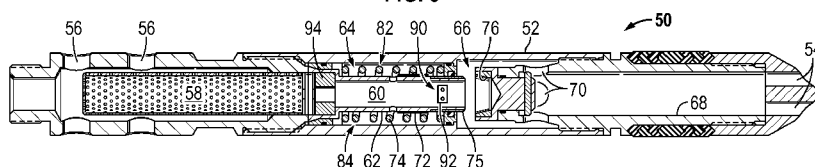




- (51) **International Patent Classification:**
E21B 43/22 (2006.01) *C09K 8/588* (2006.01)
- (21) **International Application Number:**
PCT/US2015/040268
- (22) **International Filing Date:**
14 July 2015 (14.07.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
62/026,400 18 July 2014 (18.07.2014) US
- (71) **Applicant (for CA only):** **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 125 - 9 Avenue SE, Calgary, Alberta T2G 0P6 (CA).
- (71) **Applicant (for FR only):** **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, F-75007 Paris (FR).
- (71) **Applicant (for GB, JP, NL only):** **SCHLUMBERGER HOLDINGS LIMITED**; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola, Virgin Islands, British, 1110 (VG).
- (71) **Applicant (for all designated States except AE, AO, BH, CA, CN, FR, GB, GH, IN, JP, LY, MA, MZ, NA, NG, NL, PH, SD, SY, US, VN):** **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89m, NL-2514 JG The Hague (NL).
- (71) **Applicant (for AE, AO, BF, BH, BJ, CF, CG, CI, CM, CN, GA, GH, GN, GQ, GW, IN, KM, LY, MA, ML, MR, MZ, NA, NE, NG, PH, SD, SN, SY, TD, TG, VN only):** **PRAD RESEARCH AND DEVELOPMENT LIMITED**; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola, Virgin Island, British, 1110 (VG).
- (71) **Applicant (for US only):** **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, Texas 77478 (US).
- (72) **Inventors:** **SCHUUR, Ian Thor**; 5603 Sheraton Oaks, Conroe, Texas 77305 (US). **BOOKER, John Andrew**; 9311 N Fitzgerald Way, Missouri City, Texas 77459 (US).
- (74) **Agents:** **STONEBROOK, Michael** et al.; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, Texas 77042 (US).
- (81) **Designated States (unless otherwise indicated, for every kind of national protection available):** AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) **Designated States (unless otherwise indicated, for every kind of regional protection available):** ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).
- Published:**
— with international search report (Art. 21(3))

(54) **Title:** INTELLIGENT WATER FLOOD REGULATION**FIG. 5**

(57) **Abstract:** A technique facilitates remote monitoring and control of water flood regulator assemblies from a surface location, or other remote location, and for at least one zone in a well. For each zone, a regulator assembly comprising a regulator is deployed and is adjustable to enable regulation of a flow of water into a corresponding water flood injection zone. A control system is operatively coupled with the assembly to enable selective adjustment of the assembly for regulation of the water flow rate without employing intervention operations. In some applications, the surface controlled intelligent water flood regulator provides real time injection point flow information and enables real time adjustment.

PATENT APPLICATION

INTELLIGENT WATER FLOOD REGULATION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present document is based on and claims priority to U.S. Provisional Application Serial No.: 62/026,400, filed July 18, 2014, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] In various hydrocarbon production applications, water flooding is used to enhance secondary recovery of hydrocarbons from a given reservoir. To facilitate the water flooding, water flood regulators are installed in a selective water fluid injection well to regulate the amount of injection water allowed to flow into a reservoir for enhancing the secondary recovery. Each water flood regulator has a regulating mechanism in the form of a mechanical component calibrated to vary the passage area in relation to a desired flow. Once the regulating mechanism is installed, verification that each zone is allowing the desired flow is accomplished by intervention in the well or with costly tracer testing. If the regulating mechanism fails, it can limit the injection flow and curtail production in that zone or it can over inject and damage the reservoir by

channeling. Water flood regulators generally maintain the flow rate based on the compression force of a spring and the size of an orifice installed in the regulator.

SUMMARY

[0003] In general, a system and methodology are provided to enable remote monitoring and control of water flood regulators from a surface location, or other remote location, and for at least one zone in a well. For each zone, an assembly comprising a regulator is deployed and is adjustable to enable regulation of a flow of water into a corresponding water flood injection zone. A control system is operatively coupled with the assembly to enable selective adjustment of the assembly for regulation of the water flow rate without employing intervention operations. In some applications, the surface controlled intelligent water flood regulator provides real time injection point flow information and enables real time adjustment.

