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- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

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(54) Title: AUTONOMOUS FLOW CONTROL DEVICE AND METHOD FOR CONTROLLING FLOW

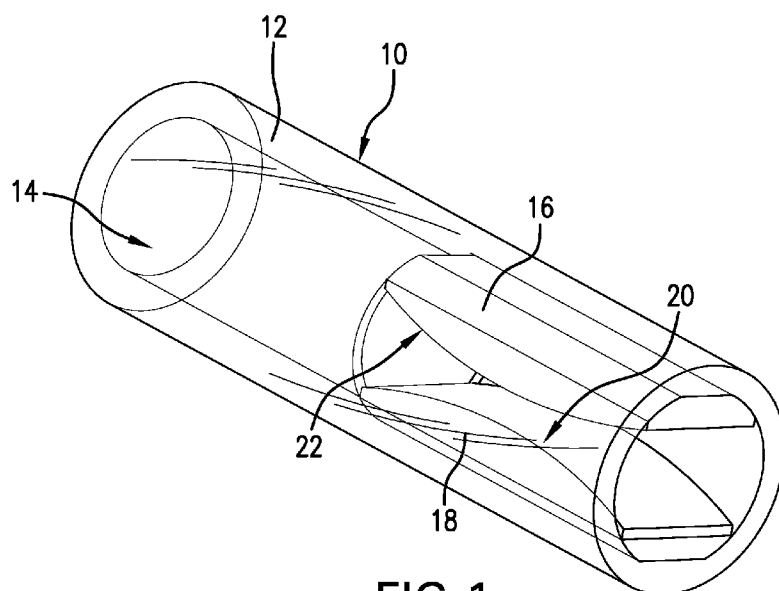


FIG. 1

(57) Abstract: A flow control device includes a housing; a choke member movably operably positioned at the housing. The member presenting a convex surface positioned to be exposed to a fluid flowing through the flow control device during use. A method for controlling flow through a flow control device.

AUTONOMOUS FLOW CONTROL DEVICE AND METHOD FOR CONTROLLING FLOW

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 14/699444, filed on April 29, 2015, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] In industries where flowing fluids are managed, there is often a need for control of rate of flow. This can be for a large number of reasons. In one example, in downhole industries, flow of fluid into or out of tubular systems disposed downhole can be important to achieving ultimate goals of whatever operation of which the flow of fluids is a part.

[0003] Flow control devices, and including inflow control devices, are an example of tools that assist in hydrocarbon production and come presently in many shapes sizes and constructions. Often they will work well for their intended purpose but the industry is always receptive to new configurations that enhance properties or reliability or other salient features of the devices.

BRIEF DESCRIPTION

[0004] A flow control device includes a housing; a choke member movably operably positioned at the housing, the member presenting a convex surface positioned to be exposed to a fluid flowing through the flow control device during use.

[0005] A flow control device including a housing; a choke member positioned at the housing and configured to automatically move from a flow position to a choked position responsive to fluid flow over the choke member at a velocity exceeding a selected threshold velocity.

[0006] A hydrocarbon production system includes a tubular string having an automatic choke member, the member responsive to fluid flowing over a surface of the member at a velocity greater than a selected threshold velocity.

[0007] A method for controlling flow through a flow control device includes flowing a fluid through the device; exceeding a selected threshold velocity of flowing fluid; reducing fluid pressure at a choke member; and automatically reducing a flow area by moving the choke member to reduce the flow area.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0009] Figure 1 is a schematic illustration of an autonomous flow control device in accordance with the present disclosure;

[0010] Figure 2 is a schematic cross section view of the flow control device of Figure 1 configured as an inflow control device in a tubing string;

[0011] Figures 3A and 3B are two schematic views of the same structure in different positions of operation;

[0012] Figures 4A and 4B are two schematic views of the same structure in different positions of operation; and

[0013] Figures 5A and 5B are two schematic views of an alternate embodiment including a spring.

