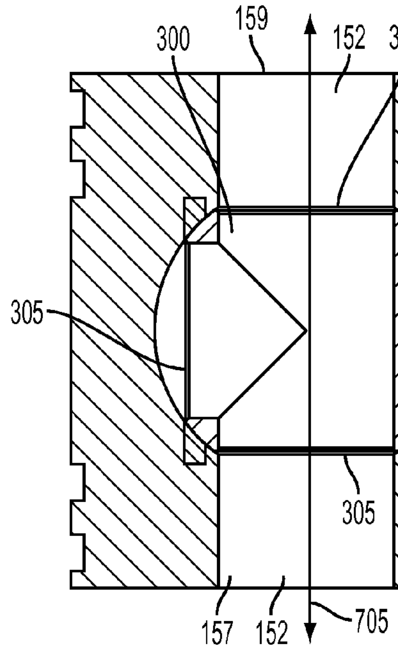
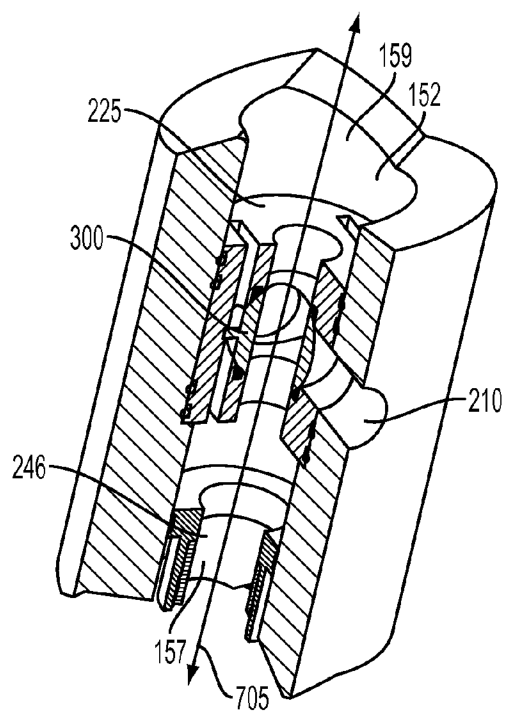


FIG. 10A1



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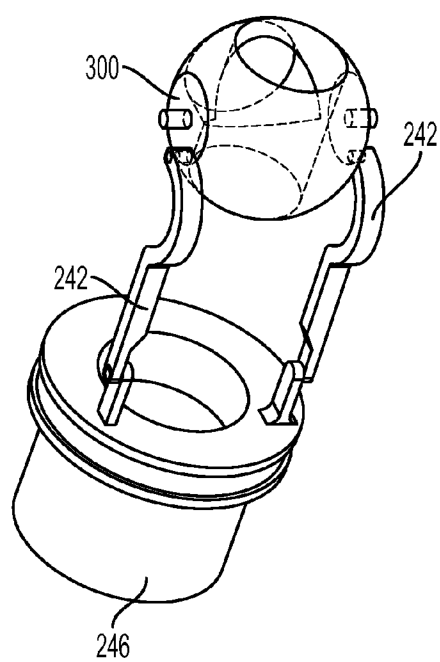
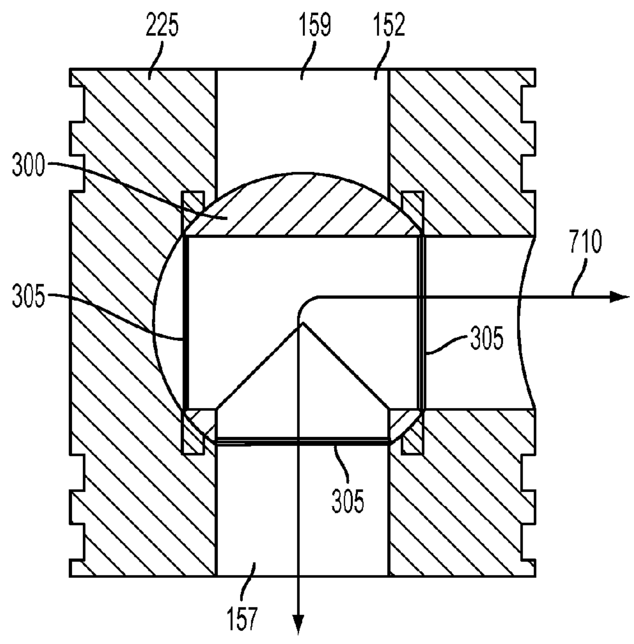


FIG. 10A3



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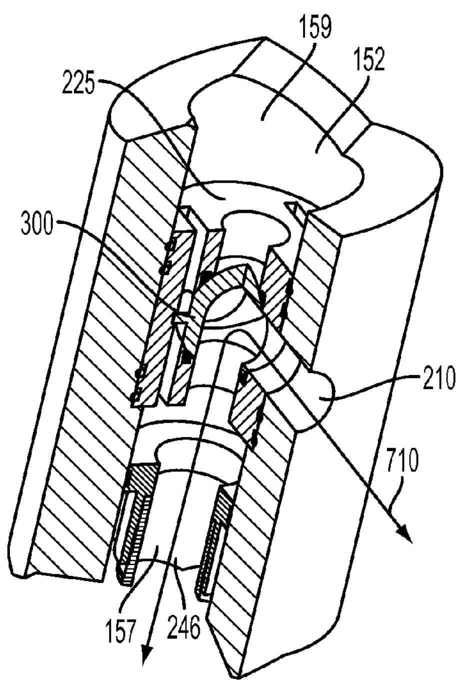

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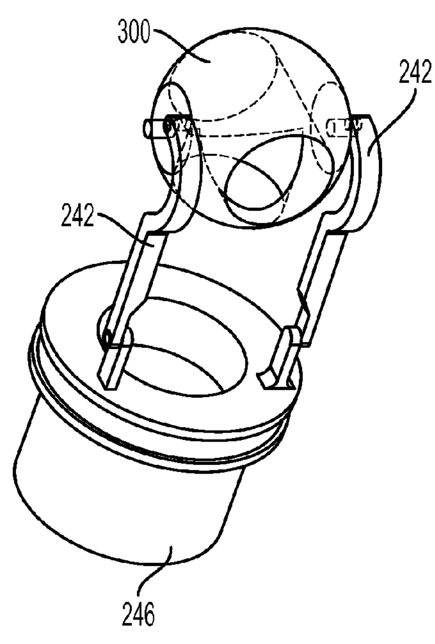


FIG. 10B3

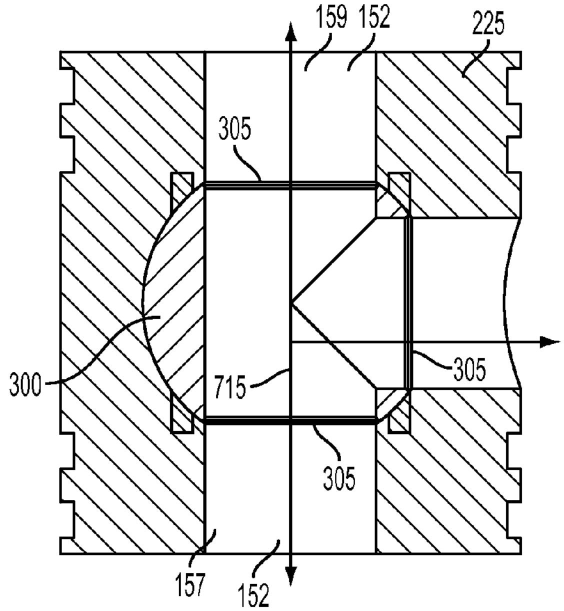
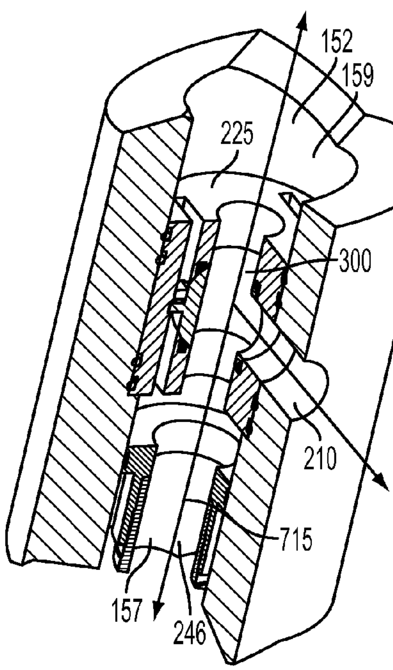


FIG. 10C1



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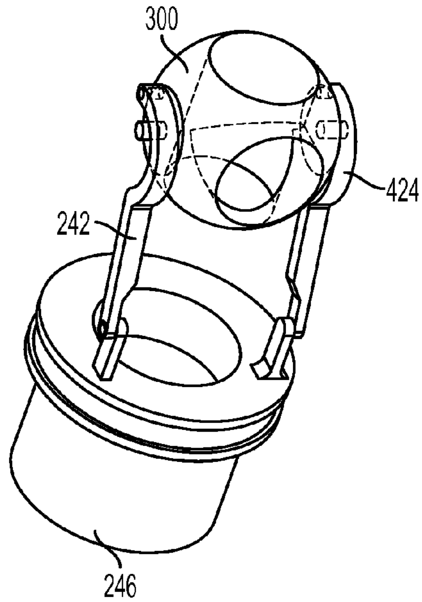


FIG. 10C3

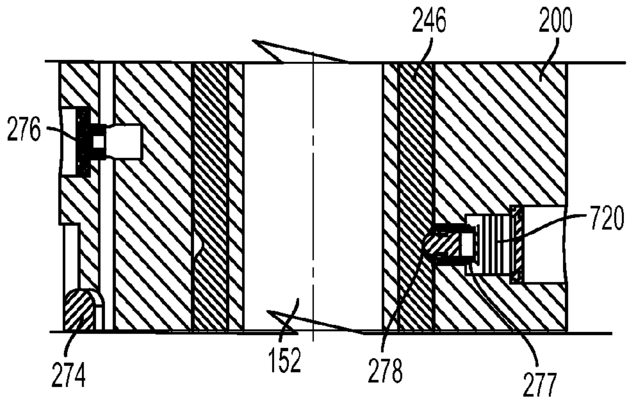
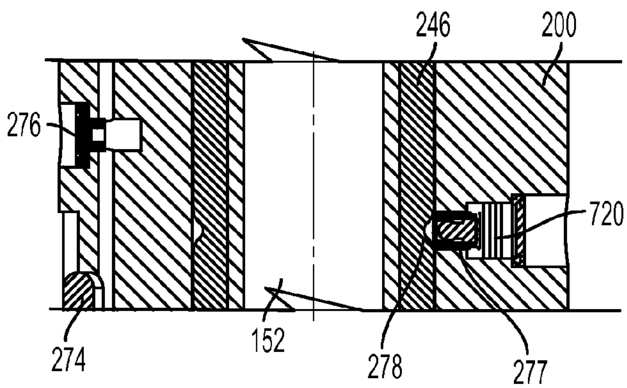


FIG. 11A



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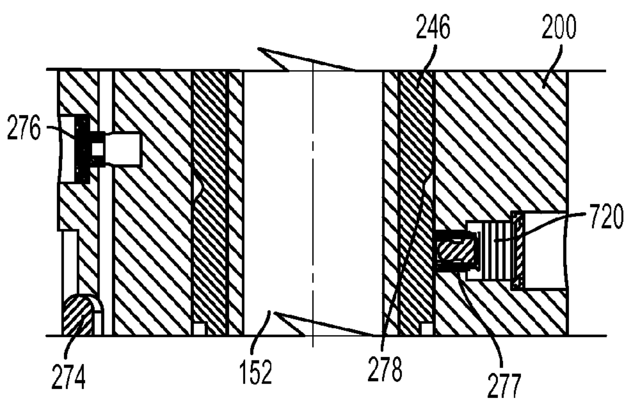


