



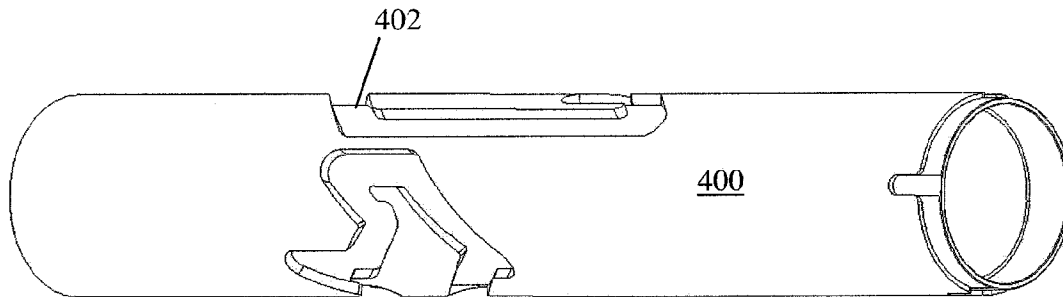
US 20070295514A1

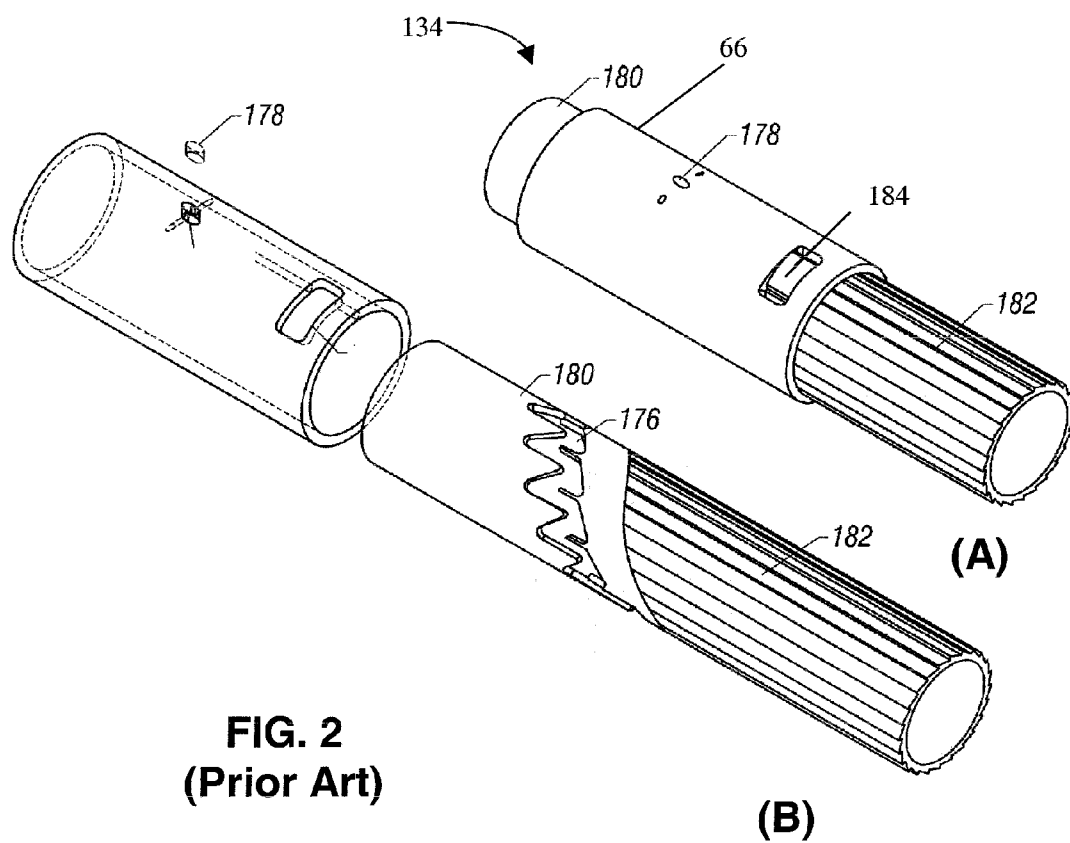
(19) **United States**(12) **Patent Application Publication**
Rohde et al.(10) **Pub. No.: US 2007/0295514 A1**(43) **Pub. Date: Dec. 27, 2007**(54) **MULTI-ROTATIONAL INDEXER**(22) Filed: **Jun. 26, 2006**(75) Inventors: **Kenneth Rohde**, Richmond, TX
(US); **Ignacio Marquez**, Houston,
TX (US)**Publication Classification**(51) **Int. Cl.**
E21B 33/12 (2006.01)(52) **U.S. Cl.** **166/386**