[0004] However, many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Certain embodiments of the disclosure will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements. It should be understood, however, that the accompanying figures illustrate the various implementations described herein and are not meant to limit the scope of various technologies described herein, and:

[0006] Figure 1 is a schematic illustration of an example of a well system comprising a plurality of regulator assemblies which are adjustable to regulate flow of

water into corresponding water flood injection zones, according to an embodiment of the disclosure;

[0007] Figure 2 is a cross-sectional view of an example of a controlled water flood regulator assembly with a power generator, according to an embodiment of the disclosure;

[0008] Figure 3 is a view of an example of a power generator illustrated in two reciprocating positions, according to an embodiment of the disclosure;

[0009] Figure 4 is a schematic illustration of an example of a telemetry system for communicating between a downhole water flood regulator assembly and a surface control, according to an embodiment of the disclosure;

[0010] Figure 5 is a cross-sectional illustration of an example of an intelligent water flood regulator assembly with a submersible thermal sensor and a water flood regulator, according to an embodiment of the disclosure; and

[0011] Figure 6 is an illustration of an example of a submersible thermal sensor assembly, according to an embodiment of the disclosure.

DETAILED DESCRIPTION

[0012] In the following description, numerous details are set forth to provide an understanding of some embodiments of the present disclosure. However, it will be understood by those of ordinary skill in the art that the system and/or methodology may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0013] The present disclosure generally relates to a methodology and system which facilitate remote monitoring and/or control of intelligent water flood regulator

assemblies from a surface location or other remote location for at least one zone in a well. For each well flood injection zone, a regulator assembly comprising a regulator is deployed and is adjustable to enable regulation of a flow of fluid, e.g. water, into the corresponding water flood injection zone. A control system is operatively coupled with each regulator assembly to enable selective adjustment of each regulator assembly for regulation of the water flow rate without employing intervention operations. In some applications, each regulator assembly is a surface controlled intelligent water flood regulator assembly able to provide real time injection point flow information and/or real time adjustment of flow rate with respect to flow into the corresponding well flood injection zone.

[0014] According to an embodiment, each surface controlled intelligent water flood regulator assembly provides real time injection point flow information and enables adjustment without employing intervention operations. Changing the flow rate through the regulators in real time dramatically increases the effectiveness of the overall water flood in the field. As a result, adjustment can be made without removing the regulator and without the corresponding work over of the injection well which would otherwise interrupt the flow to the subject zone and/or other zones in the well.

[0015] Measuring the flow in real time and transmitting the value to the surface also enables verification of the operation of the regulators according to the specifications provided in a flood plan. In some applications, the construction of the system and individual regulator assemblies also enables retrofitting into existing side pocket mandrels, thus greatly reducing the cost and time to implement the present system in the field.

[0016] The intelligent water flood regulator assemblies may use power for making flow measurements, for communicating with the surface, and/or for changing the flow rate of the regulators. Additionally, the regulator assemblies may use telemetry to enable communication with the surface, e.g. to enable sending current flow rate data to a reservoir engineer, and for receiving commands from the surface, e.g. receiving

commands from the reservoir engineer to change the flow rate into the zone of interest. The regulator assemblies also may be constructed to measure flow through the regulator in real time. The regulator assemblies are further controllable to modify flow through the regulator according to values received from the surface and to constantly maintain this flow until a new command is received from the surface.

[0017] Referring generally to Figure 1, an example of a well system 20 is illustrated as comprising a tool string 22 deployed in a water flood injection well 24. According to an embodiment, the well system 20 comprises an intelligent water flood regulation system 26 having at least one water flood regulator assembly 28. In the example illustrated, a plurality of the regulator assemblies 28 is deployed along tool string 22 which, in turn, is deployed in a wellbore 30. Depending on the application, the wellbore 30 may comprise a vertical wellbore and/or a deviated wellbore, e.g. horizontal wellbore.

[0018] The wellbore 30 extends into a formation having a subterranean reservoir 32, such as a hydrocarbon containing reservoir. Each regulator assembly 28 is associated with a corresponding well zone 34. For example, each corresponding well zone 34 may be a water flood injection zone into which water is injected via the corresponding intelligent water flood regulator assembly 28 to facilitate secondary recovery of hydrocarbons. In at least some applications, water injected via each regulator assembly 28 flows out of wellbore 30 and into the corresponding water flood injection zone 34 via perforations 36.

