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(54) Title: VARIABLE CIRCULATION RATE SUB FOR DELIVERING A PREDETERMINED STRAIGHT THROUGH FLOW

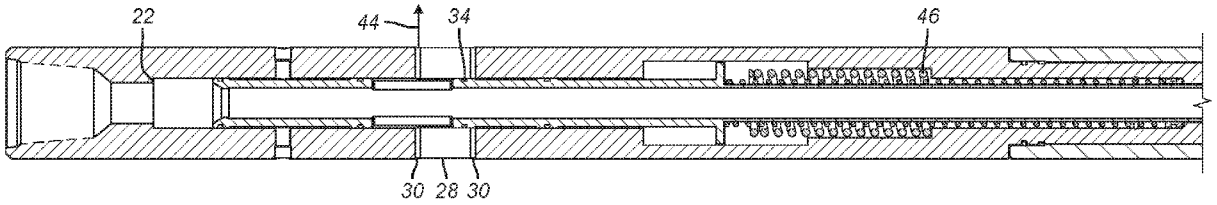

FIG. 2

(57) Abstract: A housing is integrated into a tubing string having a straight through passage and a lateral wall exist. Inside the passage is a flow responsive member with an applied preload force. Flow corresponding to a predetermined differential pressure in the housing will not move the valve member so all flow will go straight through in a downhole direction. As flow increases, the preload bias is overcome to align the passage through the housing and openings in the valve member with wall openings. As flow into the housing increases, more lateral wall opening area is aligned with the passage to increase circulation flow while holding through flow downhole constant. Dropping a ball on the valve member blocks through flow and allows opening of total bypass passages. The ball can be removed by blowing it through the seat or otherwise failing or disintegrating it.

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VARIABLE CIRCULATION RATE SUB FOR DELIVERING A PREDETERMINED STRAIGHT THROUGH FLOW

FIELD OF THE INVENTION

[0001] The field of the invention is downhole circulation subs and more particularly subs that vary circulation rate to hold a predetermined straight through flow responsive to incoming flow and with a capability to be selectively placed in full recirculation or automatic recirculation modes.

BACKGROUND OF THE INVENTION

[0002] In drilling operations it is sometimes necessary to deliver a predictable flow rate to a mud motor, directional drilling equipment or the bit. Automatic systems have been developed to accomplish this task but they are complex and very expensive to install and operate. One example of such a system that sequentially opens and closes surface mounted choke valves is described in WO2015/179408 beginning at paragraph 53. Systems with similar complexity are described in US 7353887. On the other hand, very basic systems that detect fluid loss during drilling and which rely on differential pressure measurements are revealed in US 3595075. Systems that respond to fluid physical properties are described in US 9260952.

[0003] More relevant to the desired simplicity of the present invention is US 9145748 FIGS. 1A and 1B where a flow activated device has two modes of flow straight through and total flow recirculation. The device of the present invention allows total flow straight through below a predetermined amount and then progressively recirculates any excess as input flow rate increases. Another mode is full recirculation by dropping a ball on a seat and selectively overcoming the flow responsive circulation mode by blocking the main flow passage and sending all incoming fluid laterally through a wall port for recirculation. The total recirculation mode can then be overcome by either blowing a seated ball through a seat or otherwise weakening or disintegrating the ball. Normal drilling can resume as the flow through the string is reinstated to the desired flow rate, above which recirculation begins again. These and other aspects of the present invention will become more readily apparent to those skilled in the art from a review of the detailed description of the

preferred embodiment and the associated drawings while recognizing that the full scope of the invention is to be determined by the appended claims.

SUMMARY OF THE INVENTION

[0004] A housing is integrated into a tubing string having a straight through passage and a lateral wall. Inside the passage is a flow responsive member with a preload force applied to it. Flow corresponding to a predetermined pressure difference in the housing will not move the valve member, so all flow will go straight through in a downhole direction. As flow increases, the preload bias is overcome to align the passage through the housing and openings in the valve member with wall openings. As flow into the housing increases, more lateral wall opening area is aligned with the passage to increase circulation flow while holding through flow downhole constant. Dropping a ball on the valve member blocks through flow and allows opening of total bypass passages. The ball can be removed by blowing it through the seat or otherwise failing or disintegrating it.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. 1 is a section view of the device in a position where all flow runs through the housing axially;

[0006] FIG. 2 is the view of FIG. 1 where flow has increased beyond a predetermined amount and some recirculation takes place with the through flow rate holding steady;