Correspondence Address:

SCHLUMBERGER RESERVOIR COMPLE-
TIONS**14910 AIRLINE ROAD**
ROSHARON, TX 77583(57) **ABSTRACT**(73) Assignee: **SCHLUMBERGER**
TECHNOLOGY
CORPORATION, Sugar Land,
TX (US)

An indexing device for flow control includes a first cylinder having a plurality of slots disposed thereon along a path that changes rotational direction at least once before the path completes a circle around the first cylinder; and a second cylindrical member forming a concentric assembly with the first cylinder, such that an index pin disposed on the second cylindrical member is configured to move in the plurality of slots on the first cylinder when the first cylinder and the second cylindrical member move relative to each other.

(21) Appl. No.: **11/426,358**



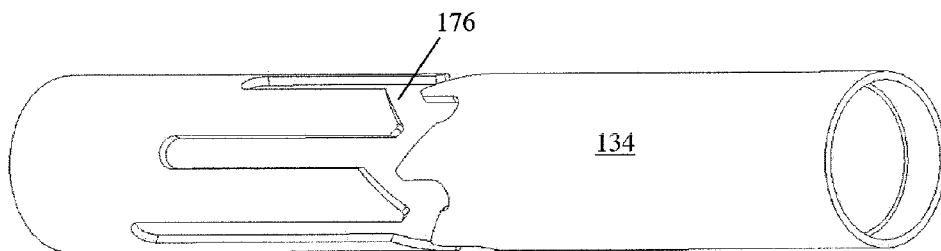


FIG. 3A
(Prior Art)

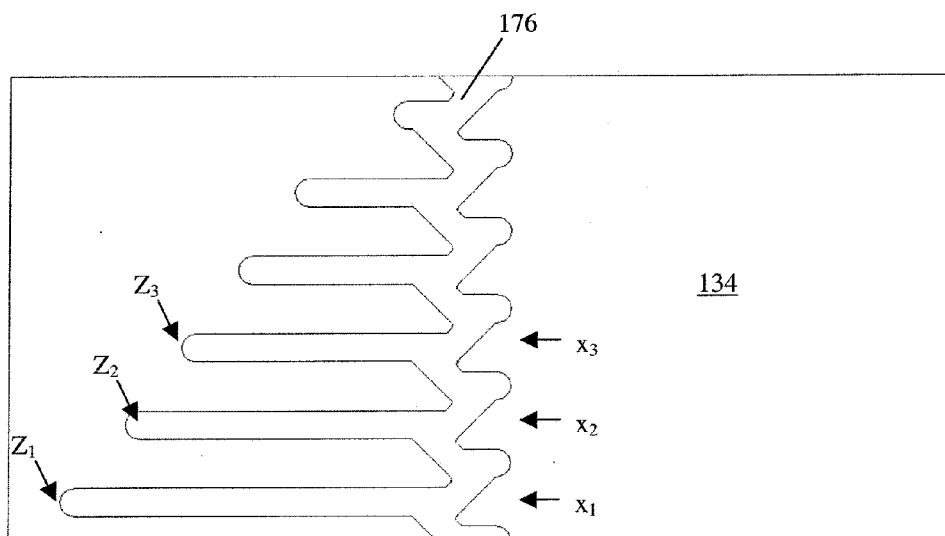


FIG. 3B
(Prior Art)