[0019] As illustrated, the water flood regulator assemblies 28 may be operatively coupled with a control system 38. In some applications, the control system 38 is a surface control system positioned at a surface location 40 and coupled with the at least one regulator assembly 28 via a suitable telemetry system 42. The telemetry system 42 may be used for transferring data from each regulator assembly 28 to the control system 38. Additionally, the telemetry system 42 may be used to carry control signals, e.g. command signals, from the control system 38 to each water flood regulator assembly 28

so as to adjust the flow rate of water flooding into the corresponding water flood injection zone 34. Control system 38 may have a variety of configurations for processing data and/or providing command signals to enable remote adjustment of selected regulator assemblies 28 to a desired flow rate. By way of example, the control system 38 may be a computer-based control system having a processor 44 for processing data in determining appropriate command signals. The control system 38 also may comprise a memory 46 for storing data and for working in cooperation with the processor 44.

[0020] In some applications, the intelligent water flood regulator assemblies 28 may be retrofit into a given tool string 22. By way of example, the tool string 22 may be constructed with one or more side pocket mandrels 48 configured to receive and release corresponding regulator assemblies 28. The side pocket mandrels 48 are positioned at desired locations along the tool string 22 so as to correspond with the appropriate well zones 34 into which water is to be injected. The side pocket mandrels 48 allow corresponding regulator assemblies 28 (or at least portions of the regulator assemblies) to be deployed and retrieved, as desired, with respect to the tool string 22 located in wellbore 30.

[0021] Referring generally to Figure 2, an embodiment of the intelligent water flood regulator assembly 28 is illustrated. In this example, the regulator assembly 28 comprises a regulator 50 having a housing 52 out of which water is selectively discharged through at least one discharge port 54, e.g. a plurality of discharge ports 54. The water discharged from ports 54 is flooded into the corresponding water flood injection zone 34. In this example, the regulator 50 also comprises at least one inflow port 56, e.g. a plurality of inflow ports 56. The water used to flood the water flood injection zone 34 is flowed into regulator 50 through inflow ports 56 and then travels into, for example, a filter assembly 58. From the filter assembly 58, the water flows along an interior 60 of a rod/tube 62 which may be part of an electromagnetic flow control system 64. The water flows from tube 62, through a flow rate control mechanism 66 (if mechanism 66 is open), into a transfer tube 68 via ports 70, and out through discharge ports 54. It should be noted, however, that the types of components and arrangements of components for

directing water through the regulator assembly 28 may vary according to the parameters of a given structure and/or application. In some applications, for example, the water may flow through an orifice before exiting the interior 60 of tube 62.

[0022] In this example, the electromagnetic system 64 may comprise magnets 72, e.g. permanent magnets, mounted along tube 62 for travel within a corresponding coil 74. With added reference to Figure 3, application of current to coil 74 in a given direction induces a desired magnetic field which drives magnets 72 and tube 62 inwardly toward mechanism 66 to reduce flow of water through regulator 50. By way of example, an end 75 of tube 62 may be constructed for sealing engagement with a corresponding seat 76 of mechanism 66 so as to block flow through regulator 50 when desired. By application of current to coil 74 in an opposite direction, a desired magnetic field is induced so as to drive magnets 72 and tube 62 outwardly with respect to corresponding seat 76. By increasing the distance between the end 75 of tube 62 and seat 76, a greater flow of water is enabled through regulator 50. The flow of electrical power to coil 74 may be controlled via suitable electronics 78 connected with coil 74 via a conductive communication line 80. In some applications, the coil 74 may be constructed as a spring 82 (or used in cooperation with a separate spring 82) to bias the tube 62 in a desired direction, e.g. toward or away from seat 76. It should be noted that in other embodiments the flow rate through regulator 50 may be changed by, for example, adjusting the load on spring 82 or by adjusting an orifice size (e.g. adjusting the size of orifice 94 discussed below).

[0023] The regulator assembly 28 also may be constructed to generate its own power by utilizing a downhole generator 84. By way of example, the intelligent water flood regulation system 28 may be surface controlled and constructed to generate its own power by converting the motion of mechanical flow regulating components into energy. This energy is then stored in a downhole storage device 86, e.g. a battery or capacitor, and used to enable taking of flow measurements, communicating those measurements to the surface, and/or adjusting the regulator flow rate according to commands received from the surface control system 38 regarding a new target flow value.