DETAILED DESCRIPTION

[0014] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0015] Referring to Figure 1, a flow control device 10, which may be an inflow control device, is illustrated. The device includes a housing 12 that is illustrated with a flow channel 14 although the channel 14 is superfluous to the inventive concept and not necessary. What is important is at least one choke member 16 or 18. Either one of the illustrated choke members can be employed or both can be employed. Where only one of them is employed, the opposite side of the housing 12 may be flat or may present a convex surface. In any of these cases, at least one of the choke members is movable in a direction that reduces an effective flow area between a convex surface of that choke member and a facing surface. As illustrated, two choke members 16 and 18 are shown, each with a convex surface, labeled 20 and 22 respectively. Movement of one or both choke members is toward the other choke member or housing surface in such a way as to reduce the flow area between the choke members. The convexity of at least one of the surfaces 20 and 22 and laminar fluid flow through a flow area between the opposing surfaces causes pressure of the flowing fluid to reduce proportionally to velocity of the fluid flow. Because at least one of the choke members is mobile toward the opposing surface, a higher velocity fluid flow over the choke

member will drop pressure on that surface and draw the choke member or choke members depending upon whether one or both are mobile toward the opposing surface. This will reduce the flow area through the device 10. This results in an automatic choking when fluid flow rate increases. The amount of restriction and where on the velocity curve choking occurs is adjustable through the length and slope of the convex surface 20 or 22.

.Determination of these parameters is left to computational fluid dynamics and finite element analysis based upon such factors as fluid density, solid content, the boundary layer nature, the surface shear stresses and on the regime imposed by the gas/water phases modifying the flow regime. The velocity of sound is calculated locally as a function of the variable-hydraulic-distance separating both fixed or movable surfaces as to establishing the subsonic, sonic and supersonic flow-conditions. Further, the mass of the individual choke members 16 and/or 18 is relevant to the ultimate function of the device. These parameters may be used to determine an appropriate profile for a specific application. Sometimes greater resistance to erosion could be a dictating factor while in other embodiments response time may be of more importance. Generally, a smaller radius curve will produce a more rapid response time while a larger radius curvature will respond less quickly. Likewise a lower mass choke member will respond more quickly while a higher mass choke member will respond less quickly. Advantageously, the device may be constructed of any material be it polymeric, metallic, ceramic, etc. that is appropriate for the fluid that will be encountered during use. No seals are needed and erosion of components of the device 10 is extremely low simply due to the flow type through the device.

[0016] With respect to mobility of the choke member(s) 16 and/or 18, reference is made to Figures 3A, B and 4A, B. Each pair of figures shows the same configuration in different positions. Figures 3A, B are configured with a recess 30 in the housing 12 for each of the choke members 16 and 18 that are shown. A slide pin 32 ensures the choke member stays in place while allowing the choke member to move radially. One or both of the choke members may be so configured (both being shown as such). Figure 3B illustrates the configuration after fluid flow has exceeded the design point for velocity and the choke members (both in the illustration) have moved toward the other and reduced the flow area therebetween, thereby automatically choking the device in response to a flow velocity above a selected threshold.

[0017] Alternatively, referring to Figures 4A and 4B, the choke member(s) are located via pivot pins 34 instead of the slide pins 32, thereby allowing the choke member(s) to pivot rather than move radially. While the movement of the choke member or choke

members toward the opposing surface (being another choke member or the housing) occurs differently than in Figures 3A, 3B, the same result of a reduced flow area is achieved and this occurs under the same conditions of flow exceeding a design point for movement of the choke member or choke members.

[0018] While the configurations disclosed will operate well for any fluid conveying apparatus in need of flow regulation, they are particularly suited for use as inflow control devices 10 within a string 40 in a hydrocarbon production system. Figure 2 illustrates one way in which the devices disclosed herein may be employed in a downhole environment as an inflow control device. Inflow control devices are concerned with controlling rapid inflow of fluid that would allow fingering or coning that is often experienced near the heel of the borehole but can occur in other sections too. Rapid inflow is often associated with water or gas entering the borehole as opposed to oil. Water and gas have a significantly different viscosity than oil and hence will flow faster. The inflow control device as disclosed is advantageous because it will autonomously choke off the flow if the velocity increases, which usually indicates water or gas infiltration.

[0019] Referring to figures 5A and 5B, an alternate embodiment is illustrated in two conditions of operation. The embodiment employs a resilient member or members 50 (one shown) whose purpose it is to offset the mass of a choke member. In the illustration only one resilient member is shown and is operably connected to one of the choke members...in this case choke member 18. It is to be understood however that resilient members may be utilized for both choke members and that one or more than one resilient member may be utilized with each choke member. Further, although figures 5A and 5B use the type of choke members illustrated in figures 3A and 3B, the application of resilient members 50 is equally applicable to the type of choke members illustrated in figures 4A and 4B.