FIG. 11C

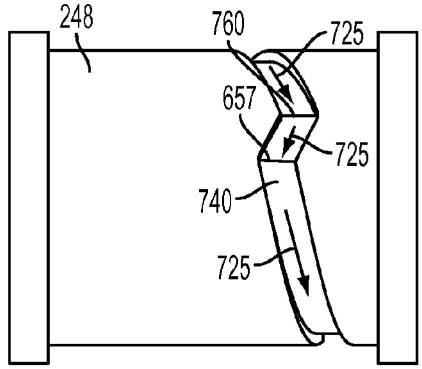


FIG. 12A

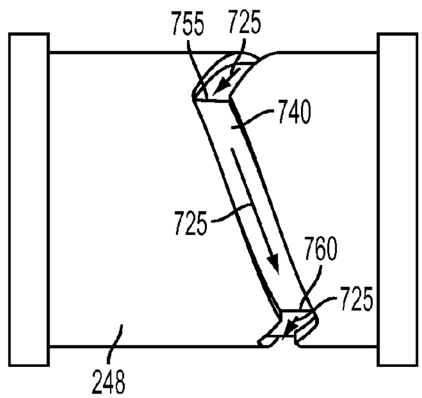


FIG. 12B

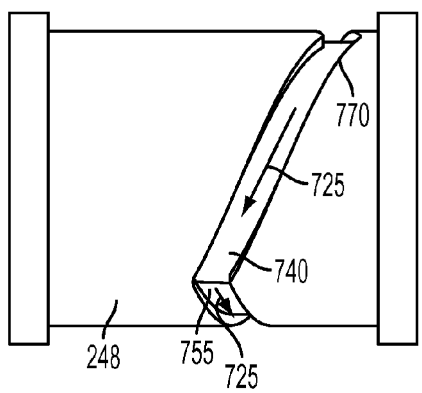


FIG. 12C

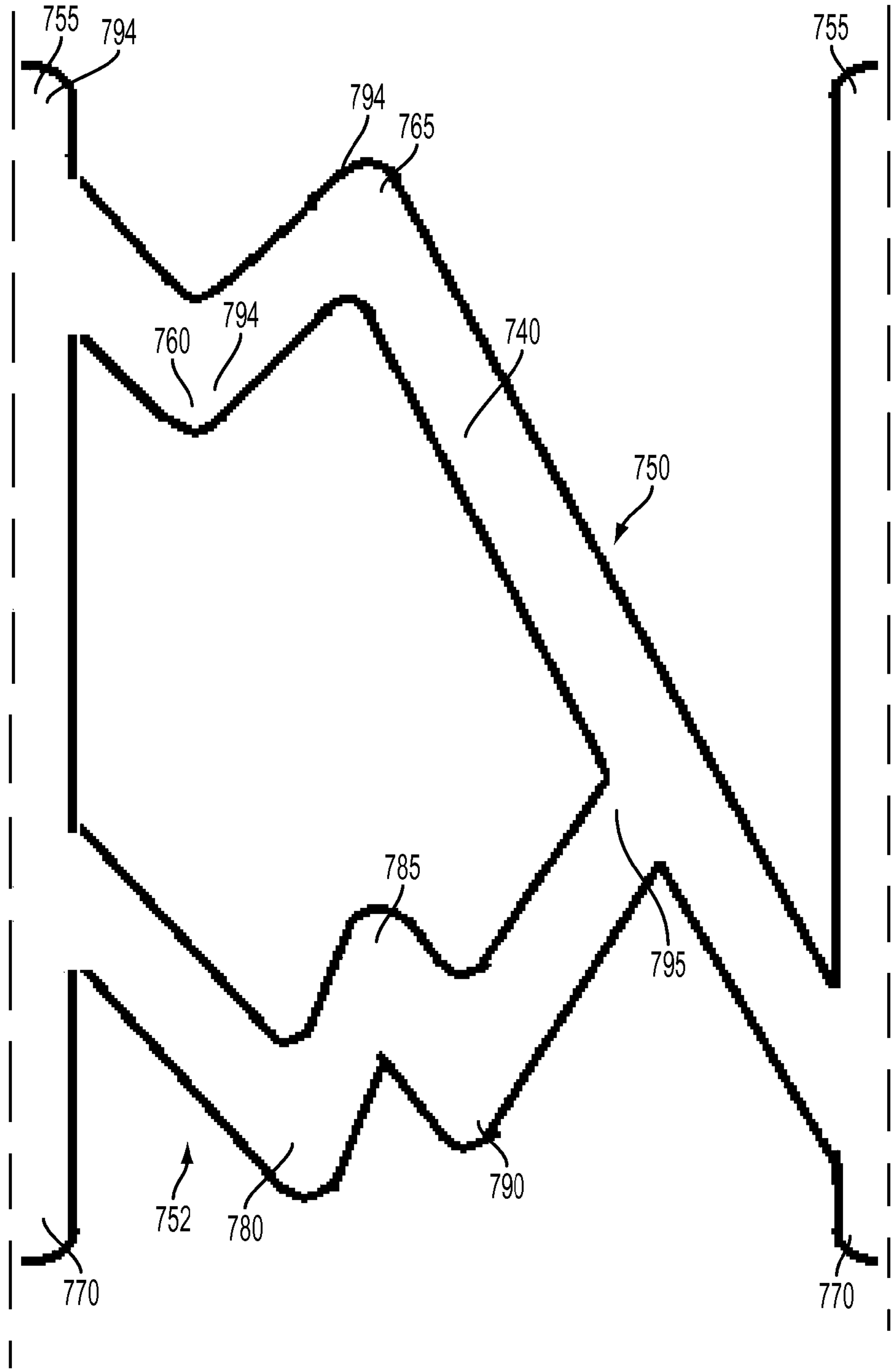


FIG. 13

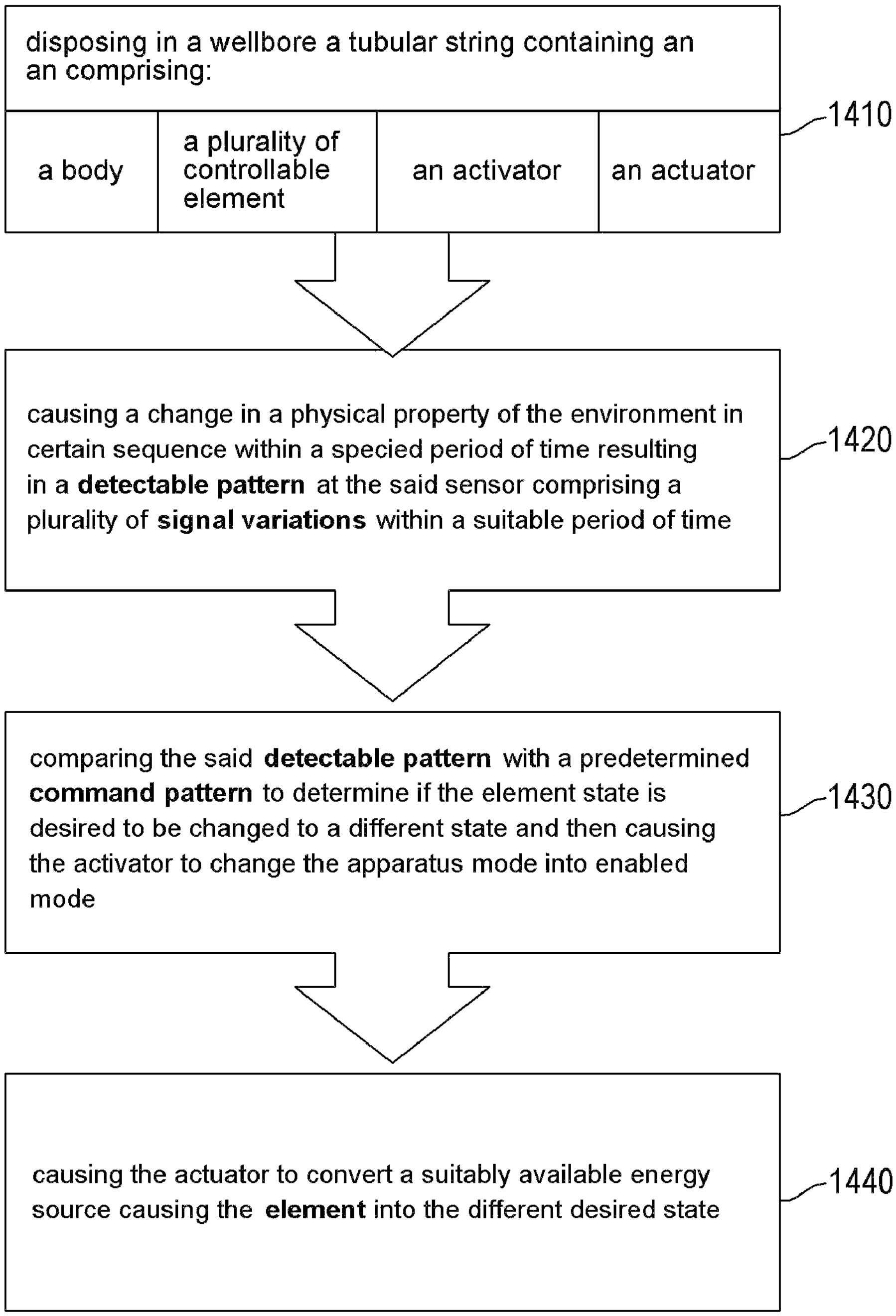

disposing in a wellbore a tubular string containing an
an comprising:
a body
a plurality of controllable element
an activator
an actuator
1410
causing a change in a physical property of the environment in certain sequence within a specied period of time resulting in a detectable pattern at the said sensor comprising a plurality of signal variations within a suitable period of time
1420
comparing the said detectable pattern with a predetermined command pattern to determine if the element state is desired to be changed to a different state and then causing the activator to change the apparatus mode into enabled mode
1430
causing the actuator to convert a suitably available energy source causing the element into the different desired state
1440

FIG. 14

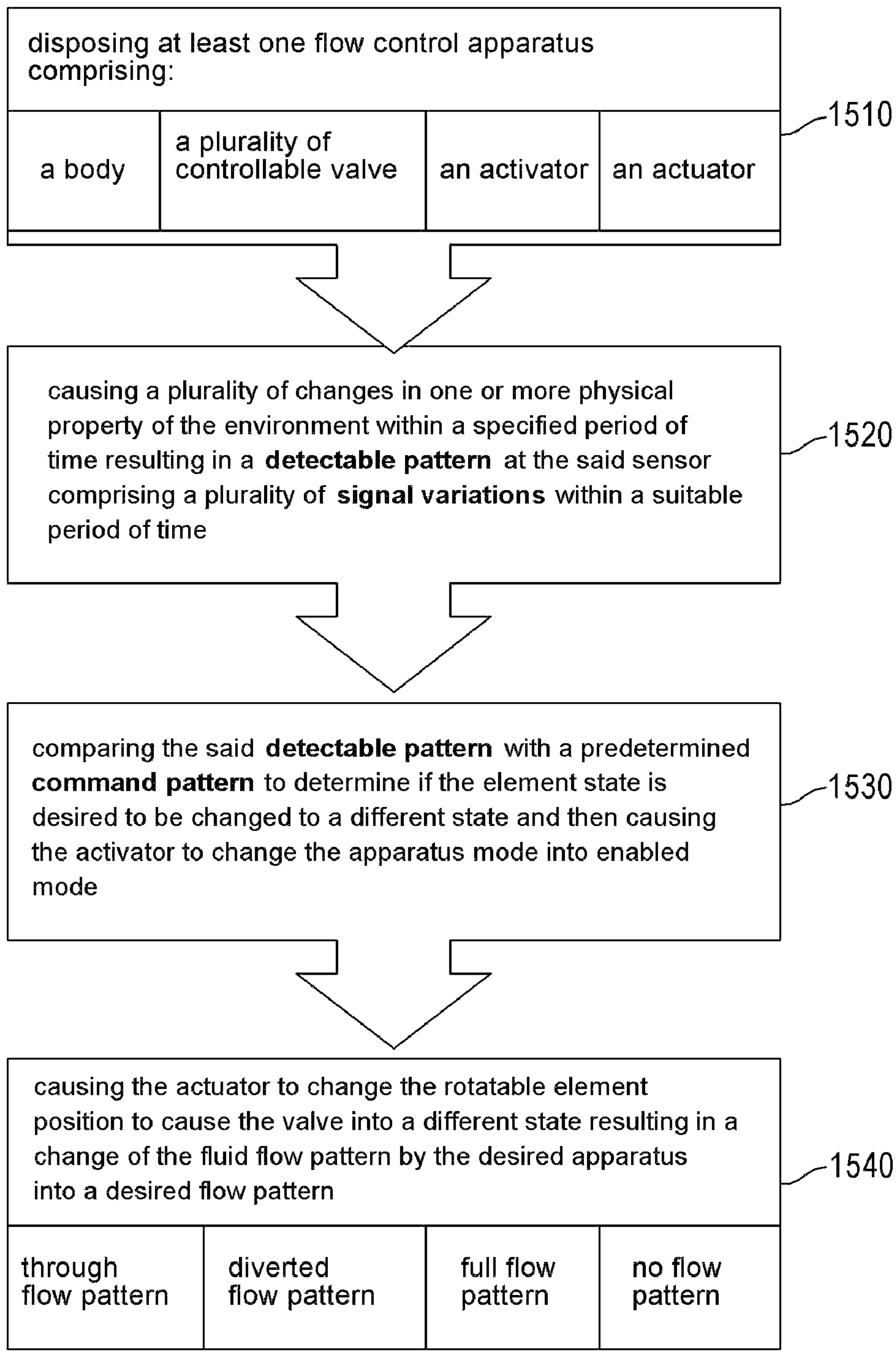

disposing at least one flow control apparatus comprising:
a body
a plurality of controllable valve
an activator
an actuator
1510
causing a plurality of changes in one or more physical property of the environment within a specified period of time resulting in a **detectable pattern** at the said sensor comprising a plurality of **signal variations** within a suitable period of time
1520
comparing the said **detectable pattern** with a predetermined **command pattern** to determine if the element state is desired to be changed to a different state and then causing the activator to change the apparatus mode into enabled mode
1530
causing the actuator to change the rotatable element position to cause the valve into a different state resulting in a change of the fluid flow pattern by the desired apparatus into a desired flow pattern
1540
through flow pattern
diverted flow pattern
full flow pattern
no flow pattern

FIG. 15

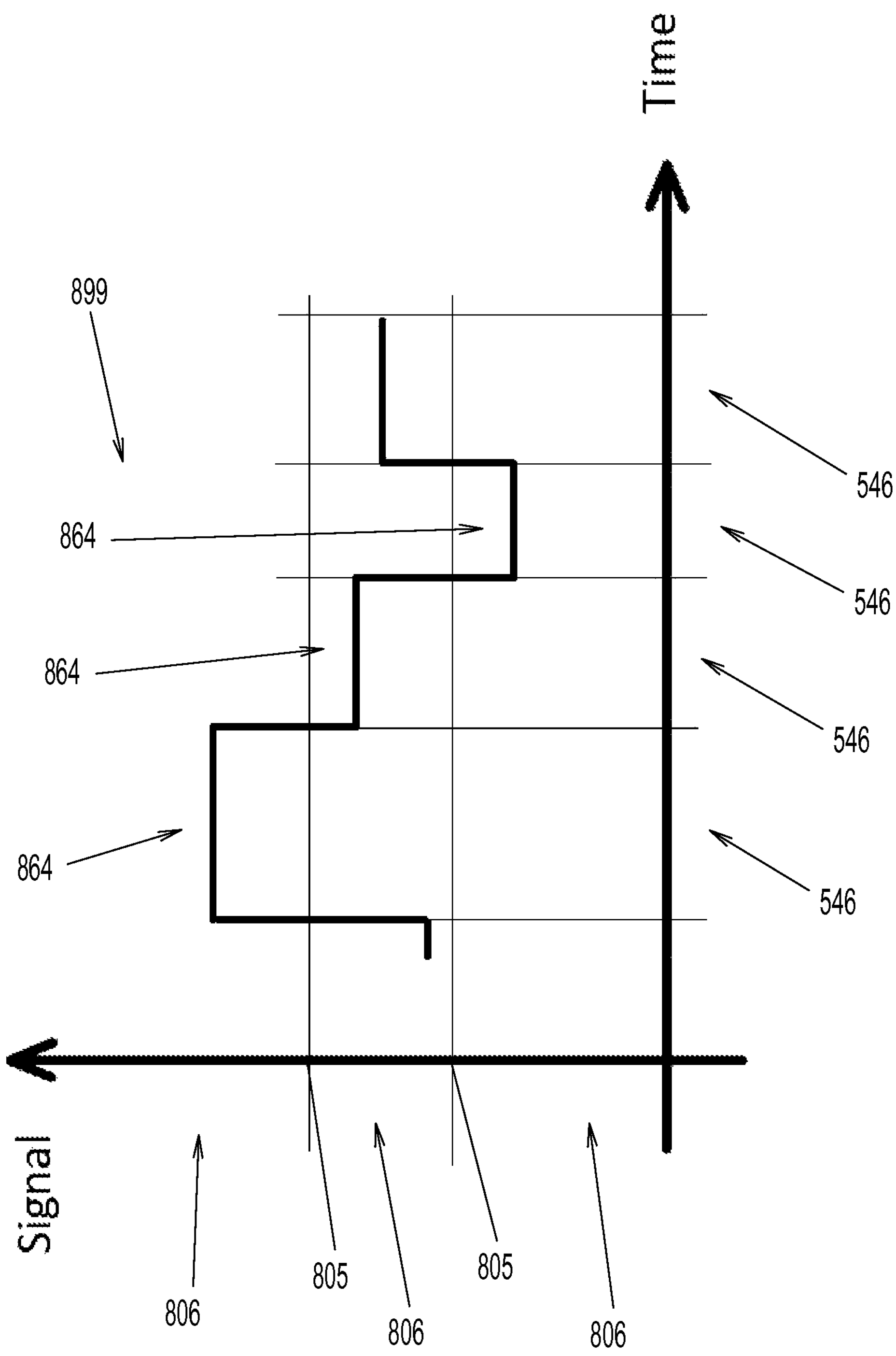
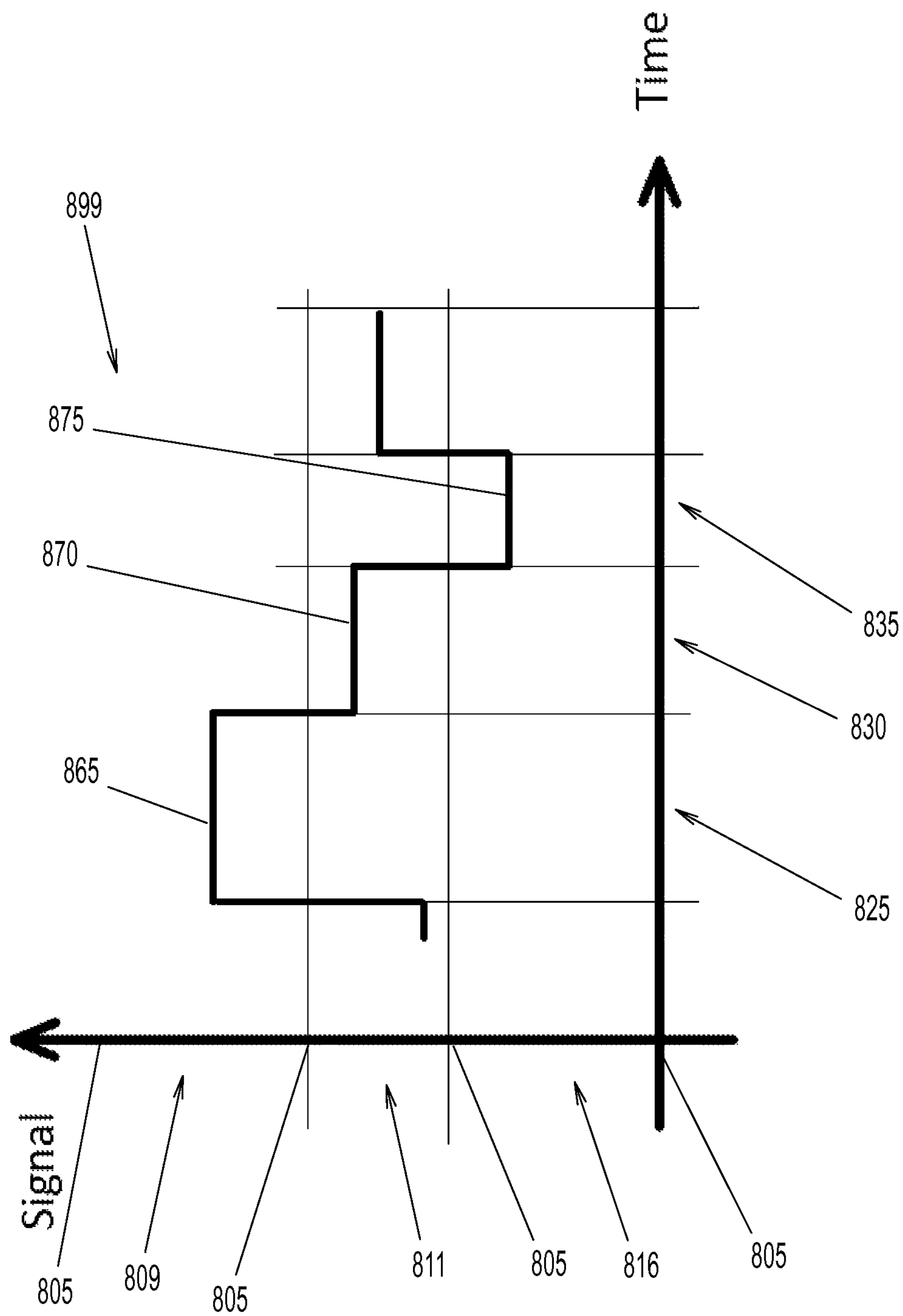