[0024] In one type of embodiment, the regulator assembly 28 may generate power downhole by utilizing the relative movement between tube 62/magnets 72 and coil 74. For example, the magnets 72 will move through the corresponding coil 74 when tube 62 oscillates with respect to seat 76 of flow control mechanism 66 as the regulator assembly 28 adjusts a flow rate. The magnet or magnets 72 may comprise permanent magnets attached to the outside of tube 62 so that power may be generated according to Faraday's law of induction as the tube 62 (and magnets 72) oscillates with respect to coil 74. The power generated is then delivered through communication line 80 and stored in power storage device 86, e.g. a battery or capacitor, for subsequent use. Additionally, the regulator assembly 28 can be constructed with spring 78 in the form of a nonlinear spring to cause the oscillations during a constant flow situation. Other options for harvesting power include using the vibration of the regulator assembly 28 (or components of regulator assembly 28) for generating electrical power; or using the water flow through regulator 50 to move a mechanical device, e.g. a paddle or micro spinner, coupled with a generator for generation of electrical power.

[0025] Referring generally to Figure 4, an example of telemetry system 42 is illustrated. This embodiment of telemetry system 42 is constructed to enable communication of data and/or control/command signals along tool string 22 between each of the regulators assemblies 28 and the surface control 38. According to an embodiment, signals may be communicated up and down the wellbore 30 via acoustic propagation. An example of such an acoustic telemetry system 42 is the MuZIC™ wireless telemetry system available from Schlumberger Corporation. The communication of acoustic data signals and command signals may be enabled through a network of repeaters 88. Each of the intelligent water flow regulator assemblies 28 is able to both initiate communications to the surface and transfer those communications along the tubing string 22. For example, data packets of those communications can be repeated sequentially along the tool string 22 via the network of repeaters 88 and/or regulator assemblies 28. The repeaters 88 may be used between regulator assemblies 28 and/or along the distance between the topmost regulator assembly 28 and the surface 40.

The repeating capability is used to overcome certain transmission distance limitations that may be associated with acoustic waves.

[0026] Because the first regulator assembly 28 can be several thousand feet from the surface 40 in some wells, additional repeaters 88 may be installed in such a well to span the distance. Although Figure 4 illustrates repeaters 88 mounted externally, the repeaters 88 also can be installed with the tool string, e.g. completion, 22 and powered externally from the surface. The repeaters 88 also can be installed internally within an existing tool string 22 and powered similarly to regulator(s) 50. Communication over the substantial distance also can be accomplished by lowering a suitable telemetry device into the well on a cable to communicate with the topmost regulator assembly 28. Although acoustic telemetry has been described, other options for communicating with and between regulator assemblies 28 may be employed and include electromagnetic (EM) propagation of signals or lowering a cable into the well periodically to communicate with the regulator assemblies 28 via suitable mechanisms, such as inductive couplers.

[0027] According to an embodiment, data regarding flow rate through a given regulator 50 and/or data on other flow related characteristics may be obtained downhole via a sensor or sensors 90, as illustrated in Figure 5. The data from the sensor or sensors 90 is transmitted uphole to control system 38 via telemetry system 42. By way of example, a method for determining flow through a given regulator 50 comprises use of sensor 90 in the form of a thermal flow sensor 92. The thermal flow sensor 92 may be placed at a variety of locations along the flow path of water moving through the regulator 50. By way of example, the thermal flow sensor may be placed in the tube 62 after an orifice 94 of regulator 50, as illustrated in Figure 5. In this type of application, the size of the orifice 94 works in cooperation with flow control mechanism 66, e.g. via positioning of tube 62, to control the amount of water exiting regulator 50 and flowing into the corresponding water flood injection zone 34.

[0028] Embodiments utilizing thermal flow sensor 92 may employ knowledge of the density of the fluid, but in water flood applications the fluid is water and the density is normally constant. In the example illustrated, the measurements made by thermal flow sensor 92 are made after the orifice 94 of the regulator 50 and thus the measurements are independent of orifice erosion. Additionally, these types of measurements are fairly simple and can be easily characterized in a flow loop. In some applications, precautions may be taken to reduce the effects of scaling on the thermal flow sensor 92.

[0029] An embodiment of thermal flow sensor 92 is illustrated in Figure 6. In this example, the thermal flow sensor 92 comprises a temperature sensor 96 and a velocity sensor 98 which detect temperature and velocity for determination of, for example, heat removal 100 and ultimately flow rate according to known equations. In some embodiments, the temperature and velocity data may be transmitted to control system 38 for processing to determine flow rate. However, the determination of flow rate also can be achieved by suitable processing at a downhole location, e.g. by data processing on a suitable processor incorporated into electronics 86. It should also be noted that a variety of other types of sensors are available and may be used to determine flow rate along a given flow passage.