[0007] FIG. 3 is the view of FIG. 2 with a ball dropped on the valve member blocking straight through flow and enabling all flow to recirculate.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0008] Referring to FIG. 1, a housing **10** with an uphole connection **12** to a tubular string that is not shown. A downhole end **14** can be connected to a bottom hole assembly for drilling that is also not shown. For a number of reasons, the bottom hole assembly that is not shown needs a predetermined flow rate out the downhole end **14**. Flow coming into uphole end **12** enters passage **16** where a valve member **18** is located that has flow path **20** therethrough that aligns with passage **16**. Housing **10** has an internal shoulder **22** that acts as an uphole travel stop for the valve member **18** under the bias of a stored force. In this case, the preferred mode for the force is a coiled spring **24**. Sleeve **26** schematically illustrates a device that can be used to change the

preload on spring **24** which has the effect of changing the amount of flow coming into uphole end **12** that will go straight through to downhole end **14** without being circulated through openings **28**, **30** or **32**. In the FIG. 1 position openings **28** and **30** are blocked by seals **34** and **36** straddling them, while ports **32** are blocked by seals **38** and **40**. Valve member **18** has an opening **42** between seals **34** and **40**. In FIG. 1, opening **42** is effectively closed against the housing **10** due to the position of seals **40** and **34**. Wall ports **28** and **30** are used for recycle flow beyond a predetermined amount headed to the bottom hole assembly. Openings **32** are for full recycle when no flow goes to the bottom hole assembly and ports **28** and **30** are preferably blocked. During such times, a blocker can be pumped into the formation without having to pass through smaller control openings **28** and **30** which can be needed later when flow to the bottom hole assembly again needs to be controlled and the full recycle ports **32** are closed, as will be described below.

[0009] The position of the components in FIG. 1 is held until a predetermined flow into uphole end **12** exerts enough force on valve member **18** to begin movement of valve member **18** against the spring **24** as the spring compresses. Seal **34** is pushed downhole past openings **28** so that some circulation flow can start out openings **28** while straight through flow remains unchanged. For example, if the target straight through flow is 10 barrels per minute (BPM) and the input flow is increased to 15 BPM, the result will be 5 BPM passing through ports **28** and 10 BPM continuing straight through to the bottom hole assembly. If the input flow is picked up to say 20 BPM, the valve member would move further to the right and increase the effective annular flow area through the ports. An increase in flow beyond the valve's designed range will cause shorter and stiffer spring **46** to engage the valve member and effectively stop its movement to the right. Those skilled in the art will appreciate that the above described device can be mathematically modeled taking into account the quantity and geometry of the openings, the strength of spring **24**, and the amount of applied preload to ensure that a predetermined amount will flow axially to the bottom hole assembly and that when the incoming flow exceeds that predetermined amount, the valve member **18** movement and sequential opening of lateral ports in the housing **10** to

circulation flow will maintain the flow to the bottom hole assembly at the desired predetermined level.

[0010] When used in a drilling assembly and the formation begins to take on fluids, there would be a reason to stop drilling and use the drill string with the housing **10** to deliver seal material in significant quantities to the formation. In that case, a ball **48** is landed on seat **50** and pressure is applied to shift the valve member **18** far enough past openings **32** to redirect all flow with the sealing material to the formation through openings **32**. Openings **32** can be plugged with balls **52** after the pumping of the sealing material is concluded to increase the pressure high enough to blow ball **50** and right after it balls **52**. A ball catcher that is not shown can collect the balls **50** and **52** in a capture volume that surrounds the main flow passage that is the continuation of passage **16**. In that case, the FIG. 1 position is regained and drilling can resume. The opening of passages **32** and their subsequent closing with balls **52** and the capture of balls **50** and **52** in a ball catcher is described in a co-pending application filed on November 2, 2016 and having serial number 15/341,180.

[0011] It should be noted that the number of openings and their spacing and the number of rows can be varied depending on the desired control accuracy desired for control of through flow and the control of the variable recirculation rate. Spring **46** can be optionally replaced by a shoulder in housing **10** that selectively engages the valve member **18** after a finite movement. Spring **24** can be a coiled spring, a stack of Belleville washers or a pressure chamber holing a compressible gas. Ports **28** and **30** instead of being discrete rows of ports can be presented in the form of axial slots that get progressively wider. Ports **32** can also be integrated into the widening axial slot arrangement for the lateral exit openings. Since the lateral ports can be closed even after dropping the balls as in FIG. 3 the integrity of the string to conduct pressure is maintained so that a pressure test can be run or drilling resumed after the conclusion of the lateral pumping of sealant material out ports **32**.