FIG. 16



Time
899
875
870
865
835
830
825
Signal
805
809
805
811
805
816
805

FIG. 17

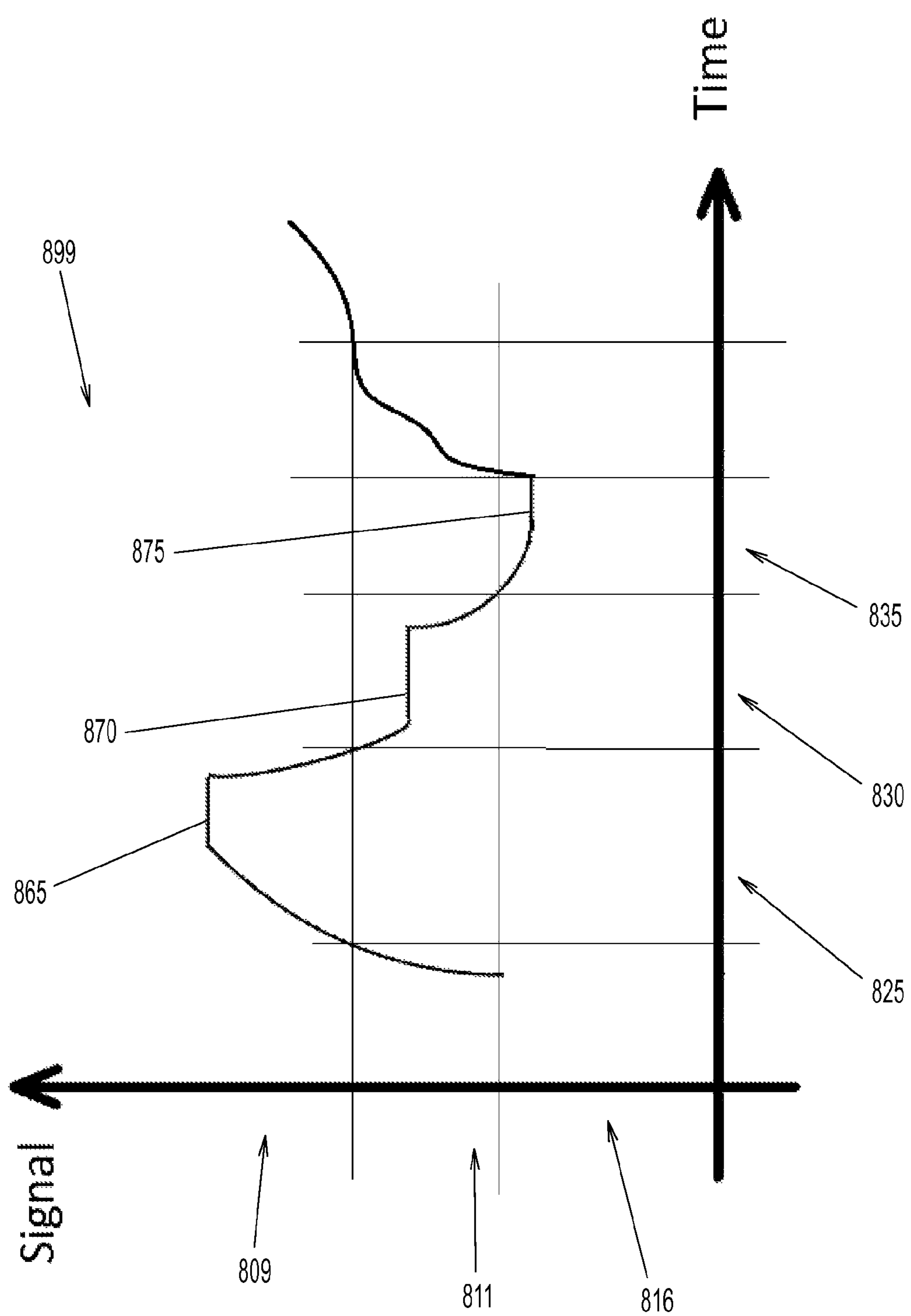


FIG. 18

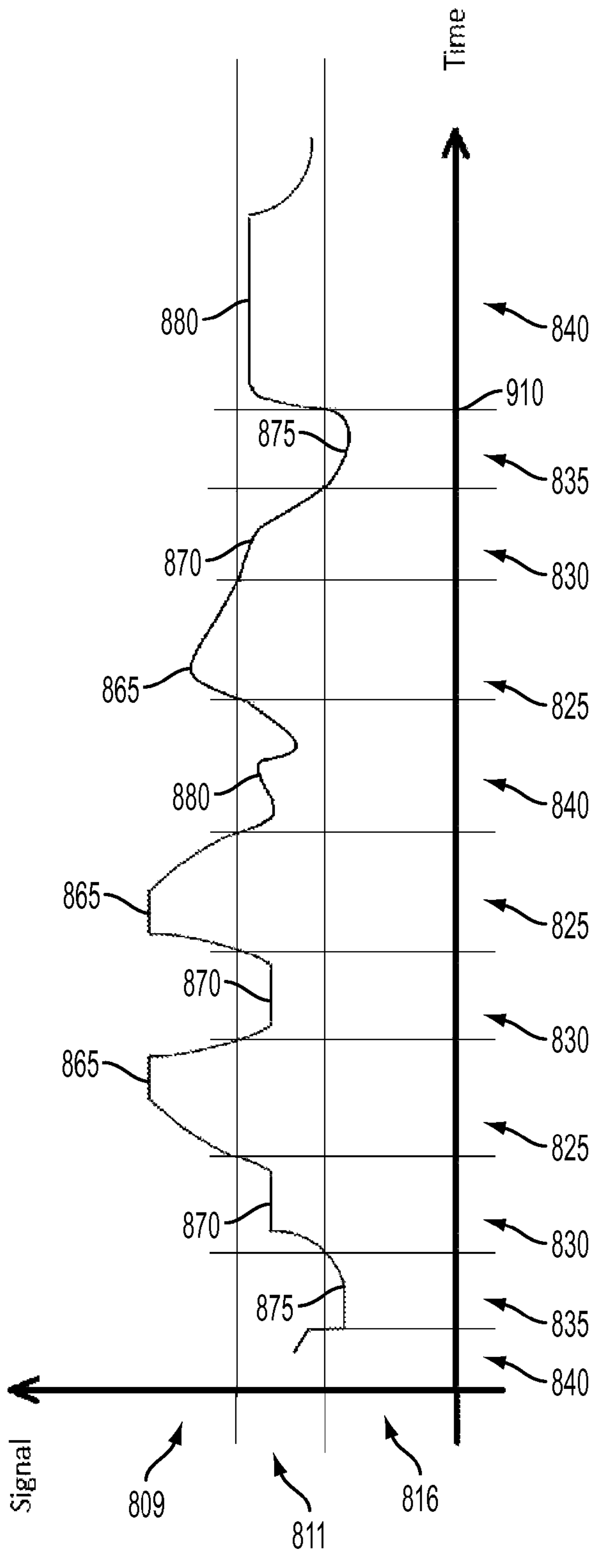

Time
880
840
910
875
835
870
830
865
825
880
840
865
825
870
830
865
825
870
830
875
835
840
Signal
809
811
816

FIG. 19

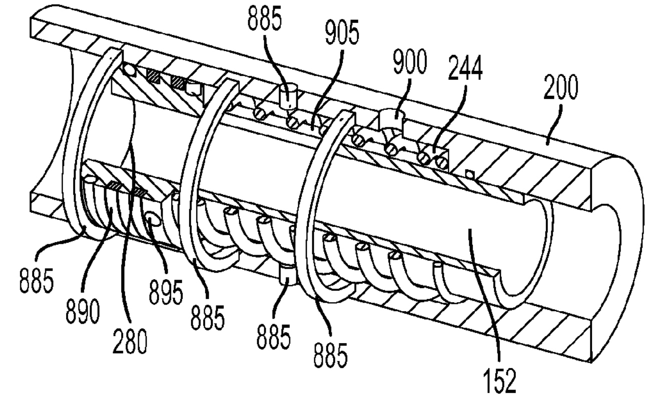


FIG. 20A

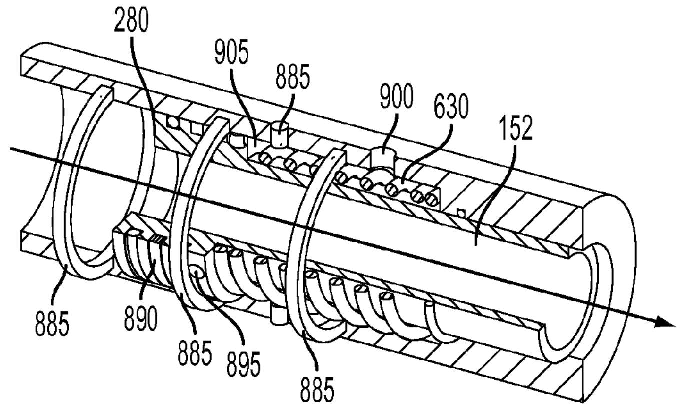


FIG. 20B

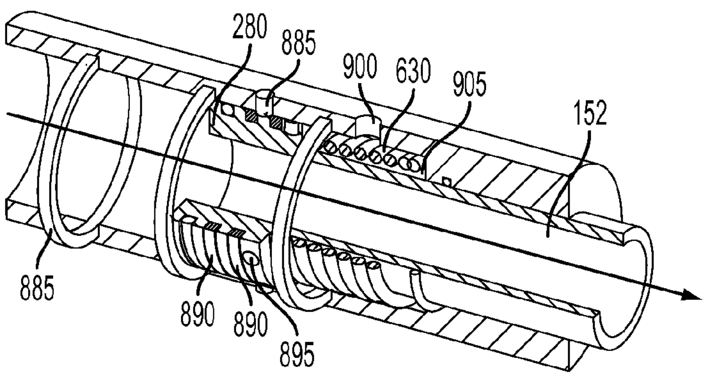


FIG. 20C

APPARATUS AND METHOD TO REMOTELY CONTROL FLUID FLOW IN TUBULAR STRINGS AND WELLBORE ANNULUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

Oil and gas drilling and completion control of fluid flow within a tubular string control of fluid flow between a tubular string inner flow passage and its annular flow passage selectively and remotely sending a command to an apparatus disposed within wellbore.

2. Description of Related Art

One aspect of the current invention is to introduce method and apparatus for selectively and remotely control fluid flow through tubular string and wellbore annulus and change fluid flow profile within wellbore, for example, divert a fraction or all of the fluid within the inner fluid flow passage to the wellbore annulus. The current invention makes it possible to control fluid flow profile and accordingly significantly reduce risks and operating cost associated with cutting beds, risks associated with fluid-losses caused by various reasons some of which were explained by way of examples, and risks associated with accumulation of suspended cuttings among other operating risks where change of fluid flow profile within the wellbore is desired. Another aspect of the current invention is to introduce a method for remotely operating a downhole apparatus selectively into a desired state without limiting operations such as flow rate or flow pressure when it is not desired to change fluid flow pattern. Different forms of solutions in existence as sighted in published patents as sighted.

One known form of flow control apparatus such as those U.S. Pat. No. 4,889,199 are operated using what is called drop ball. Another form of flow control apparatus, sometimes called bypass tool or called circulation apparatus, defines ports in the apparatus body which are initially closed by an axially movable sleeve.