[0030] In operation, a command signal may be sent from the surface control system 38 to a selected regulator assembly 28 at a specific position along tool string 22. If a flow rate adjustment is to be made, the command signal requests the appropriate adjustment of flow rate with respect to water passing through the regulator 50. In this example, the regulator assembly 28 uses its own stored energy to mechanically adjust the flow control mechanism 66, thus adjusting the amount of flow through orifice 94 located along tube 62. For example, the position of tube 62 may be shifted via the appropriately applied current to coil 74 so as to adjust the position of tube 62 relative to corresponding seat 76 of flow control mechanism 66. Consequently, the amount of flow through that particular orifice 94 and regulator 50 may be controlled from the surface or from another suitable remote location or locations. Again, it should be noted that in other

embodiments the flow rate through regulator 50 may be changed by, for example, adjusting the load on spring 82 or by adjusting an orifice size.

[0031] In some embodiments, the intelligent water flood regulator assembly 28 may comprise other mechanisms which are controllable to adjust the flow rate through regulator 50. For example, a given water flood regulator assembly 28 may comprise an electric motor used to shift tube 62. In some applications, an electric motor or other actuator may be used to directly adjust the size of orifice 94 to change the flow rate through the regulator 50. In many of these embodiments, feedback regarding reaching the requested flow rate may be provided by an integrated sensor or sensors 90 which provide data to control system 38. For example, a flow meter, e.g. thermal sensor 92, may be positioned along an interior 60 of tube 62 so as to monitor the flow of fluid, e.g. water, passing through regulator 50. Depending on the application, other techniques and mechanisms also may be employed for adjusting the flow through each regulator 50.

[0032] Additionally, the intelligent, water flood injection system 26 may be constructed in a variety of configurations depending on the parameters of a given water flood application. For example, the water flood injection system 26 may be constructed with a single regulator assembly 28 or multiple regulator assemblies 28 depending on the number of zones to which water flooding treatments may be applied to enhance secondary recovery. Additionally, the regulator assemblies 28 may be used in many types of applications, including many types of hydrocarbon recovery applications and other applications in which a controlled outflow of water or other fluid is desired.

[0033] Similarly, each intelligent water flood regulator assembly 28 may comprise a variety of components arranged in several configurations. For example, several types of actuators may be used to selectively control the flow rate through a given regulator 50. Various downhole power supplies, e.g. batteries or capacitors, may be used to provide power for operating the actuator(s) and/or sensor(s) providing data on the flow rate. The control system 38 also may be constructed in a variety of configurations with various types of processors and/or software for processing data from sensor or sensors 90

and for providing control/command signals to the individual intelligent regulator assemblies 28. The various signals may be carried uphole and downhole by several types of suitable telemetry systems.

[0034] Although a few embodiments of the disclosure have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this disclosure. Accordingly, such modifications are intended to be included within the scope of this disclosure as defined in the claims.

CLAIMS

What is claimed is:

- 1 1. A system for flow control in a water flood injection well, comprising:
2
3 a downhole water flood regulator assembly having:
4 a regulator disposed downhole to provide a flow of water into a
5 water flood injection zone;
6 a sensor for detecting the flow rate through the regulator; and
7 a mechanism for controlling the flow rate through the regulator;
8 and
9 a surface control system which receives data from the sensor and sends
10 command signals to the mechanism to adjust the flow rate.
- 1 2. The system as recited in claim 1, wherein the downhole water flood regulator
2 assembly further comprises a power storage device located downhole proximate
3 the regulator.
- 1 3. The system as recited in claim 2, wherein the downhole water flood regulator
2 assembly further comprises a power generator for supplying power to the power
3 storage device.
- 1 4. The system as recited in claim 3, wherein the power generator generates power by
2 utilizing oscillations of a permanent magnet through a coil.
- 1 5. The system as recited in claim 1, wherein the sensor comprises a thermal flow
2 sensor.

- 1 6. The system as recited in claim 1, wherein the downhole water flood regulator
2 assembly comprises a plurality of downhole water flood regulator assemblies
3 disposed along a tool string in a wellbore.
- 1 7. The system as recited in claim 1, wherein the sensor and the mechanism operate
2 in real time to enable real time adjustment of flow rates into the water flood
3 injection zone.
- 1
1 8. The system as recited in claim 1, wherein the regulator is received in a side pocket
2 mandrel disposed along the tool string.
- 1 9. The system as recited in claim 7, further comprising a telemetry system having
2 repeaters disposed along the tool string for carrying data uphole and command
3 signals downhole.
- 1
1 10. A method, comprising:
2
3 deploying a water flood regulator into a water flood injection well;
4 injecting water into a surrounding reservoir via the water flood regulator;
5 monitoring a flow rate of the water through the water flood regulator with
6 a sensor;
7 sending data related to the flow rate to a surface control system;
8 processing the data to determine whether the flow rate should be adjusted;
9 and
10 sending control signals downhole to the water flood regulator to adjust the
11 flow rate of water flowing into the surrounding reservoir.
- 1
1 11. The method as recited in claim 10, wherein deploying comprises deploying a
2 plurality of water flood regulators along a tool string positioned in a wellbore.