[0020] The resilient member acts as a tension spring to help draw the choke member 18 from the position shown in figure 5B to the position shown in figure 5A after a flow regime that would otherwise cause the choke members to assume the position shown in figure 5B (as described above) ceases to exist. This embodiment offsets the mass of the choke member itself so that the device will be more responsive to the flow regime only and not be impeded by the mass of the choke members. In some embodiments like that shown the resilient member is a bellows that is filled with an appropriate fluid for the temperature and other conditions in which the device is to be employed. In other embodiments, other types of springs may be substituted such as metal, rubber, plastic, etc. and in all forms such as coil, leaf, wave, solid, etc. type springs.

[0021] A method for controlling flow through a flow control device is also contemplated. The method relies upon the Bernoulli principle and uses a reduction in pressure in a flowing fluid that has exceeded a selected threshold velocity to move the choke member(s) disclosed above in a way that reduces a flow area through the device 10. The movement occurs automatically so that no intervention is needed and so that infinite adjustments occur as fluid flow rates vary over time.

[0022] The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Further, it should further be noted that the terms “first,” “second,” and the like herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. The modifier “about” used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., it includes the degree of error associated with measurement of the particular quantity).

[0023] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited.

CLAIMS

What is claimed is:

1. A flow control device (10) comprising:
a housing (12);
a choke member (16, 18) movably operably positioned at the housing (12), the member presenting a convex surface (20, 22) positioned to be exposed to a fluid flowing through the flow control device during use.
- 2 The flow control device (10) as claimed in claim 1 wherein the choke member (16, 18) reduces a flow area between the convex surface (20, 22) and an opposing surface when in use and fluid flow over the convex surface (20, 22) exceeds a selected threshold velocity.
- 3 The flow control device (10) as claimed in claim 1 wherein the choke member (16, 18) moves radially.
- 4 The flow control device (10) as claimed in claim 1 wherein the choke member (16, 18) moves pivotally.
- 5 The flow control device (10) as claimed in claim 1 wherein the choke member (16, 18) is two choke members each having convex surfaces (20, 22) and wherein the convex surfaces (20, 22) oppose each other.
- 6 The flow control device (10) as claimed in claim 1 further including a resilient member.
- 7 A flow control device (10) comprising:
a housing (12);
a choke member (16, 18) positioned at the housing (12) and configured to automatically move from a flow position to a choked position responsive to fluid flow over the choke member (16, 18) at a velocity exceeding a selected threshold velocity.
- 8 The flow control device (10) as claimed in claim 7 wherein the choke member (16, 18) responsiveness to fluid flow is due to a pressure drop at the choke member (16, 18) from the fluid flow velocity.
- 9 A hydrocarbon production system comprising:
a tubular string (40) having an automatic choke member (16, 18), the member responsive to fluid flowing over a surface of the member at a velocity greater than a selected threshold velocity.
- 10 A method for controlling flow through a flow control device (10) comprising:
flowing a fluid through the device;

exceeding a selected threshold velocity of flowing fluid;
reducing fluid pressure at a choke member (16, 18); and
automatically reducing a flow area by moving the choke member (16, 18) to reduce the flow area.