One known form of flow control apparatus such as those published in U.S. Pat. No. 4,889,199 are operated using what is called drop ball. It includes a body with port which normally closed by sleeve, the sleeve also defining a bore restricting profile. When it is desired to move the sleeve to open the port, a ball is inserted into the string at the surface and pumped down the inner flow passage of the tubular string to engage the such drop ball operated apparatus often sleeve profile. Introduce limitations to the drilling practices and causing increase in operating cost. For example, the drop ball introduces restrictions within the inner flow passage and imposing limitation on running services using wireline to access, for example, to run free point services or interact with logging while drilling equipment located beneath the drop ball operated apparatus. Other downhole remotely operated apparatus such as those in sited references induce limitation in the operating practice where fluid flow properties such as flow rate or pressure has to be kept within certain levels to maintain the apparatus in the corresponding state. This limitation causes the drilling operation efficiency to suffer as it may be desirable to operate the drilling fluid for example at a different flow profile such as different flow rate or pressure that my undesirably cause the apparatus to change mode.

SUMMARY OF THE INVENTION

An apparatus for remotely and selectively control fluid flow in tubular strings and wellbore annulus, comprising: a

body defining the boundaries between an inner flow passage through the apparatus and an annular flow passage within the wellbore annulus and having two suitable end connection (s) and at least one lateral hole suitable for connecting the inner flow passage and the annular flow passage;

a controllable valve operable in plurality of desired states for altering the fluid flow pattern within the wellbore wherein the valve is having at least one rotatable element wherein the rotatable element is rotatable to plurality of desired positions. The valve further divides the inner flow passage into upstream and downstream wherein the upstream is the portion of the inner flow passage between the valve and through one end connection of the body and the downstream is the portion of the inner flow passage between the valve and through the other end connection of the body;

an activator disposed within the body capable of selectively change the apparatus in either one of two modes: a disabled mode wherein the valve is not operable, and an enabled mode wherein the valve is operable to a desired state, comprising a means for detecting an intended change in the environment; and

an actuator capable of changing the rotatable element position to cause the valve into a desired state comprising a means for transforming a suitably available energy source into a mechanical movement.

The rotatable element is suitably selected to cause the valve into a specific state and to cause a change of the flow pattern into one or more of the following patterns:

No flow pattern wherein the flow passage between the upstream and the downstream is restricted and the flow passage between the inner flow passage and the annular flow passage is also restricted and the valve is in no flow state;

Through flow pattern wherein the passage between the upstream and the downstream of the inner flow passage is not restricted whereas the passage between the inner flow passage and the annular flow passages is restricted and the valve is in through flow state;

Diverted flow pattern wherein the flow passage between the upstream and the annular flow passage is not restricted whereas the flow passage to the downstream is restricted and the valve is in diverted flow state; and

Full flow pattern wherein the flow passage between the upstream and the downstream of the inner flow passage is not restricted and the flow passage between the inner flow passage and the annular flow passages is not restricted and the valve is in full flow state.

The rotatable element is of a specific form having at least one surface. One possible form of the rotatable element is a ball shaped rotatable element having plurality of surfaces whereas at least one surface comprises a portion of a spherical shape. The form of the rotatable element further comprises plurality of ports located on its surfaces and further comprises a plurality of cavities connecting the ports to form a plurality of flow passage through the rotatable element.

The flow control apparatus further comprises a plurality of sensor means for detecting an intended change in a physical property of the environment resulting in a signal within the apparatus suitable for processing. Such a sensor means could take the form of pressure sensor affected by pressure variation within the wellbore caused, by way of example, by a change of the flow control apparatus depth by moving the tubular string deeper into the earth or bringing the tubular string up to surface for a certain distance within the wellbore. Another means of causing the pressure to change at the pressure sensor within the flow control apparatus is through a means of changing of fluid flow pressure introduced from surface. Another form of the sensor means could be a flow sensor affected by variation of flow property such as fluid flow rate within the wellbore. Another possible form of the sensor means is an electrode for detecting an electrical signal such as a change of the potential voltage or electric current of the electrode with respect to the tubular string caused by induced electric signal into the formation.

A further other possible form of the sensor means is an accelerometer affected by a change of tubular string movement in one or more direction such as a change of the tubular string rotation speed or such as moving the tubular string within the wellbore deeper into the earth or through axial movement or other movement or any combination thereof. Another form of the sensor means is a form of magnetometer affected by magnetic field changes due to change of surrounding magnetic conductivity, or affected by change of the detected earth magnetic signal in certain pattern caused by a change of the apparatus location within wellbore for example by way of moving the tubular string.

The flow control apparatus further comprises a controller means in for processing the signal generated by the sensor means explained above. The controller means is capable of comparing the detected signal pattern to a predetermined command pattern. When a command pattern is detected, the controller means cause the specific change within the apparatus such as causing the apparatus to be in the enabled mode or to cause the apparatus to be in the disabled mode.

The flow control apparatus further comprises a locking means for restricting the change of the apparatus mode. The locking means is capable for selectively restricting the change of the valve state when it is not desired to change the same. The locking means is also suitable for enabling the change of the apparatus mode and is suitable for enabling the change of the valve state when it is desired to perform such a change as per command pattern detected or processed within the activator.

The flow control apparatus further comprises an actuator means for causing a mechanical movement of the rotatable element and accordingly causing a change in the valve state therefore causing a change in flow pattern. One possible form of the actuator means is a form of electric motor powered by a battery, a generator, a charged capacitor or other suitable electric energy source disposed within the apparatus or available on a different location within the tubular string or on surface connected to the apparatus by a connecting means such as wireline cable introduced form surface to the apparatus through the wellbore.

Another possible form of the actuator energy source is an energized resilient element such as a compressed spring. The resilient element stores energy when caused to change its state from relaxed state to a stressed state alternatively called an energized state by means of compressing the resilient element from its relaxed state or by means of coiling or stretching the resilient element from original relaxes state. The resilient element in such a stressed mode when connected to the rotatable element could cause it into a different state particularly when the flow control apparatus is in enabled mode. Another form of the energized resilient element is a form of compressed spring disposed within the flow control apparatus before disposing the flow control apparatus into the wellbore.

A further possible form of an energized resilient element is a spring that is caused to be stressed, by way of example, in a form of compression while within the wellbore by another energy source such as the hydraulic energy harvested from fluid flow within the wellbore. The energized resilient element is capable of releasing mechanical energy when it is made possible to move from stressed position to a relaxed position. Another possible form of the actuator transforming a mechanical energy source caused by an inertia mass element disposed within the flow control apparatus. When the flow control apparatus is in the enabled mode, the inertia mass element is energized by way of momentum or inertia through movement of tubular string, and is possible to cause a change of the valve state when connected to the rotatable element.

Another form of energy transformation caused by the actuator is to transform a hydraulic energy means of the fluid flowing through the inner flow passage or annular flow passage or any combination thereof to generate a mechanical energy causing the rotatable element to change position.

A possible embodiment of the actuator element transforming hydraulic energy from fluid flowing through the wellbore is an orifice disposed within the inner flow passage that is stressed to a level or pushed against a resilient element in certain direction when the fluid flow through the inner flow passage. It is understood that the energy sources explained herein are made by way of example and not exhaustive. The same function could be achieved by other means of energy sources suitably available within the apparatus caused to be utilized or harvested when it is desired to change the position of the rotatable element or when it is desired to change the state of the valve or when it is desired to change the mode of the apparatus or when it is desired to change the fluid flow pattern within the wellbore.

BRIEF DESCRIPTION OF THE DRAWINGS

A complete understanding of the present invention may be obtained by reference to the accompanying drawings, when considered in conjunction with the subsequent, detailed description, in which:

FIG. **1** is a section view of a possible embodiment of a wellbore drilling system wherein a plurality of the fluid flow control apparatus are disposed within drilling tubular string;

FIG. **2** is a section view of a preferred embodiment of the flow control apparatus;

FIG. **3** is a detail view of a possible embodiment of rotatable element by way of example;

FIG. **4** is a perspective cutaway view of a possible embodiment of the actuator in a form of rack and pinion;

FIG. **5** is a detail view of a possible embodiment of the actuator linkage and mechanical energy source;

FIG. **6** is a section view of a possible embodiment of actuator and energy source disposed within the flow control apparatus body;

FIG. **7** is a detail view of an example of a possible flow passage caused by having a form of a rotatable element disposed in different possible position within the valve body wherein the rotatable element comprising a curved outer surface;

FIG. **8** is a detail view of an example of a possible flow passage caused by having a form of a rotatable element disposed in different possible positions within the valve body wherein the rotatable element is a form of a two ports rotatable element comprising a spherical surface and having two ports and one cavity connecting the two ports;

FIG. **9** is a detail view of an example of a possible flow passage caused by having a form of a rotatable element disposed in different possible position within the valve body wherein the rotatable element is a form of a cylindrical shaped rotatable element having two ports and one cavity connecting the two ports;

FIG. **10** is a detail view of an example of a possible flow passage caused by having a form of a rotatable element disposed in different possible position within the valve body wherein the rotatable element is a form of a three ports rotatable element comprising a spherical surface and having three ports and one cavity connecting the three ports;

FIG. **11** is a section view of a possible embodiment of the activator when the flow control apparatus is in disabled mode as in detail (a), and in enabled mode as in detail (b) and detail (c);

FIG. **12** is a barrel cam viewed from different angles in details (a), (b), (c) showing a possible cam track profile;

FIG. **13** is a detail view of a possible embodiment of barrel cam track with a plurality of track passage and a plurality of movement levels;

FIG. **14** is a flowchart of the disclosed method describing the steps suitable for remotely and selectively controlling an apparatus disposed in a wellbore;

FIG. **15** is a flowchart of the disclosed method describing the steps for selectively and remotely controlling a flow passage causing desired flow pattern within a wellbore;

FIG. **16** is a diagram of a possible form of signal pattern comprising a sequence of signal variations over a period of time;

FIG. **17** is a diagram of a possible form of reference pattern comprising a predetermined set of signal variations within a specific period of time;

FIG. **18** is a diagram of a possible form of signal variations within a suitable period of time acceptable as matching with the reference pattern;

FIG. **19** is a diagram of a possible form of detectable patter of signal variations within a suitable period of time having a possible form of matching pattern to the reference patter; and

FIG. **20** is a detailed prospective cutaway view of a possible embodiment of an a means for transforming hydraulic energy from fluid in the wellbore into electric energy source suitable for operating the valve, or a mechanical movement directly into making a suitable movement of the rotatable element.

For purposes of clarity and brevity, like elements and components will bear the same designations and numbering throughout the Figures.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** is a section view of a possible embodiment of a wellbore **100** drilling system wherein a plurality of the fluid flow control apparatus **150** are disposed within drilling tubular string **110** during well forming operation. Majority of drilling systems used in current days include a tubular string **110** composed of a drill bit **120** having a plurality of perforations **125** located through the drill bit **120** to allow fluid flow there through. A heavy tubular with bigger outer diameter among other equipment such as mud motors or logging while drilling equipment or directional drilling control systems, or any combination thereof that is frequently called bottom hole assembly **130** connected to the drill bit **120** from one end. Bottom hole assembly **130** is normally connected by form of thread from the other end to other tubular conduit such as drill pipe **140** connecting the bottom hole assembly **130** to surface. The drill pipe **140** outer diameter is commonly known to be smaller when compared to the bottom hole assembly **130**, therefore the annular volume surrounding the drill pipe **140** within the wellbore **100** over any particular length is larger than the annular volume surrounding the bottom hole assembly **130** of equivalent length within the wellbore **100**. Plurality of fluid flow control apparatus **150** disposed within the wellbore **100** are connected to a portion of the tubular string **110** by a suitable means normally a form of thread on each end connection **155** of the flow control apparatus **150**. The wellbore **100** formed into the earth may have a deviated section **180** where the wellbore **100** is not vertical. A cased hole **185** section is the portion of the wellbore **100** having a tubular of large diameter called casing lining the inner side of the wellbore **100** to protect wellbore **100** from damage. While drilling a deeper section into earth formations an open hole **188** section of the wellbore **100** is formed. A surface mud pumping system **190** is disposed with most drilling operations and includes a drilling fluid tank **194** to store drilling fluid and a pump **192** to force fluid into the inner flow passage **152** defined as the inner space within the tubular string **110**. Cuttings **170** generated from hole making are carried out through the annular flow passage **154**.

An annular flow passage **154** is defined as the space between the inner wall of the wellbore **100** and the outer wall of the tubular string **110**. Cutting beds **175** are sometimes formed by accumulation of cuttings **170** deposited normally at the lower side of wellbore **100** particularly in deviated section **180** of open hole **188** or cased hole **185** of wellbore **100**. Plurality of fractures **160** connected to wellbore **100** may naturally exist or formed during the drilling operations. When fractures **160** exist in a wellbore **100**, they may act as a passage causing a portion of drilling fluid to flow into earth formation causing what is commonly known as losses. When losses are encountered, well control is compromised and drilling operation risks and costs are increased. The flow control apparatus **150** comprises a valve **220**. The valve **220** further divides the inner flow passage **152** into upstream **157** section and downstream **159** section where upstream **157** section is defined as the portion of the inner flow passage **152** from the valve **220** and through the upstream **157** end connection **155** of the flow control apparatus **150** and the downstream **159** section as defined as the portion of the inner flow passage **152** from the valve **220** and through the downstream **159** end connection **155** of the flow control apparatus **150**.

FIG. **2** is a section view of a preferred embodiment of the fluid flow control apparatus **150** comprising a body **200** defining the boundaries between an inner flow passage **152** through the apparatus and the annular flow passage **154** within the wellbore annulus **156** and having a suitable connecting means such as a form of thread to connect the apparatus body **200** to a portion of the tubular string **110** through an end connection **155** disposed on each end connection **155** of the body **200**. One of the end connections is the upstream **157** end connection **155**, and the other end connection **155** is the downstream **159** end connection **155**. The body **200** further comprises one or more lateral hole **210** suitable for connecting the inner flow passage **152** to the annular flow passage **154**. The flow control apparatus **150** further comprises a valve **220**. The valve **220** is the element of the flow control apparatus **150** which allows or restricts the flow connectivity between the upstream **157** section, the downstream **159** section, the inner flow passage **152** and the lateral hole **210** connecting to the annular flow passage **154**. The valve **220** is composed of a valve housing **225** and a plurality of rotatable elements. The valve housing **225** could be an integral part of the body **200** or a separate element inserted into the body **200** inner space. The rotatable element **300** is suitable to be rotated into a plurality of positions. Each position taken by the rotatable element **300** causes the valve **220** to be in a state suitable to connect the flow passages to establish a particular flow pattern within the flow control apparatus **150**, hence wellbore **100** as will be explained later when describing FIGS. **7**, **8**, **9** and **10**.