1 12. The method as recited in claim 10, wherein monitoring the flow rate comprises
2 monitoring a plurality of parameters with a plurality of sensors.

1 13. The method as recited in claim 10, wherein sending data and control signals
2 comprises using a wireless telemetry system to transmit the data and the control
3 signals along a wellbore.

1 14. The method as recited in claim 10, wherein processing the data comprises
2 processing the data in real time.

1 15. The method as recited in claim 14, wherein sending comprises sending control
2 signals in real time to adjust the flow rate.

1 16. The method as recited in claim 11, wherein sending comprises sending control
2 signals to adjust an orifice size or to shift a tube so as to change the flow rate.

1 17. The method as recited in claim 10, wherein deploying comprises deploying the
2 water flood regulator into a side pocket mandrel.

1 18. A system, comprising:
2

3 a tool string deployed in a water flood injection well, the tool string having
4 a plurality of regulator assemblies which are adjustable to regulate flow of water
5 into corresponding water flood injection zones; and

6 a control system operatively coupled with the plurality of regulator
7 assemblies to selectively adjust individual regulator assemblies of the plurality of
8 regulator assemblies, thus regulating the flow rate of water into each
9 corresponding water flood injection zone during a water flood injection operation.

1 19. The system as recited in claim 18, wherein each regulator assembly comprises a
2 regulator and a sensor positioned to monitor flow rate through the regulator.