[0012] The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below:

We claim:

1. A flow regulation device to a bottom hole assembly supported on a tubular string in a wellbore, comprising:

a housing (10) comprising a through passage(16) and at least one lateral wall opening (28,30,32) communicating with said passage (10); **characterized by**

a valve member (18) biased in said passage (10) by a first bias (24) having a flow path therethrough directing up to a predetermined flow entering said housing (10) to said bottom hole assembly, said valve member (18) maintaining said predetermined flow to said bottom hole assembly in response to increases in flow to said housing (10) above said predetermined flow by movement of said valve member (18) against said bias (24) to selectively open said at least one lateral wall opening (28,30,32) to divert flow from said housing (10) that in excess of said predetermined flow away from said bottom hole assembly.

2. The device of claim **1**, wherein:

said first bias (24) comprises at least one of a coiled spring, Belleville washers and a compressible fluid.

3. The device of claim **1**, wherein:

said at least one lateral wall opening (28,30,32) comprises a plurality of lateral wall openings (28,30,32) arranged in axially spaced rows, wherein movement of said valve member (18) against said first bias (24) opens at least one of said rows.

4. The device of claim **1**, wherein:

said valve member (18) is movable into a configuration where no flow is directed to the bottom hole assembly by blocking said flow path in said valve member (18) with a first object (48) and shifting said valve member (18) with said first object (48) to selectively open at least one full recycle port in said housing (10).

5. The device of claim **4**, wherein:

said at least one lateral wall opening (28,30,32) is closed by said valve member (18) when said at least one full recycle port is open.

6. The device of claim **5**, wherein:

said at least one full recycle port is selectively closed by at least one second object (52) thereby allowing pressure buildup on said first object (48) to force said first (48) and second objects (52) through said flow path to enable said first bias (24) to close said at least one full recycle port for resumption of said predetermined flow to the bottom hole assembly.

7. The device of claim **1**, wherein:

said predetermined flow is adjustable with a preload applied to said first bias (24) on said valve member (18).

8. The device of claim **3**, wherein:

a second bias (46) engages said valve member (18) after all said axially spaced rows of said lateral wall openings (28,30,32) are open.

9. The device of claim **8**, wherein:

said second bias (46) is stronger than said first bias (24).

10. The device of claim **1**, wherein:

said at least one lateral wall opening (28,30,32) comprises a plurality of circumferentially spaced axially elongated tapered lateral wall openings (28,30,32).

11. The device of claim **10**, wherein:

said valve member (18) is movable into a configuration where no flow is directed to the bottom hole assembly by blocking said flow path in said valve member (18) with a first object (48) and shifting said valve member (18) with said first object (48) to selectively open at least one full recycle port in said housing (10).

12. The device of claim **11**, wherein:

said at least one full recycle port comprises a plurality of full recycle ports axially aligned with said tapered lateral wall openings (28,30,32).

13. The device of claim **12**, wherein:

said recycle ports and tapered lateral wall openings (28,30,32) are integrated into a continuous port.

14. The device of claim **1**, wherein:

said valve member (18) holding housing (10) pressure in said passage (10) at flow rates below said predetermined flow.