The flow control apparatus **150** further comprises an actuator **240** capable of transforming a suitably available energy into a mechanical energy suitable for rotating the rotatable element **300** into a desired position. By way of example, the actuator **240** in this figure is composed of an actuation mandrel **246** disposed within the body **200** and movable with respect to the body **200**. The actuation mandrel **246** is having an inner surface that is forming part of the inner flow passage **152** and is having a flow orifice **280** profile suitable to be affected by the fluid flowing through the inner flow passage **152**. When a fluid flows through the actuation mandrel **246** the hydraulic energy from the fluid flow exerts a suitable force on the flow orifice **280** causing the actuation mandrel **246** to move with respect to the body **200** and exert a suitable force on the actuation linkage **242** suitably attached to the rotatable element **300** push-pull point **308** causing the rotatable element **300** to rotate and change its position. The actuation mandrel **246** is suitably attached to a resilient element such as a spring **244**. When the actuation mandrel **246** moves by effect of hydraulic energy from fluid flow, it pushes the resilient element in a suitable direction that causes it to deform and build strain energy which is stored within the resilient element. When the resilient element is allowed to relax and deform back to the previous shape, it will release the stored strain energy into a mechanical movement that is suitable for the actuation mandrel **246** to utilize in order to perform the desired actuation. The above is a demonstration of the actuator **240** causing a transformation of hydraulic energy from fluid flowing through the wellbore **100** inner flow passage **152** to a mechanical energy in the form of actuation mandrel **246** movement. The above is a further demonstration of the actuator **240** causing a transformation of mechanical energy originating from actuation mandrel **246** movement into another form of energy such as strain energy stored within a suitable resilient element located within the apparatus. The spring **244** form of the resilient element is held on the other end by a spring retainer **254** suitably maintained in its position by a suitable fastener such as a spring retainer bolt **256** connecting the spring retainer **254** to the body **200**. The spring **244** form of a resilient element is located within the apparatus to keep the actuation mandrel **246** biased in certain direction. The flow control apparatus **150** further comprises an activator **270**. The activator **270** includes a means of detecting a physical change in the environment using one or more sensor **272** disposed within the apparatus. The sensor **272** is capable of being affected by intended change in one or more physical property of the environment caused by action initiated on surface by the operator.

The activator **270** further comprises a locking means to put the flow control apparatus **150** into either enabled mode or disabled mode. In the enabled mode, the actuator **240** within the flow control apparatus **150** will be operable, whereas in the disabled mode, the actuator **240** within the flow control apparatus **150** is inoperable. By way of example, the locking means comprises a lock **277** element such that when engaged with a suitable locking groove **278** suitably connected to the actuation mandrel **246**, it will restrict the movement of one or more of the actuator **240** elements such as the actuation mandrel **246** and cause the flow control apparatus **150** to be in a disabled mode. When the apparatus is in disabled mode, the valve **220** is not operable to change its state. When the lock **277** is disengaged from the locking groove **278**, the actuator **240** disposed within the flow control apparatus **150** will not be restricted by the lock **277** element and the flow control apparatus **150** will be in enabled mode and the valve **220** will be operable into a different state.

The activator **270** further comprises a controller **274** suitable to analyze the signal output of the sensor **272** and compare it to a command pattern **899** to determine the desired mode then cause suitable changes within the activator **270**. The controller **274** comprises a movement limiting means to limit the actuation linkage **242** movement and cause it to stop after a desired displacement. By a way of example, the movement limiting means of movement control comprises a barrel cam **248** disposed within the body **200** and suitably connected to the actuation mandrel **246**. The barrel cam **248** comprises a cam track **740** with a profile suitable for a cam follower **250** disposed within the body **200** to limit the movement of the barrel cam **248** travel between specific predetermined two or more track point such as those explained in FIG. **13**. Any of the track point restricts the barrel cam **248** displacement from movement in one or more direction. As the barrel cam **248** is suitably connected to the actuation mandrel **246**, when the flow control apparatus **150** is in enabled mode, the movement of the barrel cam **248** as determined by the cam follower **250** travelling the cam track **740** causes the actuation mandrel **246** movement to be restricted between specific desired positions.

FIG. **3** is a detail view of possible embodiments of the rotatable element **300**. Detail A is a view of a two ports rotatable element **310** having at least one spherically formed surface and having one port **305** on its surface and another port **305** on its surface wherein both ports are suitably connected through a cavity within the rotatable element **300**. Detail B is a view of a cylindrical rotatable element **320** having at least one surface curved in a cylindrical form, and having one port **305** on its surface and another port **305** on its surface wherein both ports are suitably connected through a cavity within the rotatable element **300**. Detail C is a view of a three ports rotatable element **330** having at least one form of a spherical surface and having at least three ports on its surfaces wherein each port **305** is suitably connected to another port **305** through a cavity within the rotatable element **300**. Detail D is a view of a general form of a possible embodiment of a rotatable element **300** having at least one outer surface **340** suitable to engage with one or more fluid flow passage such as the inner flow passage **152**, upstream **157** section, downstream **159** section and a lateral hole **210** connecting to the annular flow passage **154**.

FIG. **4** is a prospective cutaway view of a possible embodiment of actuation linkage **242** causing the rotatable element **300** to change position using what is known in the art as rack **410** and pinion **420**, where at least one pinion **420** is suitably connected to the rotatable element **300** and at least one rack **410** is connected to the actuation mandrel **246** and both the rack **410** and the pinion **420** are suitably engaged so that when the rack **410** moves in certain direction the pinion **420** rotates around a suitably located pivot **307**. Engagement between rack **410** and pinion **420** is commonly formed by way of a matching thread however other forms are also possible, such as by way of example, a friction surface or a magnetic coupling. In this figure the valve **220** is composed of a valve housing **225** located inside the body **200** and the rotatable element **300** is in the form of three ports rotatable element **330** explained earlier.

FIG. **5** is a detailed view of another possible embodiment of actuation linkage **242** suitable to cause rotatable element

300 to change position. In this figure movement of the actuation mandrel 246 in a suitable direction cause the actuation linkage 242 to exert a suitable force on the push-pull point 308 causing the rotatable element 300 to change position. An inertia element 510 is disposed within the actuation mandrel 246 having a suitable mass capable of storing kinetic energy in proportion to its mass and speed of movement. When the tubular string 110 moves in certain direction such as when moved along the wellbore 100 axis by pulling in the direction out of wellbore 100 to earth surface or lowering it deeper into earth through the wellbore 100, the flow control apparatus 150 follow the same movement as it is rigidly connected at its end connection 155 through a form of thread to a portion of the tubular string 110 and causing elements disposed within the flow control apparatus 150 to follow the same movement as the tubular string 110. A possible embodiment energy source disposed within the actuator 240 having a means of transforming mechanical energy from tubular string 110 movement within the wellbore 100 into mechanical energy capable of operating the valve 220 is explained hereafter. An inertia element 510 disposed within the actuation mandrel 246 having a suitable mass explained in FIG. 5 is referred to. When the tubular string 110 moves in certain direction such as along the wellbore 100 axis by pulling it out of wellbore 100 or lowering it deeper into earth through the wellbore 100, the flow control apparatus 150 follow the same movement as it is rigidly connected at its ends through a form of thread to a portion of the tubular string 110 and causing elements disposed within the flow control apparatus 150 to follow the same movement as the tubular string 110 the inertia element 510 will store kinetic energy in proportion to its mass and to its movement speed and accordingly to the movement speed of the tubular string 110. When tubular string 110 movement changes, the inertia element 510 will lag the change of movement in time before it follows the new movement of the tubular string 110 due to its stored kinetic energy. When the flow control apparatus 150 is in enabled mode, the change of energy stored in inertia element 510 due to change in tubular string 110 movement can cause movement of the actuation mandrel 246 in a suitable direction causing the rotatable element 300 to change position.

By way of example, in the case when the tubular string 110 is lowered into earth formation then stops, a change of movement occurs. The kinetic energy stored within the inertia element 510 will cause it to continue movement in the original direction if the flow control apparatus 150 is in enabled mode that could be transformed into a mechanical movement to cause the change of rotatable element 300 position.

FIG. 6 is a section view of a possible embodiment of actuator 240 having an electric motor 620 means of transforming a suitably available electrical energy source into a mechanical energy capable of changing the position of the rotatable element 300 by means of linkage in the form of a suitable gear engagement such as worm gear 610 and pinion 420. When the suitable electric energy source is connected to the electric motor 620 causing the worm gear 610 connected to the electric motor 620 output to adequately rotate the pinion 420 that is suitably connected to the rotatable element 300 around the pivot 307 and as a result changing the rotatable element 300 position.

In this figure an alternative energy source disposed within the apparatus in a form of energized resilient element means of mechanical energy source disposed within the apparatus. An energized spring 630 by way of example such as a strained coiled spring 244 or other form of resilient element strained is suitably connected to the pinion 420 by means of a suitable linkage such as a worm gear 610. When the flow control apparatus 150 is enabled, stored mechanical energy disposed within the energized spring 630 is allowed to relax to a less strain state by releasing strain energy into mechanical movement causing the worm gear 610 to adequately move the pinion 420 that is suitably connected to the rotatable element 300 around the pivot 307 and as a result changing the rotatable element 300 position. The example explained above of strain energy stored in a resilient element is similar to the energy stored in a watch winding spring 244 explained in sighted U.S. Pat. No. 163,161 filed in 1874. A means of transforming mechanical energy source disposed within the apparatus in a form of and energized resilient element is explained. The electric motor 620 is suitable for transforming an electrical energy from a suitable electrical energy source disposed within the flow control apparatus 150 in a form of suitable battery 276 or an electric generator. Eclectic generator could be in the form of turbine transforming hydraulic fluid flowing through the wellbore 100 into electrical power source that could be used directly or stored in a form of electrical storage such as rechargeable battery 276 or a capacitor. In a different embodiment the electrical energy source could be disposed within the tubular string 110 or in the bottom hole assembly 130. In another embodiment the electrical energy source could be on surface in a form of battery 276 or electric line from domestic energy source or from drilling system generator. Those electrical energy sources not disposed within the flow control apparatus 150 could be connected to the apparatus actuator 240 by a connecting means such as wireline cable commonly used for wireline services in the oil well making by companies such as Schlumberger or Halliburton, and other electric wireline service providers.

FIG. 7 is a detailed view of possible embodiment of the valve 220 presented in different states by way of presenting the rotatable element 300 in different positions. The valve 220 is capable of forming one of more possible flow passage 700. Detail (AI) is a section view and detail (A2) is a prospective cutaway view of the valve 220 in one state where the rotatable element 300 is in a position such that it restricts flow passage between the inner flow passage 152 and the annular flow passage 154 by way of aligning the outer surface 340 to obstruct flow passage between the inner flow passage 152 and the lateral hole 210. The rotatable element 300 in this position further restrict flow passage within the inner flow passage 152 between the upstream 157 section and downstream 159 section passages by way of aligning the outer surface 340 to obstruct the inner flow passage 152 between the upstream 157 section and downstream 159 section. This figure demonstrate the no flow pattern wherein the flow passage between the upstream 157 section and the downstream 159 section is restricted and the flow passage between the inner flow passage 152 and the annular flow passage 154 is also restricted.

Detail (B1) is a section view and detail (B2) is a prospective cutaway view of the valve 220 in one state where the rotatable element 300 is in a position such that it restricts flow passage between the inner flow passage 152 and the annular flow passage 154 by way of aligning the outer surface 340 to obstruct the flow passage between the inner flow passage 152 and the lateral hole 210. The rotatable element 300 in this position does not restrict flow passage within the inner flow passage 152 between the upstream 157 section and downstream 159 section by way of aligning the outer surface 340 such that the inner flow passage 152 between the upstream 157 section and downstream 159 section is not obstructed. This figure demonstrate the through flow pattern **705** wherein the passage between the upstream **157** section and the downstream **159** section of the inner flow passage **152** is not restricted whereas the passage between the inner flow passage **152** and the annular flow passages is restricted.

Detail (C**1**) is a section view and detail (C**2**) is a prospective cutaway view of the valve **220** in one state where the rotatable element **300** is in a position such that one portion of the inner flow passage **152** is connected with the annular flow passage **154** by way of aligning the outer surface **340** such that it does not obstruct flow passage between one portion of the inner flow passage **152** and the annular flow passage **154** through the lateral hole **210**. The rotatable element **300** in this position further restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section passages by way of aligning the outer surface **340** such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is obstructed. This figure demonstrate the diverted flow pattern **710** wherein the flow passage between the upstream **157** section and the annular flow passage **154** is not restricted whereas the flow passage to the downstream **159** section is restricted.

Detail (D**1**) is a section view and detail (D**2**) is a prospective cutaway view of the valve **220** in one state where the rotatable element **300** is in a position such that the inner flow passage **152** is connected with the annular flow passage **154** through the lateral hole **210** by way of aligning the rotatable element **300** outer surface **340** such that it does not obstruct flow passage between the inner flow passage **152** and the lateral hole **210**. The rotatable element **300** in this position further does not restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section by way of aligning the outer surface **340** such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is not obstructed. This figure demonstrate the full flow pattern **715** wherein the flow passage between the upstream **157** section and the downstream **159** section of the inner flow passage **152** is not restricted and the flow passage between the inner flow passage **152** and the annular flow passages is also not restricted.

FIG. **8** is a detailed view of a possible embodiment of the valve **220** presented in different states by way of showing the rotatable element **300** in different positions. In this figure, the rotatable element **300** is in the form of two ports rotatable element **310**. Detail (AI) is a section view and detail (A**2**) is a prospective cutaway view of the valve **220** in one state where the rotatable element **300** is in a position such that it restricts flow passage between the inner flow passage **152** and the annular flow passage **154** by way of aligning the outer surface **340** to obstruct the flow passage between the inner flow passage **152** and the lateral hole **210**. The rotatable element **300** in this position does not restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section by way of aligning the outer surface **340** such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is not obstructed. This figure demonstrate the through flow pattern **705** wherein the passage between the upstream **157** section and the downstream **159** section of the inner flow passage **152** is not restricted whereas the passage between the inner flow passage **152** and the annular flow passages is restricted.

Detail (B**1**) is a section view and detail (B**2**) is a prospective cutaway view of the valve **220** in one state where the rotatable element **300** is in a position such that one portion of the inner flow passage **152** is connected with the annular flow passage **154** by way of aligning the outer surface **340** such that it does not obstruct flow passage between one portion of the inner flow passage **152** and the annular flow passage **154** through the lateral hole **210**. The rotatable element **300** in this position further restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section passages by way of aligning the outer surface **340** to such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is obstructed. This figure demonstrate the diverted flow pattern **710** wherein the flow passage between the upstream **157** section and the annular flow passage **154** is not restricted whereas the flow passage to the downstream **159** section is restricted.

Detail (C**1**) is a section view and detail (C**2**) is a prospective cutaway view of the valve **220** in one state where the rotatable element **300** is in a position such that the inner flow passage **152** is connected with the annular flow passage **154** through the lateral hole **210** by way of aligning the rotatable element **300** outer surface **340** such that it does not obstruct flow passage between the inner flow passage **152** and the lateral hole **210**. The rotatable element **300** in this position further does not restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section passages by way of aligning the outer surface **340** such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is not obstructed. This figure demonstrate the full flow pattern **715** wherein the flow passage between the upstream **157** section and the downstream **159** section of the inner flow passage **152** is not restricted and the flow passage between the inner flow passage **152** and the annular flow passages is not restricted.