1

20. The system as recited in claim 19, wherein the control system is a surface control system.

FIG. 1

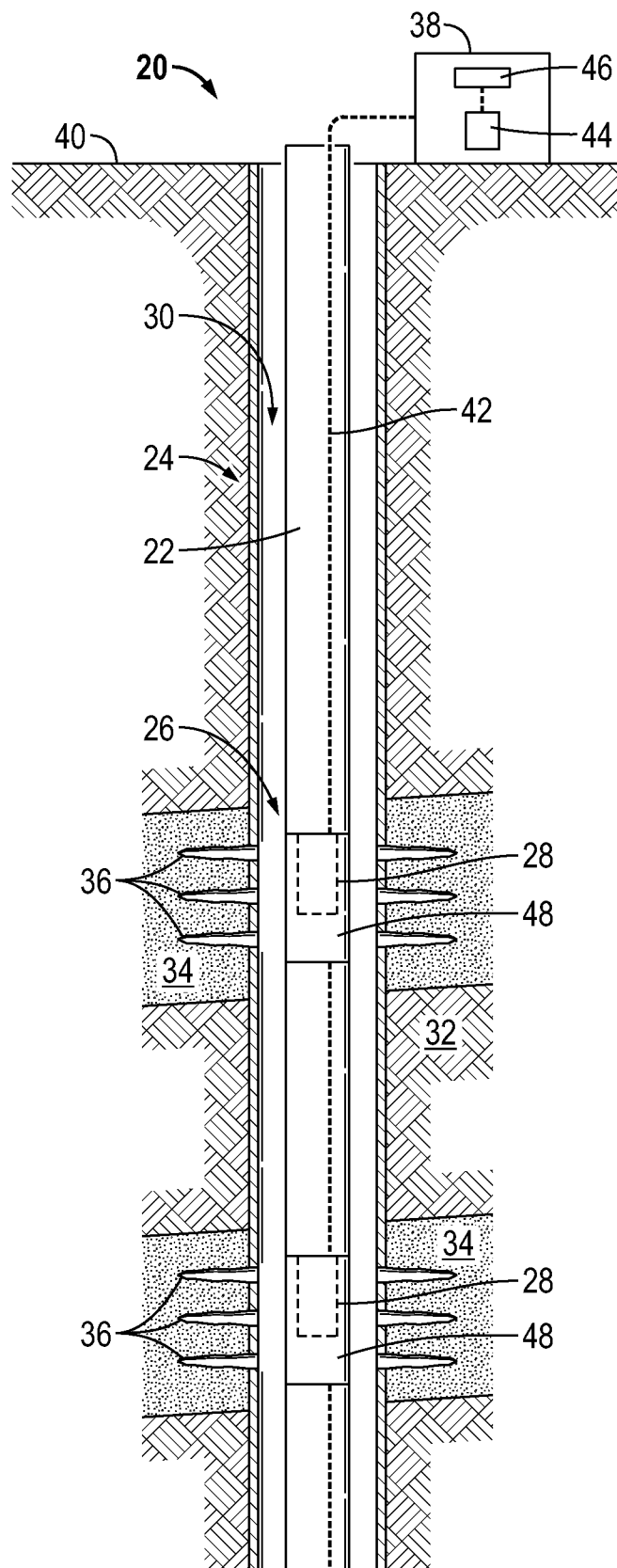


FIG. 2

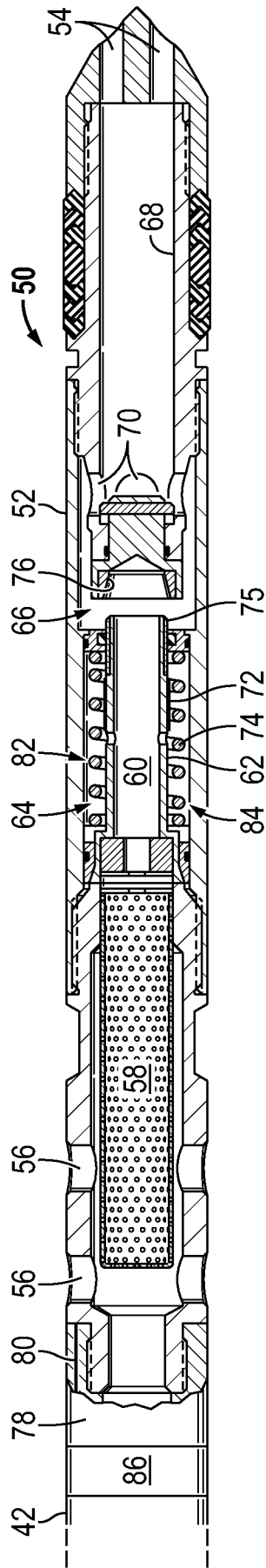


FIG. 3

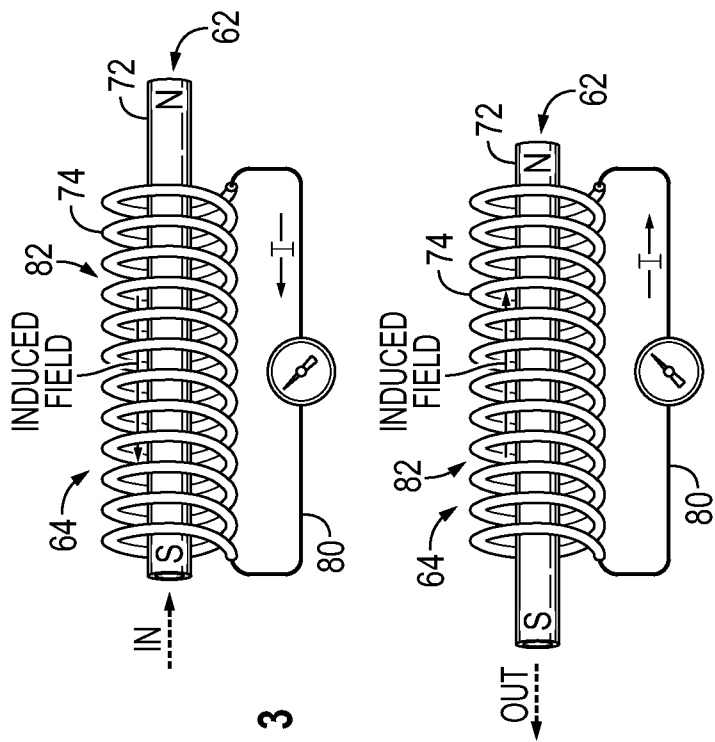
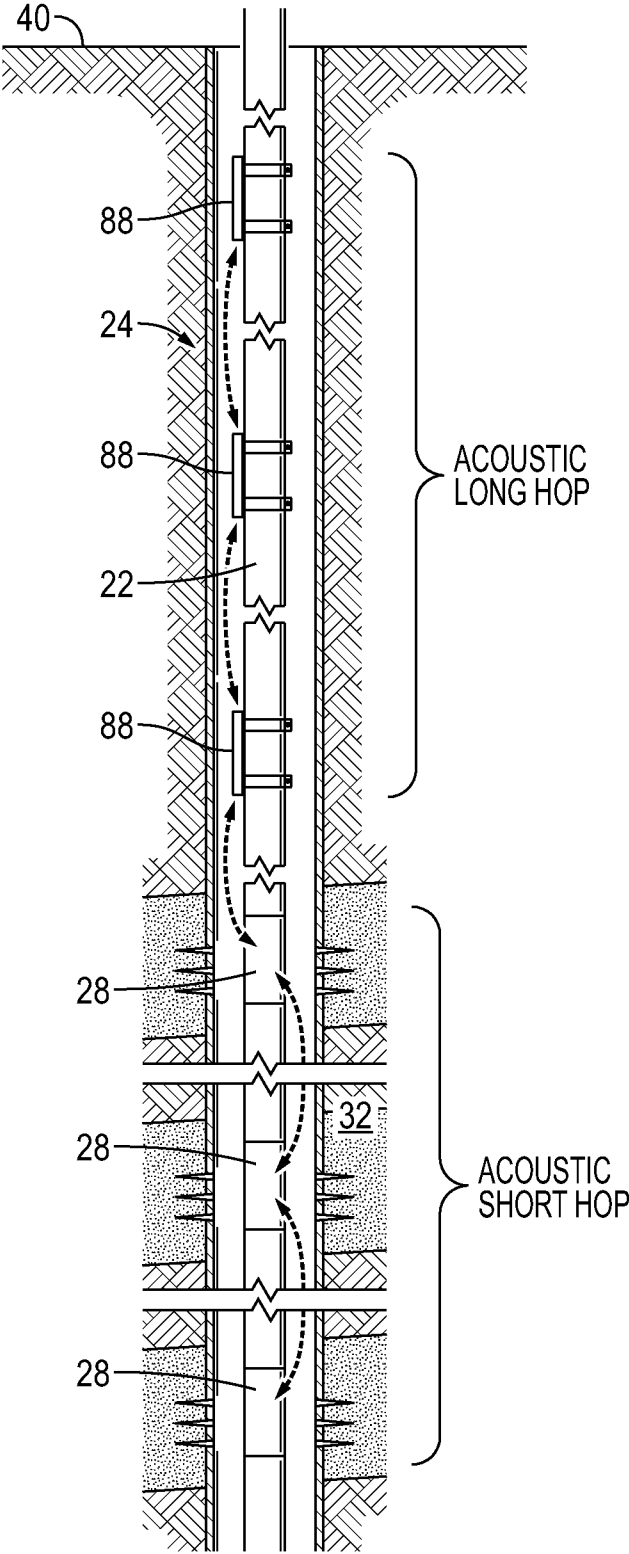