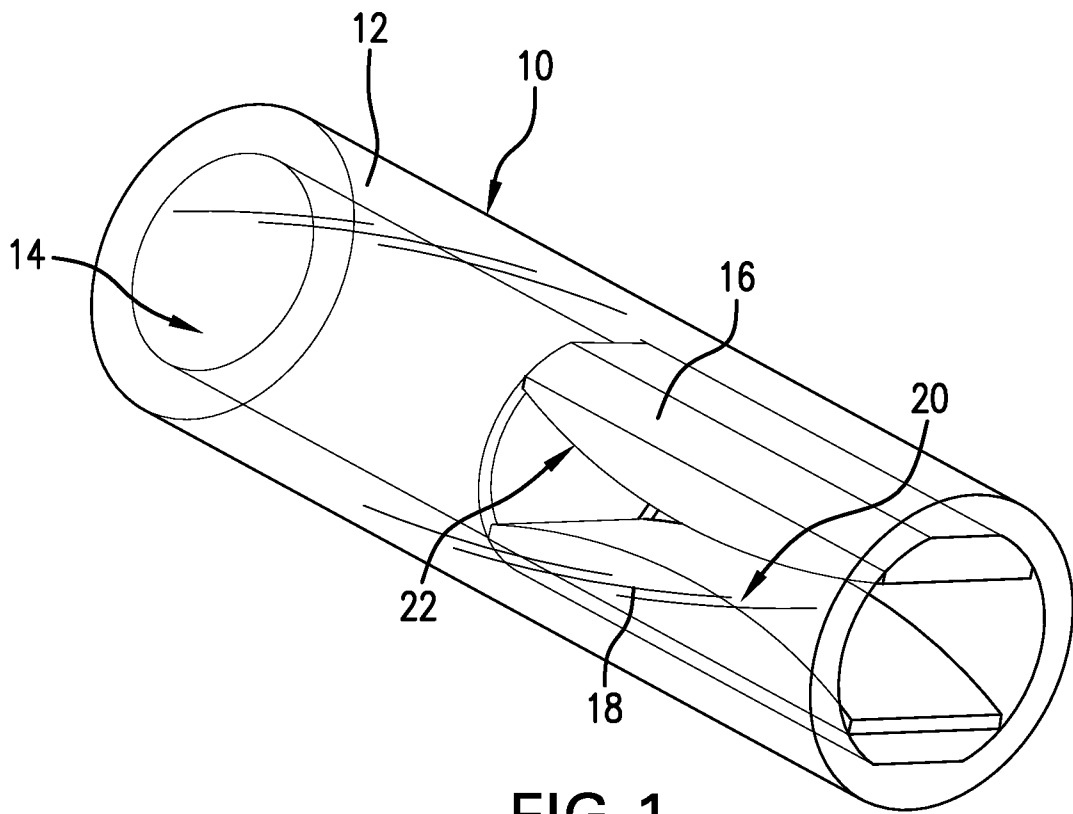


FIG. 1

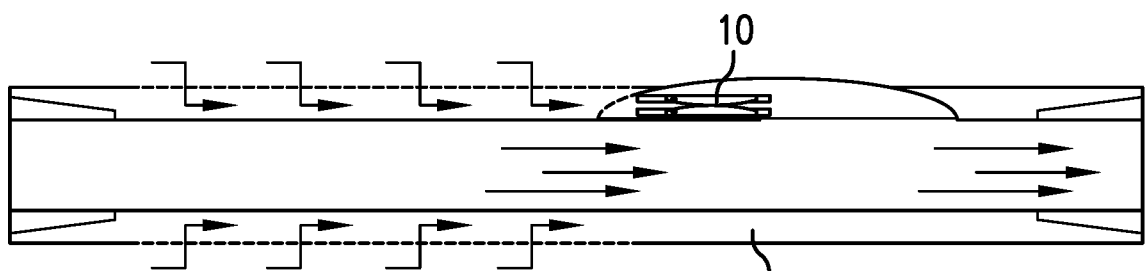


FIG. 2

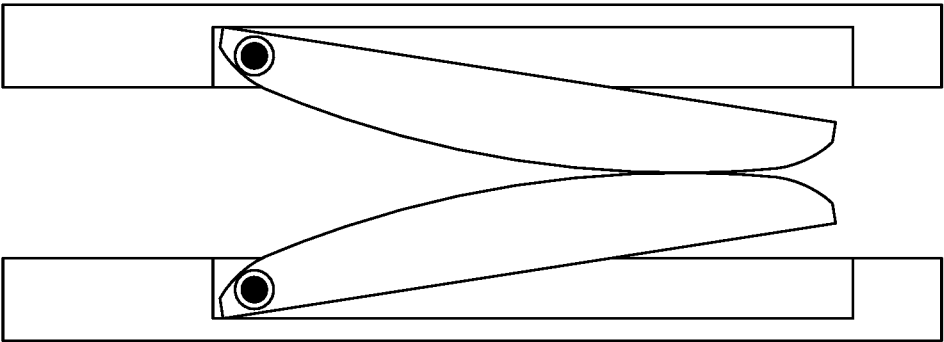


FIG. 4B

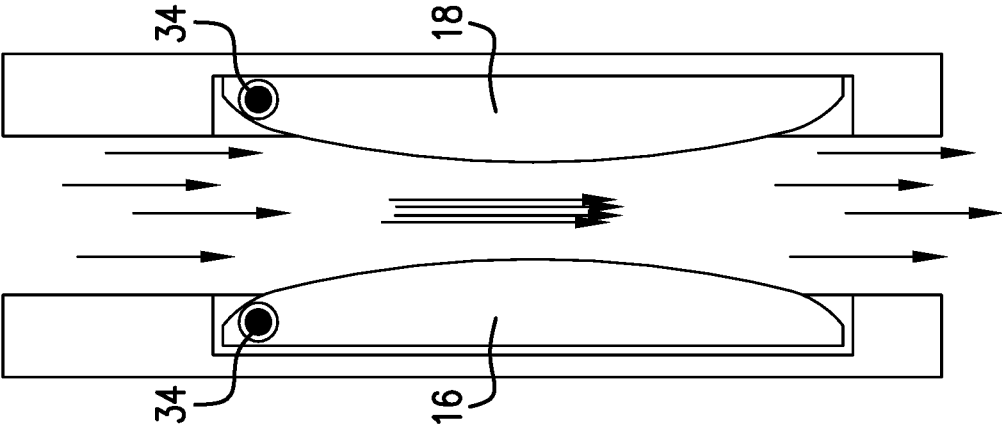


FIG. 4A

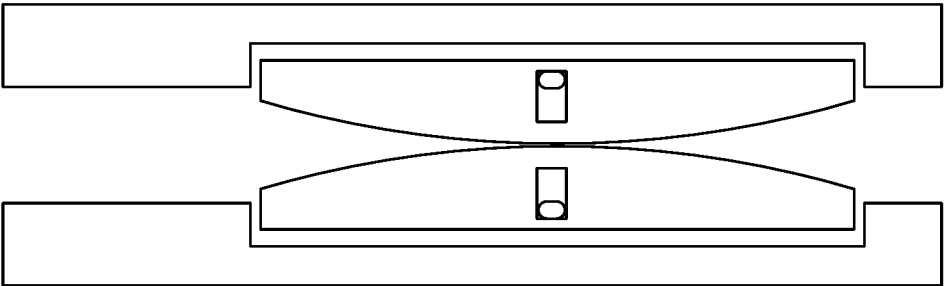


FIG. 3B

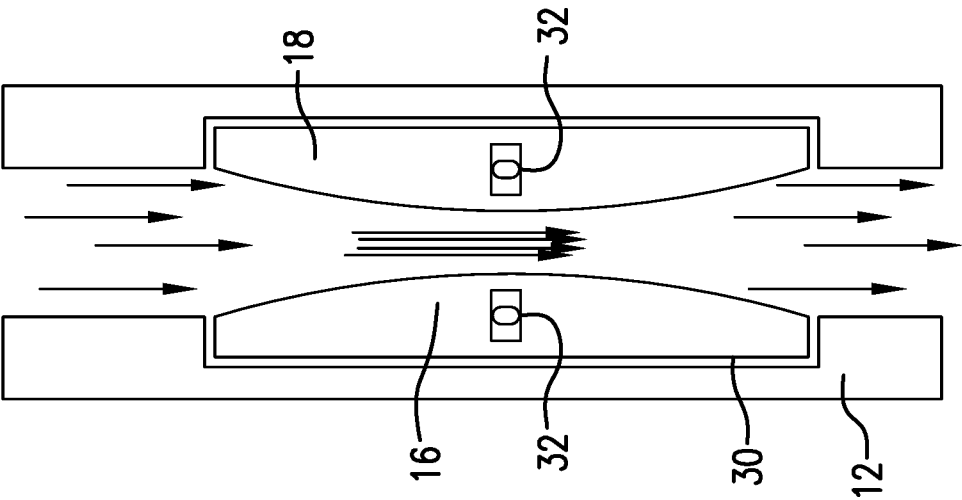
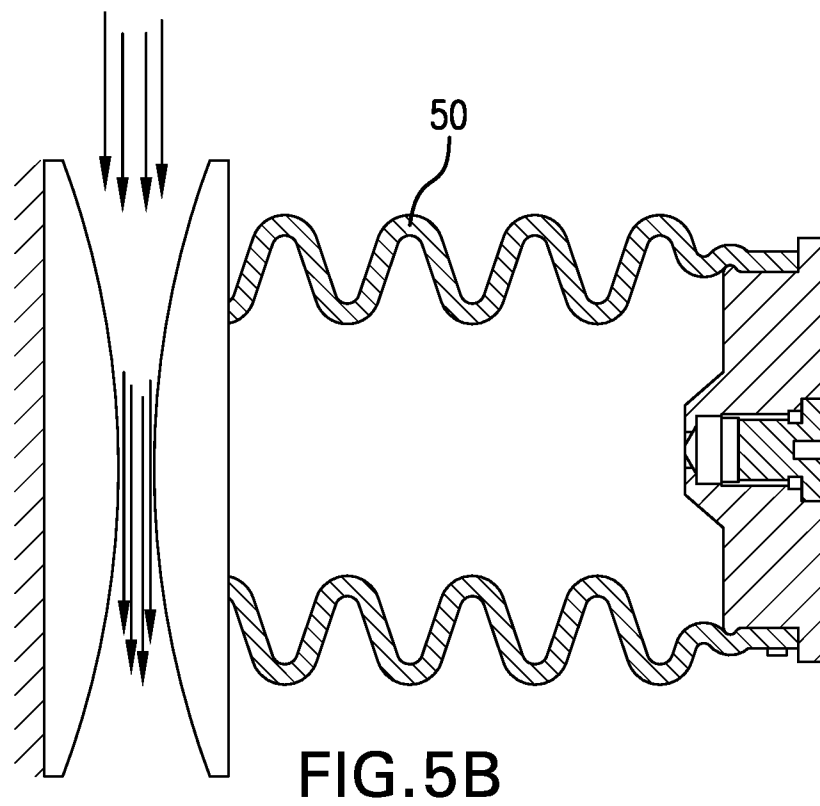
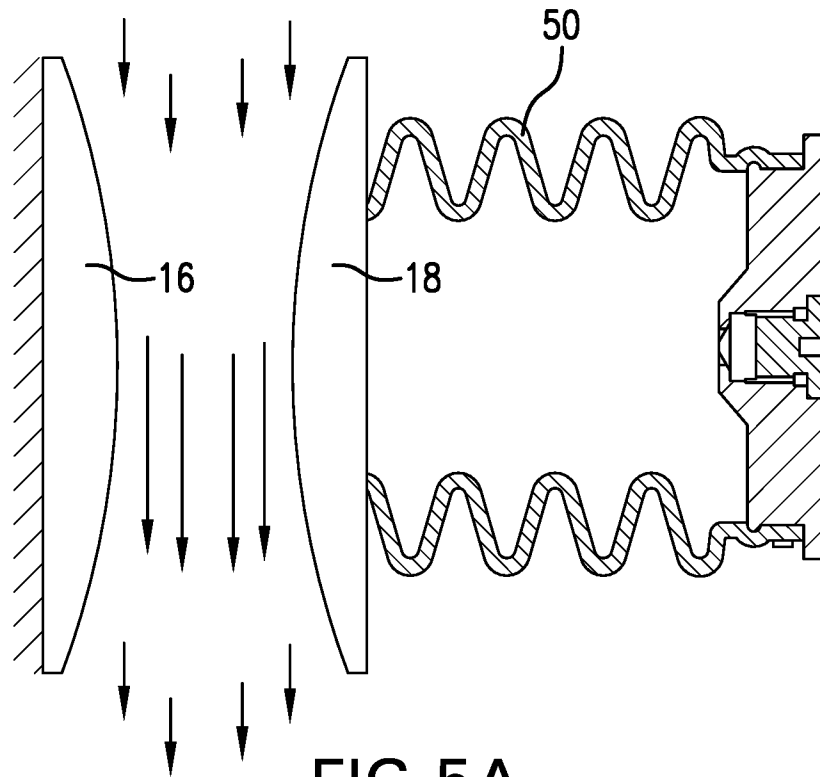


FIG. 3A



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/024643**A. CLASSIFICATION OF SUBJECT MATTER****E21B 34/06(2006.01)i, F16K 3/314(2006.01)i, F16K 1/16(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 34/06; E21B 43/12; F15D 1/00; E21B 43/24; E21B 43/16; E21B 43/08; E21B 34/08; F16K 3/314; F16K 1/16

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: flow, control, housing, choke member, convex surface, fluid, automatic, string, threshold velocity, pressure, radially, pivotally and resilient member

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0294370 A1 (PATTERSON et al.) 25 November 2010 See paragraphs [0012]-[0014], claim 18 and figures 1-2.	1,3-6
Y		2,7-10
Y	US 2015-0060084 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 05 March 2015 See paragraphs [0029]-[0041] and figure 9.	2,7-10
A	US 2015-0053420 A1 (HALLIBURTON ENERGY SERVICES, INC.) 26 February 2015 See paragraphs [0028]-[0106] and figures 2-7.	1-10
A	US 6786285 B2 (JOHNSON et al.) 07 September 2004 See column 3, line 6 - column 6, line 67 and figures 1-7.	1-10
A	US 2003-0132001 A1 (WILSON et al.) 17 July 2003 See paragraphs [0025]-[0044] and figures 2-5.	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30 June 2016 (30.06.2016)

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Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/024643

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