FIG. **9** is a detailed view of possible embodiment of the valve **220** presented in different states by way of showing the rotatable element **300** in different positions. In this figure, the rotatable element **300** is in the form of a cylindrical shaped rotatable element **300**. Detail (AI) is a section view and detail (A**2**) is a prospective cutaway view of the valve **220** in one state where the rotatable element **300** is in a position such that it restricts flow passage between the inner flow passage **152** and the annular flow passage **154** by way of aligning the outer surface **340** to obstruct the flow passage between the inner flow passage **152** and the lateral hole **210**. The rotatable element **300** in this position does not restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section by way of aligning the outer surface **340** such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is not obstructed. This figure demonstrate the through flow pattern **705** wherein the passage between the upstream **157** section and the downstream **159** section of the inner flow passage **152** is not restricted whereas the passage between the inner flow passage **152** and the annular flow passages is restricted.

Detail (B**1**) is a section view and detail (B**2**) is a prospective cutaway view of the valve **220** in one state where the rotatable element **300** is in a position such that one portion of the inner flow passage **152** is connected with the annular flow passage **154** by way of aligning the outer surface **340** such that it does not obstruct flow passage between one portion of the inner flow passage **152** and the annular flow passage **154** through the lateral hole **210**. The rotatable element **300** in this position further restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section passages by way of aligning the outer surface **340** to such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is obstructed. This figure demonstrate the diverted flow pattern **710** wherein the flow passage between the upstream **157** section and the annular flow passage **154** is not restricted whereas the flow passage to the downstream **159** section is restricted.

Detail (C**1**) is a section view and detail (C**2**) is a prospective cutaway view of the valve **220** in one state where the rotatable element **300** is in a position such that the inner flow passage **152** is connected with the annular flow passage **154** through the lateral hole **210** by way of aligning the rotatable element **300** outer surface **340** such that it does not obstruct flow passage between the inner flow passage **152** and the lateral hole **210**. The rotatable element **300** in this position further does not restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section passages by way of aligning the outer surface **340** such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is not obstructed. This figure demonstrate the full flow pattern **715** wherein the flow passage between the upstream **157** section and the downstream **159** section of the inner flow passage **152** is not restricted and the flow passage between the inner flow passage **152** and the annular flow passages is not restricted.

FIG. **10** is a detailed view of a preferred embodiment of the valve **220** presented in different states by way of showing the rotatable element **300** in different positions. In this figure, the rotatable element **300** is in the form of a three ports rotatable element **330**. Detail (AI) is a section view and detail (A**2**) is a prospective cutaway view and detail (A**3**) is an exploded view of the valve **220** in one state where the rotatable element **300** is in a position such that it restricts flow passage between the inner flow passage **152** and the annular flow passage **154** by way of aligning the outer surface **340** to obstruct the flow passage between the inner flow passage **152** and the lateral hole **210**. The rotatable element **300** in this position does not restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section by way of aligning the outer surface **340** such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is not obstructed. This figure demonstrate the through flow pattern **705** wherein the passage between the upstream **157** section and the downstream **159** section of the inner flow passage **152** is not restricted whereas the passage between the inner flow passage **152** and the annular flow passages is restricted.

Detail (B**1**) is a section view and detail (B**2**) is a prospective cutaway view and detail (B**3**) is an exploded view of the valve **220** in one state where the rotatable element **300** is in a position such that one portion of the inner flow passage **152** is connected with the annular flow passage **154** by way of aligning the outer surface **340** such that it does not obstruct flow passage between one portion of the inner flow passage **152** and the annular flow passage **154** through the lateral hole **210**. The rotatable element **300** in this position further restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section passages by way of aligning the outer surface **340** to such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is obstructed. This figure demonstrate the diverted flow pattern **710** wherein the flow passage between the upstream **157** section and the annular flow passage **154** is not restricted whereas the flow passage to the downstream **159** section is restricted.

Detail (C**1**) is a section view and detail (C**2**) is a prospective cutaway view and detail (C**3**) is an exploded view of the valve **220** in one state where the rotatable element **300** is in a position such that the inner flow passage **152** is connected with the annular flow passage **154** through the lateral hole **210** by way of aligning the rotatable element **300** outer surface **340** such that it does not obstruct flow passage between the inner flow passage **152** and the lateral hole **210**. The rotatable element **300** in this position further does not restrict flow passage within the inner flow passage **152** between the upstream **157** section and downstream **159** section passages by way of aligning the outer surface **340** such that the inner flow passage **152** between the upstream **157** section and downstream **159** section is not obstructed. This figure demonstrate the full flow pattern **715** wherein the flow passage between the upstream **157** section and the downstream **159** section of the inner flow passage **152** is not restricted and the flow passage between the inner flow passage **152** and the annular flow passages is not restricted.

FIG. **11** is a section view of a possible embodiment of a locking means to cause the flow control apparatus **150** into enabled mode or disabled mode. By way of example the locking means comprising at least two elements. One element is a lock **277** element and the other element is a locking profile such as a locking groove **278**. One of the elements is disposed in a suitable location within the body **200** and the other element is disposed within a suitable location within an actuator **240** element. The lock **277** is further movable between at least two positions by means of a lock driver **720** suitable to change the lock **277** position from one position to another. Detail A is a section view of the lock **277** engaged with the locking groove **278**. Detail B is a view of the lock **277** disengaged from the locking groove **278**, and detail C is a view of the lock **277** disengaged from the locking groove **278** and the actuation mandrel **246** moved to a different position.

The lock **277** viewed in FIG. **11** is caused to change position by a suitable lock driver **720**. The lock driver **720** in one embodiment is a suitable solenoid. In another embodiment the lock **277** viewed in FIG. **11** is driven by lock driver **720** in a form of a suitable motor. It is understood that the lock **277** can be driven by other suitable lock driver **720** to cause it to move between at least two positions such that, in one position is lock **277** is disengaged from the locking groove **278**, and in another position the lock **277** is suitably engaged the locking groove **278**. For example, when a suitable electric charge is connected to the solenoid, the solenoid becomes energized causing the lock **277** to retract into the body **200** and the lock **277** is caused to disengage away from the locking groove **278** causing the flow control apparatus **150** into enabled mode. The solenoid is operable such that when energized with a different charge the lock **277** is caused to extend into the inner wall of the body **200** and is caused to be suitably engaged with the locking groove **278** causing the flow control apparatus **150** into a disabled mode. The same function made by the solenoid means of lock driver **720** could be achieved by a suitable motor in another embodiment or another suitable means to cause the lock **277** to change position in a different embodiment.

When the lock **277** is engaged with the suitable locking groove **278** disposed within the actuation mandrel **246**, it restricts the movement of the actuation mandrel **246** therefore restricting the movement of the actuation linkage **242** and therefore the movement of the rotatable element **300** is restricted and the valve **220** is restricted from changing its state and not operable into a different state. The flow control apparatus **150** is said to be in disabled mode when the valve **220** is not operable to a different state. When the lock **277** is disengaged from the locking groove **278**, the actuator **240** mandrel disposed within the flow control apparatus **150** will not be restricted by the lock **277** element and the flow control apparatus **150** will be in enabled mode and the valve **220** will be operable into a different state. The flow control apparatus **150** is said to be in enabled mode when the valve **220** is operable to a different state. The locking means explained is by way of example.

Another possible embodiment of the lock **277** means is explained; in a different embodiment of the actuator **240** such as the embodiment in FIG. **6** where the actuator **240** comprises a suitable electric motor **620** is achieved by disconnecting the electric source form the electric motor **620** causing the electric motor **620** to be inoperable and accordingly the rotatable element **300** is restricted from changing position by means of the gear arrangement where the worm engaged with the pinion **420** act as a break when the worm gear **610** is not rotatable, and the flow control apparatus **150** is then said to be in the disabled mode. When the electric motor **620** is connected to the suitable electric energy source, it rotates in certain direction causing the worm gear **610** to rotate and resulting in a change of the rotatable element **300** position and the valve **220** is operable into a different state and the flow control apparatus **150** is said to be in enabled mode.

FIG. **12** is a view of barrel cam **248** viewed from different angles in details (A), (B), (C), showing a possible cam track **740** profile. The barrel cam **248** comprising a suitable cam track **740** disposed on a curved surface having plurality of stop points. A Cam follower **250** suitably disposed within the apparatus such that the cam follower **250** and the barrel cam **248** are movable to each other wherein either the cam follower **250** or the barrel cam **248** is restricted from moving in at least one direction with respect to the body **200**. By way of example, the cam follower **250** in FIG. **2** is not movable with respect to the body **200** main axis that is parallel to the wellbore **100** axis, while the barrel cam **248** in FIG. **2** is movable with respect to the cam follower **250** when the actuation mandrel **246** moves within the body **200**. The cam track **740** comprises at least one stop point **794** such that when the cam follower **250** traverses the cam track **740** in a traverse direction **725** and passes a stop point **794**, the cam follower **250** will be restricted from traversing the cam track **740** in the opposite direction by restriction means such as a step within the cam track **740**. In this example, while the barrel cam **248** is moving relative to the body **200**, the cam follower **250** traverse the track in the traverse direction **725** from track point **1 755** to track point **2 760** then to track point **3 765** then to track point **4 770** and then continue traversing the cam track **740** to reach the starting track point **1 755**. Throughout the barrel cam **248** movement is controlled by the cam track **740** profile and the cam follower **250**, the axial and rotational movement of the barrel cam **248** suitably mounted on the actuation mandrel **246** result in a controlled movement of the actuation mandrel **246**.

FIG. **13** is a view of a cam track **740** disposed in another possible embodiment having one or more cam track **740** by way of example herein as upper track **750** and lower track **752**. Each of the upper track **750** and the lower track **752** having at least one stop point **794** suitably located onto the cam track **740** to cause the cam follower **250** traversing the cam track **740** to have plurality of possible combinations of sequence of stop points. In this figure when the cam follower **250** traverse the upper track **750** starting from track point **1 755** then track point **2 760** followed by track point **3 765** and track point **4 770** to then to track point **1 755** when the cam follower **250** fully travers the upper track **750**. The cam follower **250** could be suitably controlled to traverse the lower track **752** starting from track point **1 755** then track point **5 780** followed by track point **6 785** then track point **7 790** then track point **8 795** then track point **4 770** and then back to the starting point at track point **1 755** when the cam follower **250** complete the traverse of the lower track **752**. It is understood that this figure demonstrate by way of example possible combination of stop points in a cam track **740** where the cam follower **250** traversing the upper track **750** in this example passes by a total of four track stop points, while traversing the lower track **752**, the cam follower **250** would pass by 6 track stop points before complete the lower track **752** to the starting point. This form of multi cam track **740** is advantageous and desirable in control systems. It is understood that plurality of tracks and plurality of track stop points are possible using this concept.

FIG. **14** is a flow chart describing the steps used in the disclosed method for remotely and selectively controlling an apparatus disposed within a wellbore **100** comprising a body **200**, a plurality of controllable element and activator **270** and an actuator **240** by means of causing a change in at least one physical property of the environment in certain sequence within a specified period of time resulting in a detectable pattern of signal variations within the apparatus comprising plurality of signal variations within a suitable period of time. The detectable pattern is further compared with a predetermine pattern called a command pattern **899** to determine whether a controllable element state within the apparatus is desired to be changed and then cause the activator **270** to change the apparatus mode into enabled mode. The actuator **240** is then caused to transform a suitably available energy source to cause the controllable element into the different state.

FIG. **15** is a flowchart of the disclosed method for selectively and remotely controlling a flow passage causing desired flow pattern within a wellbore **100** through disposing an apparatus comprising a body **200**, a plurality of controllable valve **220**, an activator **270** and an actuator **240** by means of causing a change in at least one physical property of the environment in certain sequence within a specified period of time resulting in a detectable pattern of signal variations within the apparatus comprising plurality of signal variations within a suitable period of time. The detectable pattern is further compared with a predetermine pattern called a command pattern **899** to determine whether a controllable valve **220** state within the apparatus is desired to be changed and then cause the activator **270** to change the apparatus mode into enabled mode. The actuator **240** is then caused to transform a suitably available energy source to cause the controllable valve **220** into the different state suitable to change the flow pattern into the desired flow pattern. A flow pattern can take any of the flowing patterns, no flow, full flow, a diverted flow and a through flow as explained in FIGS. **7**, **8**, **9**, and **10**.

FIG. **16** is a diagram of a possible form of signal pattern comprising a sequence of signal variations over a period of time. This diagram is aimed to aid understanding the terms used in subsequent description in this disclosure. A signal level point **805** is any possible value of a signal. A signal level zone **806** is defined as any signal value within suitable two signal points defining the signal level zone **806** boundaries. A time period is referenced to as the period of time between any two time points. A time zone **546** is defined as the time period when the signal value stays within a signal level zone **806**. When a signal value is changed to a different signal level zone **806**, a different time zone **546** is defined. A signal is said to have a possible reference pattern **864** if its value stays within a particular signal level zone **806** for a specific time zone **546**.

FIG. **17** is a diagram of a possible sequence of plurality of possible reference pattern **864**. For example, a reference pattern A **865** is defined for the signal value within signal level zone **1 809** and for a time zone A **825**, and a reference pattern B **870** is defined for the signal value within signal level zone **2 811** and for a time zone B **830**, similarly a reference pattern C **875** is defined for the signal value within signal level zone **3 816** and for a time zone C **835**.

FIG. **18** is a diagram of another possible signal pattern processed or interpreted as having the sequence of a reference pattern A **865**, a reference pattern B **870**, and a reference pattern C **875**. a signal is said to have other pattern **880** if it stays within a particular signal level zone **806** for other time zone **840** not matching those defined by reference pattern A **865**, or reference pattern B **870** or reference pattern C **875**.

FIG. **19** is a diagram of a possible sequence of plurality of possible reference patterns. In chronological order the activator **270** processor will interpret the sensor **272** signal by referring to reference pattern A **865**, reference pattern B **870**, reference pattern C **875**, and other pattern **880** as follows: a reference pattern C **875**, then a reference pattern B **870**, then a reference pattern A **865**, then a reference pattern B **870**, then a reference pattern A **865** then other pattern **880** then a reference pattern A **865**, then a reference pattern B **870**, then a reference pattern C **875**, then other pattern **880**.

FIG. **20** is a detailed prospective cutaway view of a possible embodiment of an actuator **240** having a means for transforming hydraulic energy from fluid in the wellbore **100** into electric energy source. An actuation mandrel **246** is disposed within the body **200** inner space having a flow orifice **280** and inner surface and outer surface **340**. A mud compartment **905** defined as the space between the inner body **200** surface and the actuation mandrel **246** outer surface **340** is having a suitably diameter at one end larger than the diameter on the other end and having at least one generator port **900** suitable for connecting fluid within the mud compartment **905** to fluid in the annular passage. The different inner diameter of the mud compartment **905** is such that when the actuation mandrel **246** moves in certain direction will cause the volume of mud compartment **905** to change. A suitable seal element is disposed within the mandrel and body **200** to restrict hydraulic communication between inner flow passage **152** and mud compartment **905**. A suitable form of resilient element is disposed within the mud compartment **905** such as a coil spring **244** wherein the movement of the actuation mandrel **246** in certain direction will cause a change in the strain of the spring **244** and the move of the actuation mandrel **246** in a different direction will cause another change in the strain of the spring. One or more electric coil **885** is disposed within the present invention and one or more magnet is further disposed within the present invention such that movement of the actuation mandrel **246** within the body **200** will cause the relative location between the magnet and the electric coil **885**. In this figure, different forms of magnets are presented by way of example such as stud magnet **895** and ring magnet **890**. An example of different form of a suitable electric coil **885** is also presented having different shapes as in figure. Detail (A) is a view of the apparatus during no circulation. Detail (C) is a view of the apparatus during mud circulation. Detail (B) is a view of the apparatus during transition between no circulation and mud circulation.