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/040268**A. CLASSIFICATION OF SUBJECT MATTER****E21B 43/22(2006.01)i, C09K 8/588(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 43/22; E21B 43/12; E21B 34/06; G06F 19/00; E21B 47/00; G01N 13/00; E21B 41/00; E21B 43/16; E21B 34/16; C09K 8/588

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: downhole water flood regulator, sensor, adjust, flow rate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5186255 A (JOHN C. COREY) 16 February 1993 See abstract, column 4, lines 62-67, column 5, lines 30-41, 59-63, claims 1,3,8,13,14 and figure 2.	1,5,8,10,12,17
Y		2-4,6,7,9,11,13-16,18-20
Y	US 2008-0262735 A1 (BRIAN L. THIGPEN et al.) 23 October 2008 See abstract, paragraphs [0016],[0026], claims 9,18 and figure 1A.	2-4,6,7,9,11,13-16,18-20
A	US 2005-0217350 A1 (KIRBY JABUSCH et al.) 06 October 2005 See abstract, claims 1,3,6,7,14,15 and figure 1.	1-20
A	US 6112817 A (BENN VOLL et al.) 05 September 2000 See abstract, claims 1,2,7-12 and figure 1.	1-20
A	WO 2008-058298 A1 (GEOFFREY JACKSON) 15 May 2008 See abstract, claims 1-5,7,9,11 and figure 1.	1-20



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 October 2015 (30.10.2015)

Date of mailing of the international search report

30 October 2015 (30.10.2015)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

Jang, Gijeong

Telephone No. +82-42-481-8364



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/040268

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 05186255 A	16/02/1993	None	
US 2008-0262735 A1	23/10/2008	AU 2008-242750 A1 AU 2008-242750 B2 BR PI0810422 A2 CA 2683994 A1 CA 2683994 C GB 2463381 A GB 2463381 B NO 20093168 A US 7805248 B2 WO 2008-131210 A2 WO 2008-131210 A3	30/10/2008 13/06/2013 14/10/2014 30/10/2008 06/08/2013 17/03/2010 07/12/2011 11/11/2009 28/09/2010 30/10/2008 22/01/2009
US 2005-0217350 A1	06/10/2005	US 7246662 B2	24/07/2007
US 06112817 A	05/09/2000	None	
WO 2008-058298 A1	15/05/2008	None	