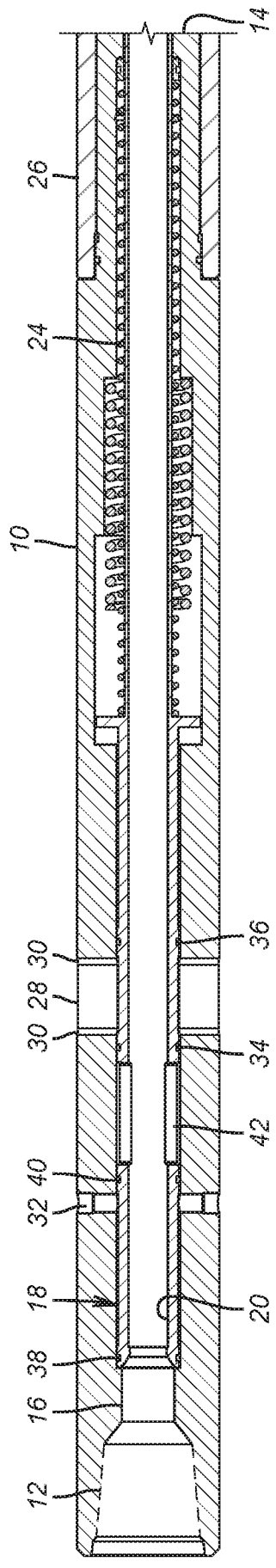

FIG. 1

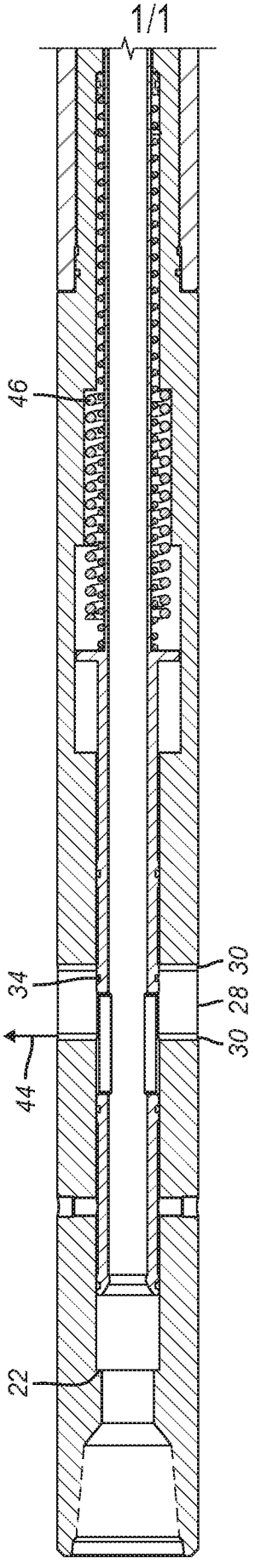

FIG. 2

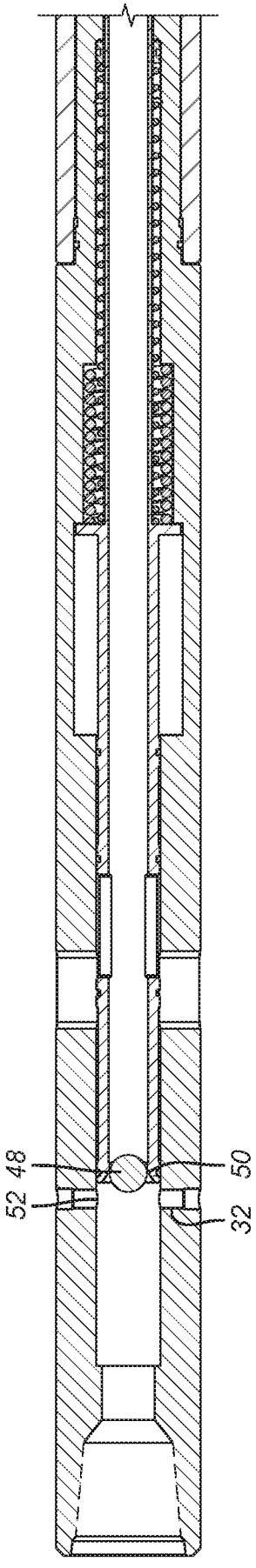

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/059351

A. CLASSIFICATION OF SUBJECT MATTER

E21B 21/10(2006.01)i, E21B 34/06(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 21/10; E21B 23/10; E21B 34/06; E21B 34/00; E21B 23/00; E21B 34/14; E21B 34/10

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: circulation, flow, rate, wall, opening, valve, ball, fluid, drilling, downhole, predetermine, bias

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0252276 A1 (CLAUSEN et al.) 07 October 2010 See paragraphs [0026]-[0037], [0052]; and figures 1, 4-5, 7.	1-14
A	US 2014-0014360 A1 (WILSON, TIMOTHY L.) 16 January 2014 See paragraphs [0025]-[0035], [0044]; and figures 1A, 2A, 3A, 4-6.	1-14
A	US 2010-0155081 A1 (MONDELLI et al.) 24 June 2010 See paragraphs [0038]-[0045] ; and figures 1-5.	1-14
A	WO 2009-024753 A1 (WELLTOOLS LIMITED et al.) 26 February 2009 See page 12, line 15 - page 19, line 6; and figures 1-4.	1-14
A	US 2016-0222758 A1 (FLOWCO PRODUCTION SOLUTIONS) 04 August 2016 See paragraphs [0026]-[0027]; and figures 4-5.	1-14

☐ 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
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"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	Date of mailing of the international search report
24 January 2018 (24.01.2018)	**29 January 2018 (29.01.2018)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/059351

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