By way of referring to wellbore **100** operation, and tubular string **110** disposed within a wellbore **100** comprising a drill bit **120**, a bottom hole assembly **130**, a plurality of flow control apparatus **150** and drill pipe **140**. Drilling risks encountered during wellbore **100** operations include by way of examples having cutting beds **175**, having suspended cuttings **170** in the well bore or having fluid losses into porous formation or fractures **160**. It is desirable to change annular flow velocity at certain points within the wellbore **100** to improve hole cleaning by way of causing the cutting beds **175** and suspended cuttings **170** to move up the wellbore **100** annular passage to surface. It is further desirable to dispose certain fluid composition such as materials and chemicals to treat formation damage and reduce fluid losses. It is further desirable to introduce cement composition in a suitable form for treating a wellbore **100** fracture through the wellbore **100** to plug the formation fractures **160** without flowing the cement through the bottom hole assembly **130** components. It is further desirable to control flow pattern within the wellbore **100** and between inner flow passage **152** and annular passage at different points within the tubular string **110** to deal with one or more of the drilling operations risks encountered.

During customary drilling operation such as when the drill bit **120** cuts and removes new formation at the bottom of the well and enlarging the wellbore **100**, it is further desirable to have continuous mechanical access through the inner flow passage **152** to enable running wireline services such as gyro survey to evaluate the well directional information. It is further desirable to dispose a drop ball activated equipment such as under reamers within the same tubular string **110**. It is further desirable to enable the operator to use optimized drilling parameters such as varying flow rate or drilling with high pressure without undesirably causing the flow control apparatus **150** into a different mode. It is further desirable to dispose plurality of flow control apparatus **150** within the same tubular string **110** at various points and operate each one individually and selectively. It is further desirable to operate the flow control apparatus **150** to cause plurality of fluid flow pattern including one or more of the following flow patterns: through flow, lateral flow, full flow or no flow. It is further desirable to dispose the flow control apparatus **150** within the tubular string **110** such that mechanical restrictions within the inner flow passage **152** caused by other components of the tubular string **110** disposed between the flow control apparatus **150** and surface does not restrict the operation of the flow control apparatus **150**. It is further desirable to operate the flow control apparatus **150** efficiently independent of the depth or the deviation of the point where the flow control apparatus **150** is disposed with respect to the tubular string **110**.

The present invention introduces an apparatus and method to address some or all of the above desirables without the need to pull the tubular string **110** out of the wellbore **100** and resulting in a substantial savings of operation time and reduce operating cost.

An apparatus for remotely and selectively control fluid flow in tubular strings and wellbore annulus **156**, comprising:

a body **200** defining the boundaries between an inner flow passage **152** through the apparatus and an annular flow passage **154** within the wellbore annulus **156** and having two suitable end connections and at least one lateral hole **210** suitable for connecting the inner flow passage **152** and the annular flow passage **154**;

a controllable valve **220** operable in plurality of desired states altering the fluid flow pattern within the wellbore **100** wherein the valve **220** is having at least one rotatable element **300** wherein the element is rotatable to plurality of desired positions. The valve **220** further divides the inner flow passage **152** into upstream **157** section and downstream **159** section wherein upstream **157** section is defined as the portion of the inner flow passage **152** from the valve **220** and through the upstream **157** end connection **155** of the flow control apparatus **150** and the downstream **159** section as defined as the portion of the inner flow passage **152** from the valve **220** and through the downstream **159** end connection **155** of the body **200**;

an activator **270** disposed within the body **200** capable of selectively change the apparatus in either one of two modes: a disabled mode wherein the valve **220** is not operable, and an enabled mode wherein the valve **220** is operable to a different state, comprising a means for detecting an intended change in the environment; and

an actuator **240** capable of changing the rotatable element **300** position to cause the valve **220** into a desired state comprising a means for transforming a suitably available energy source into a mechanical movement;

The rotatable element **300** is suitably selected to cause the valve **220** into a suitable state and to cause a change of the flow pattern into one or more of the following patterns:

a no flow pattern wherein the flow passage between the upstream **157** section and the downstream **159** section is restricted and the flow passage between the inner flow passage **152** and the annular flow passage **154** is also restricted and the valve **220** is in no flow state;

a through flow pattern **705** wherein the passage between the upstream **157** section and the downstream **159** section of the inner flow passage **152** is not restricted whereas the passage between the inner flow passage **152** and the annular flow passages is restricted and the valve **220** is in through flow state;

a diverted flow pattern **710** wherein the flow passage between the upstream **157** section and the annular flow passage **154** is not restricted whereas the flow passage to the downstream **159** section is restricted and the valve **220** is in diverted flow state;

a full flow pattern **715** wherein the flow passage between the upstream **157** section and the downstream **159** section of the inner flow passage **152** is not restricted and the flow passage between the inner flow passage **152** and the annular flow passages is not restricted and the valve **220** is in full flow state. The rotatable element **300** having a suitable embodiment explained by way of example in FIG. **3**. The activator **270** further comprises a plurality of suitable sensor **272** means for detecting an intended change in at least one physical property of the environment resulting in a signal within the apparatus suitable for processing. By way of example, in one embodiment of the apparatus, the sensor **272** means is a form of pressure sensor **272** suitable to be affected by pressure variation within the wellbore **100** caused by way of example by a change of depth or change of fluid flow pressure. In another embodiment the sensor **272** means is a flow sensor **272** suitable to be affected by variation of flow property such as fluid flow rate within the wellbore **100**. In another embodiment the sensor **272** means is a form of an electrode suitable for detecting an electrical signal such as a change of the potential voltage or electric current of the electrode with respect to the tubular string **110** caused by an induced electric signal into the formation. In another embodiment the sensor **272** means is a form of an accelerometer affected by change of tubular string **110** movement in one or more direction such as the rotation speed or axial movement speed or any combination thereof. In another embodiment the sensor **272** means is a form of magnetometer affected by magnetic field changes due to change of surrounding magnetic conductivity of the environment at the apparatus caused by change of the detected signal of earth magnetic field in certain pattern caused induced by a change of the apparatus location in earth by way of moving the tubular string **110**. It is understood that the sensor **272** means could take any other form suitable for detecting at least one change of the environment at the apparatus. The activator **270** further comprises a controller **274** means disposed within the flow control apparatus **150** in a form suitable for processing the signal generated by the sensor **272** means explained above.

The controller **274** means is capable of comparing the detected signal pattern to a predetermined command pattern **899**. When a command pattern **899** is detected, the controller **274** means causes the suitable change within the apparatus to cause the desire change of the apparatus mode then to cause the change of the controller **274** to make the suitable changes within the apparatus to change the controllable valve **220** into the desired state. The controller **274** further comprises a movement limiting means to limit the actuation linkage **242** movement and cause it to stop at a desired displacement. By a way of example, movement limiting means of movement control include a barrel cam **248** disposed within the body **200** and suitably connected to the actuation mandrel **246**. The barrel cam **248** comprises a cam track **740** with a profile suitable for the cam follower **250** disposed within the body **200** to limit the movement of the barrel cam **248** travel between specific predetermined two or more track point such as those explained in FIG. **12** and FIG. **14**. Any of the track point restricts the barrel cam **248** displacement from movement in one or more direction. As the barrel cam **248** is suitably connected with the actuation mandrel **246**, when the flow control apparatus **150** is in enabled mode, the movement of the barrel cam **248** as determined by the cam follower **250** traversing the cam track **740** causing the actuation mandrel **246** movement to be restricted to move to a specific position.

The activator **270** further comprises a locking means suitable for selectively change the apparatus mode when it is desired to change the apparatus mode to an enabled mode or to a disabled mode. By way of example the locking means comprises a lock **277** element such that when engaged with a suitable locking groove **278** suitably connected with the actuation mandrel **246**, restrict the movement of one or more of the actuator **240** elements such as the actuation mandrel **246** and cause the flow control apparatus **150** to be in a disabled mode. When the apparatus is in disabled mode, the valve **220** is not operable to change its state. When the lock **277** is disengaged from the locking groove **278**, the actuator **240** disposed within the flow control apparatus **150** will not be restricted by the lock **277** element and the flow control apparatus **150** will be in enabled mode and the valve **220** will be operable into a different state.

In a possible embodiment as described in FIG. **11**, the lock **277** is caused to change position by a suitable lock driver **720**. The lock driver **720** in one embodiment is a suitable solenoid. In another embodiment the lock **277** viewed in FIG. **11** is driven by lock driver **720** in a form of a suitable motor. It is understood that the lock **277** can be driven by other suitable lock driver **720** to cause it to move between at least two positions such that, in one position is lock **277** is disengaged from the locking groove **278**, and in another position the lock **277** is suitably engaged the locking groove **278**. In one embodiment where the lock driver **720** is a solenoid, for example, when a suitable electric charge is connected to the solenoid, the solenoid becomes energized causing the lock **277** to retract into the body **200** and the lock **277** is caused to disengage away from the locking groove **278** causing the flow control apparatus **150** into enabled mode.

The solenoid is further operable such that when energized with a different suitable charge the lock **277** is caused to extend through the inner wall of the body **200** and is caused to be suitably engaged with the locking groove **278** causing the flow control apparatus **150** into a disabled mode. The same function made by the solenoid means of lock driver **720** could be achieved by a suitable motor in another embodiment. It is understood that the locking means by way of example and does not limit the apparatus locking to these mentioned embodiments. When the lock **277** is engaged with the suitable locking groove **278** disposed within the actuation mandrel **246**, it restricts the movement of the actuation mandrel **246** therefore restricting the movement of the actuation linkage **242** and therefore the movement of the rotatable element **300** is restricted and the valve **220** is restricted from changing its state and not operable into a different state.

The flow control apparatus **150** is said to be in disabled mode when the valve **220** is not operable to a different state. When the lock **277** is disengaged from the locking groove **278**, the actuator **240** mandrel disposed within the flow control apparatus **150** will not be restricted by the lock **277** element and the flow control apparatus **150** will be in enabled mode and the valve **220** will be operable into a different state. The flow control apparatus **150** is said to be in enabled mode when the valve **220** is operable to a different state. The locking means explained is by way of example. Another possible embodiment of the locking means is explained; in a different embodiment of the actuator **240** such as the embodiment in FIG. **6** where the actuator **240** comprises a suitable electric motor **620**, the locking means is achieved by disconnecting the electric energy source form the electric motor **620** causing the electric motor **620** to be inoperable and accordingly the rotatable element **300** to be restricted from changing position by means of the gear arrangement where the worm engaged with the pinion **420** act as a break when the worm gear **610** is not rotatable, and the flow control apparatus **150** is then said to be in the disabled mode. When the electric motor **620** is connected to the suitable electric energy source, it rotates in a suitable direction causing the worm gear **610** to rotate causing the pinion **420** to rotate in a suitable direction and resulting in a change of the rotatable element **300** position and the valve **220** is operable into a different state and the flow control apparatus **150** is said to be in enabled mode during when the electric energy source is connected to the motor.

The flow control apparatus **150** further comprises an actuator **240** capable of changing the rotatable element **300** position to cause the valve **220** into a desired state therefore causing a change in flow pattern comprising a means for transforming a suitably available energy source into a mechanical movement. In one embodiment, the actuator **240** comprises a form of an electric motor **620** powered by a suitable battery **276** or a suitable generator or capacitor or other suitable electric energy source disposed within the apparatus or available on a different location within the tubular string **110** or on surface and connected to the apparatus by connecting means such as wireline cable introduced form surface to the apparatus through wellbore **100**. In this embodiment of actuator **240** having an electric motor **620** means of transforming a suitably available electrical energy source into a mechanical energy is capable of changing the position of the rotatable element **300** by means of linkage in the form of a suitable gear engagement such as worm gear **610** and pinion **420**. When the electric energy source is connected to the electric motor **620** causing the worm gear **610** connected to the electric motor **620** output to adequately rotate the pinion **420** that is suitably connected to the rotatable element **300** around the pivot **307** and will cause a change of the rotatable element **300** position and accordingly a change of the controllable valve **220** state and a suitable change of the flow pattern.

In another embodiment the actuator **240** transforms an energy source in the form of an energized resilient element such as a spring **244**. The resilient element stores energy when caused to change its state from relaxed state to a strained state alternatively called an energized state by means of causing a strain to the resilient element such as by means of coiling, compressing or stretching the resilient element from a less strained state. The resilient element in such a strained state when suitably connected to the rotatable element **300** and when the apparatus is in enabled mode, will cause the rotatable element **300** into a different position. In another embodiment, the form of resilient element energy source is pre-energized before disposing the flow control apparatus **150** into the wellbore **100**.

In a further other embodiment the resilient element energy source is energized while within the wellbore **100** by another energy source such as hydraulic flow as explained in the embodiment viewed in FIG. **20**. When the flow control apparatus **150** is enabled, stored mechanical energy disposed within the energized resilient element is allowed to relax to a less strain state by releasing strain energy into mechanical movement causing the worm gear **610** to adequately move the pinion **420** that is suitably connected to the rotatable element **300** around the pivot **307** and as a result changing the rotatable element **300** position. The example explained above of release strain energy stored in a resilient element is similar to the energy stored in a watch winding spring **244** explained in plurality of sighted patents such as U.S. Pat. No. 163,161 filed in 1874. A means of transforming mechanical energy source disposed within the apparatus in a form of and energized resilient element is explained. In a further possible embodiment, the actuator **240** comprises a means suitable to transform a form of mechanical energy source caused by an inertia mass element disposed within the flow control apparatus **150** into a mechanical movement suitable for changing the rotatable element **300** position. When the flow control apparatus **150** is in enabled mode, and when the inertia element **510** is suitably energized by way of momentum or inertia for example through movement of tubular string **110**, the inertia element **510**, suitably connected to the rotatable element **300** as explained earlier, will cause a change of the rotatable element **300** position and accordingly cause a change in the valve **220** state.

In a further other embodiment, the actuator **240** is suitable for transforming a hydraulic energy of the fluid flowing through the inner flow passage **152** or annular flow passage **154** or any combination thereof to generate a suitable mechanical energy causing the rotatable element **300** to change position explained herein. The practice of introducing drilling fluid composition into the tubular string **110** inner flow passage **152** will cause the fluid in the inner flow passage **152** to have higher pressure than the fluid in the annular flow passage **154** at the same depth, and the fluid is called to be circulated through the inner flow passage **152** and the operation is commonly called mud circulation. When no fluid is introduced into the tubular string **110** inner flow passage **152**, the fluid pressure in the inner flow passage **152** will be similar to the fluid pressure in the annular flow passage **154** at the same depth and the operation is commonly called no circulation. The apparatus actuator **240** described in FIG. **20** harvest energy from the change of pressure between the inner flow passage **152** and the annular flow passage **154** at the apparatus depth during the mud circulation and stores it through deforming a resilient element such as the spring **244** shown in figure. The mud compartment **905** defined as the space between the inner body **200** surface and the actuating mandrel outer surface **340** is having a suitably varying diameter so that fluid pressure exerted on the flow orifice **280** during mud circulation that is higher than the fluid pressure in the mud compartment **905** causing the actuation mandrel **246** to move in the direction suitable to compress the spring **244**. During no circulation the pressure in the mud compartment **905** is the same as the pressure in the inner flow passage **152** and the force exerted by the compressed spring **244** will be released causing the actuation mandrel **246** to move to the opposite direction. The actuator **240** is further having an arrangement of electric coils and magnets such as stud magnet **895** or ring magnet **890** or any combination thereof. When the actuation mandrel **246** moves with the effect of mud circulation in one direction and moves again at no circulation in the opposite direction it will cause a change of magnetic field detected by the electric coil **885** caused by the change of relative position of the electric coil **885** and the magnet element causing electric charges observed in the electric coil **885**.

In a further possible embodiment of the present invention the electric charges is utilized to move the electric motor **620** and in a further possible embodiment, the electric charges is utilized to charge a suitable means of storing electric charge such as capacitor or rechargeable battery **276**. A method of energy harvesting is now explained where electric energy is harvested from hydraulic energy within the wellbore **100**, and a mechanical energy is harvested from hydraulic energy within the wellbore **100**. It is understood that the energy sources explained herein are made by way of example and not exhaustive. The same function is possible to be achieved by other means of energy sources suitably available within the apparatus.

In a further possible embodiment, the actuator **240** comprises an actuation mandrel **246** having a suitable flow orifice **280** profile that is affected by fluid flowing through the inner flow passage **152**. When fluid flows through the actuation mandrel **246** the hydraulic energy from the fluid flow exerts a suitable force on the flow orifice **280** causing the actuation mandrel **246** to move with respect to the body **200** and exerting a suitable force on the actuation linkage **242** suitably attached to the rotatable element **300** push-pull point **308** causing the rotatable element **300** to move and causing the rotatable element **300** to change its position.

The flow control apparatus **150** explained above is normally disposed in the wellbore **100** while in initial valve **220** state of through flow state. Customary drilling operation may take place by including the steps of drilling, flowing drilling fluid into the tubular inner flow passage **152**, lowering the tubular string **110** deeper into the earth and extending deeper into the earth by way of removing layer of earth through drilling process by means of drill bit **120** operation. With reference to the preferred embodiment explained in FIG. **2**, when the valve **220** state is through flow state as in detail A of FIG. **10**, there is no restriction within the inner flow passage **152**. When desired, it is possible in this state to run a suitable wireline services such as gyro survey through the tool inner flow passage **152**. It is further possible to operate a drop ball operated device disposed within the tubular string **110** by means of introducing a suitable drop ball through the tubular string **110** inner flow passage **152** including the inner flow passage **152** portion through the flow control apparatus **150**. When it is desired to change the flow pattern of a particular flow control apparatus **150** disposed within the tubular string **110**, a suitable change in the environment is made causing a signal pattern to be detected within the apparatus.

A command pattern **899** is suitably formed sequence of signal pattern predetermined and stored within each tool and for each desired command. By way of example, a possible command pattern **899** to change a particular valve **220** disposed within a particular flow control apparatus **150** from one flow state to another flow state comprises the following sequence in order, reference pattern A **865** followed by reference pattern B **870** then followed by reference pattern C **875**. A controller **274** disposed within the flow control apparatus **150** processing the signal detected within the apparatus will observe the command pattern **899** at command time point x. At command time point x, the activator **270** will cause the desired change within the apparatus to cause it into the desired mode. The activator **270** further will cause the actuator **240** to cause the controllable valve **220** into the desired state by changing the rotatable element **300** into the desired position by means of transforming a suitably available energy source as explained earlier into a mechanical movement. It is to note that a suitable command pattern **899** is predetermined for each flow control apparatus **150** disposed within the tubular string **110**. This is another desired advantage of the present invention allowing user to dispose plurality of flow control apparatus **150** within the same tubular string **110** and cause each one individually and selectively into a possible independent valve **220** state and accordingly a suitable flow pattern. It is further to note that the command pattern **899** is suitably predetermined such that change of the environment caused during customary operations will not cause the flow control apparatus **150** to change its mode or flow pattern to change, this is another desirable advantage of the present invention such that optimal operating parameters is possible to be deployed without the risk of undesirably causing the flow control apparatus **150** to change its mode or flow pattern.

It is possible to extend and apply the same method of selectively controlling a flow control apparatus **150** using command pattern **899** to any other apparatus disposed within a tubular string **110** suitably equipped to detect such a command pattern **899** and cause the desired actuation to selectively take place. The example explained in FIG. **19** and detailed above for the flow control apparatus **150** could be implemented on any other suitably equipped apparatus having a device means suitable for any desired action such as a valve **220**. The command pattern **899** explained and disclosed herein is another desirable advantage of the present invention as it provide extra flexibility of disposing plurality of apparatus each could have a different device means to perform a different function. Such a command pattern **899** provides an advantage means to enable the operator to selectively and remotely operate plurality of apparatus disposed within a wellbore **100** into a desired mode or a desired state independently.

Furthermore, and with reference to the flow control apparatus **150**, when it is desirable to dispose a particular fluid composition to treat formation damage such as cement composition to treat formation fractures **160**, it would be desirable to operate a flow control apparatus **150** dispose within the tubular string **110** between the bottom hole assembly **130** and surface and cause its valve **220** into bypass state. When in bypass state such as the state explained in FIG. **10** detail (B**1**) (B**2**) and (B**3**). It is to note that fluid composition will all exit the lateral hole **210** into the annular passage to reach the damage formation. It is to note that the inner flow passage **152** downstream **159** section of the valve **220** is obstructed in such a way that safeguard bottom hole assembly **130** components disposed between the drill bit **120** and the flow control apparatus **150** from having such a cement composition undesirably flowing into the bottom hole assembly **130** components.

It is a further advantage that the preferred embodiment explained in FIG. **2** utilizing the valve **220** detailed in FIG. **10** will allow the user to displace all treatment composition fluid within the inner flow passage **152** with another composition fluid without leaving any tangible volume of the treatment composition fluid within the inner flow passage **152**. This is another advantage of the present invention whereas when it is desired to change the valve **220** state into through flow state after performing the disposition of treatment composition fluid into the annular passage, there will be no significant treatment composition fluid within the inner flow passage **152** that would enter the bottom hole assembly **130** inner flow passage **152** and will not be a source of risk to the bottom hole assembly **130** components. As the flow control apparatus **150** is rigidly attached to the tubular string **110** through the end connection **155** and the inner flow passage **152** is hydraulically connected to surface and the drilling fluid commonly used in drilling operations is relatively incompressible, causing any change on the surface by means of moving the tubular string **110** in any direction or causing the fluid flow to change in any particular pattern will cause a suitable change in the environment reasonably detectable by sensor **272** disposed within the flow control apparatus **150** nearly at the same time. This is another advantage of the present invention will save significant operating time when compared to a drop ball activated devices where the drop ball has to consume a significant time traversing the inner flow passage **152** from surface to reach its corresponding apparatus.

It is a further advantage of the present invention to be operated by causing a command pattern **899** within a similar time independent of the depth or location of the flow control apparatus **150**, and independent of the well deviation anywhere in the wellbore **100** where the present invention is disposed of, particularly when compared to drop ball activated apparatus where the drop ball will take different time to reach the corresponding apparatus depending on that apparatus depth, and well deviation. It is a further advantage that the present invention command pattern **899** does not demand a physical access within the inner flow passage **152** allowing the operator to dispose the flow control apparatus **150** within the tubular string **110** below other devices that may have mechanical restriction within the inner flow passage **152** such a drop ball activated apparatus disposed between the flow control apparatus **150** and surface within the same tubular string **110**. It is another further advantage that the present invention is operable in unlimited number of times and does not suffer from the limited number of operable cycles that is associated with drop ball activated apparatus imposed by what is called a ball capture means used commonly with apparatus using drop ball system.

It is another further advantage that the present invention is operable in one or more of the following flow states: through flow, diverted flow, full flow, and no flow explained earlier providing a far more flexibility to the operator. The through flow is commonly used in customary drilling operation. The diverted flow is of an advantage for composition fluid particularly when the composition is not suitable to pass through equipment disposed downstream **159** of the flow control apparatus **150**, as by the way of example the disposition of cement composition to treat fractures **160** when equipment downstream **159** of the flow control apparatus **150** is a bottom hole assembly **130** component. The full flow pattern **715** is a useful pattern to suitably control or increase the annular fluid velocity aiding to improve hole cleaning and reduce cutting beds **175** and reduce suspended cuttings **170** within the wellbore annulus **156** while at the same time allow for portion of the circulated fluid to flow through the inner flow passage **152** and possibly through the bit perforations **125** to maintain well control at all times. The no flow mode is another important mode suitable for securing the well as a form of sub surface safety valve **220** and could be used in emergency cases where it is desired not to allow flow within the bottom of the well and the inner flow passage **152** such as situations when well control is compromised for example during what is call well kick or early warning of blowout.

Since other modifications and changes varied to fit particular operating requirements and environments will be apparent to those skilled in the art, the invention is not considered limited to the example chosen for purposes of disclosure, and covers all changes and modifications which do not constitute departures from the true spirit and scope of this invention.

Having thus described the invention, what is desired to be protected by Letters Patent is presented in the subsequently appended claims.

We claim:

1. An apparatus for remotely controlling fluid flow in tubular strings and wellbore annulus, comprising:

a. a body defining the boundaries between an inner flow passage through the apparatus and an annular flow passage within the wellbore annulus, the body comprising two ends and at least one lateral hole for connecting the inner flow passage and the annular flow passage;

b. a valve operable in plurality of predetermined states for altering fluid flow pattern, wherein the valve comprises at least one rotatable element movable to a plurality of predetermined positions, wherein the valve further divides the inner flow passage into an upstream section and a downstream section, wherein the upstream section is the portion of the inner flow passage from the valve and through one end of the body and the downstream section is the portion of the inner flow passage from the valve and through the other end of the body;

c. an activator disposed within the body for selectively changing the apparatus into either one of two modes: a disabled mode, wherein the valve is not operable, and an enabled mode, wherein the valve is operable to a predetermined state; and

d. an actuator for changing the position of the rotatable element comprising a means for transforming an energy source into a mechanical movement;

wherein the activator is responsive to an intended change in the environment;

wherein the valve state is responsive to the rotatable element position; said rotatable element comprising at least one surface of spherical shape and at least two ports;

wherein the plurality of predetermined states comprise:

i. no flow state wherein the flow passage between the upstream section and the downstream section is restricted and the flow passage between the inner flow passage and the annular flow passage is restricted;

ii. through flow state wherein the passage between the upstream section and the downstream section is in fluid communication whereas the flow passage between the inner flow passage and the annular flow passage is restricted;

iii. diverted flow state wherein the flow passage between the upstream section and the annular flow passage is in fluid communication whereas the flow passage between the upstream section and the downstream section is restricted; and

iv. full flow state wherein the flow passage between the upstream section and the downstream section is in fluid communication and the flow passage between the inner flow passage and the annular flow passages is in fluid communication.

2. The apparatus of claim **1**, wherein the rotatable element comprising at least one cavity inside the element.

3. The apparatus of claim **1**, further comprising a sensor means for detecting a plurality if intended changes in at least one physical property of the environment resulting in a detectable signal within the apparatus suitable for processing, wherein the sensor means comprising a sensor.

4. A method of remotely and selectively controlling an apparatus disposed in a tubular string within a wellbore, the method comprising steps of:

a. disposing in a wellbore a tubular string including an apparatus comprising:

i. a body;

ii. at least one controllable elements operable in a plurality of predetermined states;

iii. an activator disposed within the body capable of selectively change the apparatus in either one of two modes: a disabled mode wherein the controllable element is not operable, and an enabled mode wherein the controllable element is operable to a predetermined state, wherein the activator comprising a sensor responsive to an intended change in the environment, wherein the intended change in the environment is selected from the set comprising change of fluid property introduced from surface into the wellbore, change of pressure, change of temperature, change of flow rate, change of fluid density, change of fluid viscosity, change of fluid color, change of fluid composition, change of magnetic field or a physical change detectable by the sensor; and

iv. an actuator for changing the controllable element into a predetermined state;

b. causing a change in a physical property of the environment in a predetermined sequence within a specified period of time resulting in a detectable pattern at the sensor, wherein the change in the physical property of the environment comprising a sequence of plurality of signal variations within the specified period of time;

c. comparing the detectable pattern with a command pattern to determine if the controllable element state is to be changed to a different predetermined state;

d. causing the activator to change the apparatus mode into the predetermined mode; and

e. causing the actuator to use an energy source causing the at least one controllable element into a different predetermined state.

5. The method of claim **4** wherein the change in a physical property of the environment is a change of electric field detectable by the sensor.

6. A method for remotely and selectively control fluid flow in a tubular string and wellbore annulus, the method comprising the steps of:

a. disposing a tubular string into a wellbore comprising at least one flow control apparatus comprising:

i. a body defining the boundaries between an inner flow passage through the apparatus and an annular flow passage within the wellbore annulus, the body comprising two ends and at least one lateral hole for connecting the inner flow passage and the annular flow passage;

ii. a valve operable in plurality of predetermined states for altering fluid flow pattern, the valve comprising at least one rotatable element movable to a plurality of predetermined positions, wherein the valve further divides the inner flow passage into an upstream section and a downstream section, wherein the upstream section is the portion of the inner flow passage from the valve and through one end of the body and the downstream section is the portion of the inner flow passage from the valve and through the other end of the body;

iii. an activator disposed within the body for selectively changing the apparatus into either one of two modes: a disabled mode, wherein the valve is not operable, and an enabled mode, wherein the valve is operable to a predetermined state, and

iv. an actuator for changing the position of the rotatable element;

wherein the activator is responsive to an intended change in the environment;

wherein the valve state is responsive to the rotatable element position;

wherein the predetermined states are selected from the set comprising:

1. no flow state wherein the flow passage between the upstream section and the downstream section is restricted and the flow passage between the inner flow passage and the annular flow passage is restricted;

2. through flow state wherein the passage between the upstream section and the downstream section is in fluid communication whereas the flow passage between the inner flow passage and the annular flow passage is restricted;

3. diverted flow state wherein the flow passage between the upstream section and the annular flow passage is in fluid communication whereas the flow passage between the upstream section and the downstream section is restricted; and

4. full flow state wherein the flow passage between the upstream section and the downstream section is in fluid communication and the flow passage between the inner flow passage and the annular flow passages is in fluid communication;

b. causing a plurality of changes in one or more physical property of the environment within a specified period of time resulting in a detectable pattern at the sensor comprising a plurality of signal variations within the specified period of time;

c. comparing the detectable pattern with a command pattern to determine if the valve state is to be changed to a different predetermined state and then causing the activator to cause the apparatus mode into the predetermined mode; and

d. causing the actuator to change the rotatable element position to cause the valve into a different predetermined state resulting in a change of the fluid flow pattern by the valve from an initial predetermined flow pattern to a different predetermined flow pattern.

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