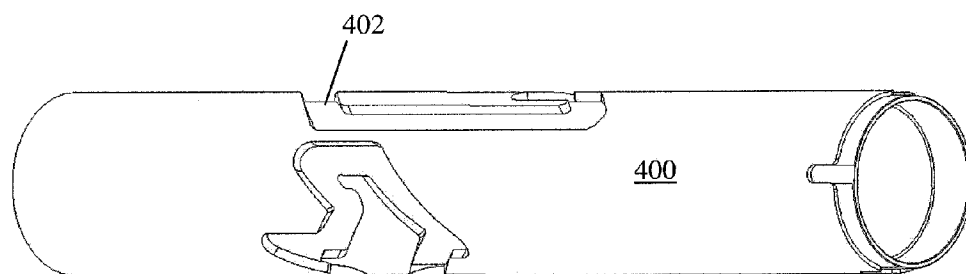


FIG. 4A

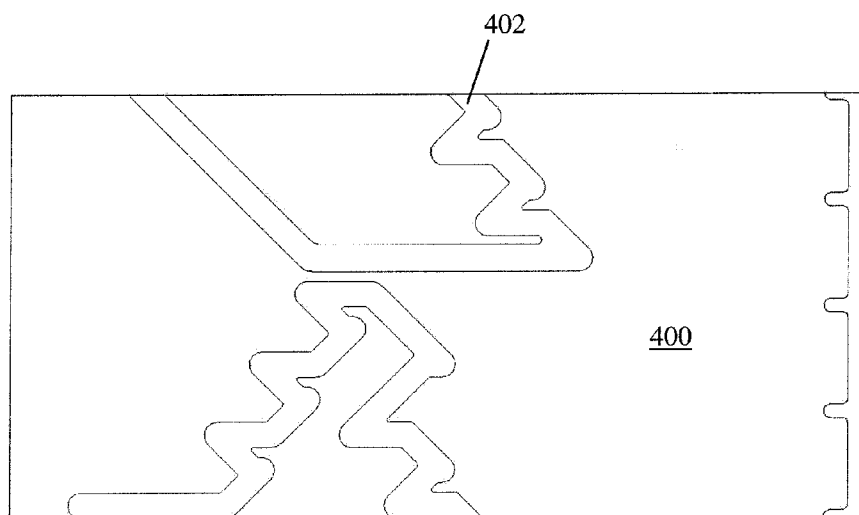
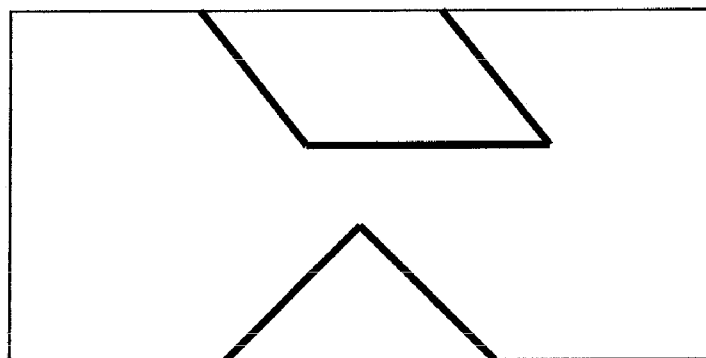
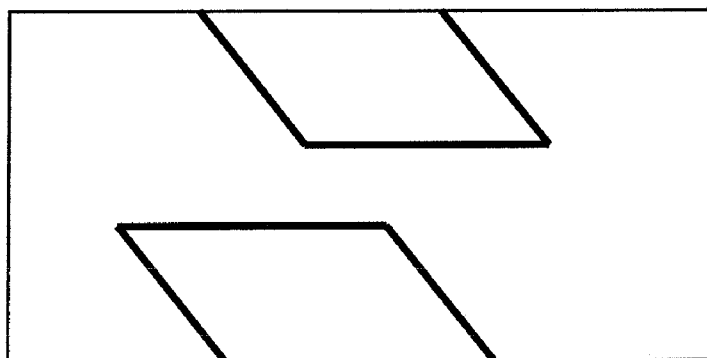


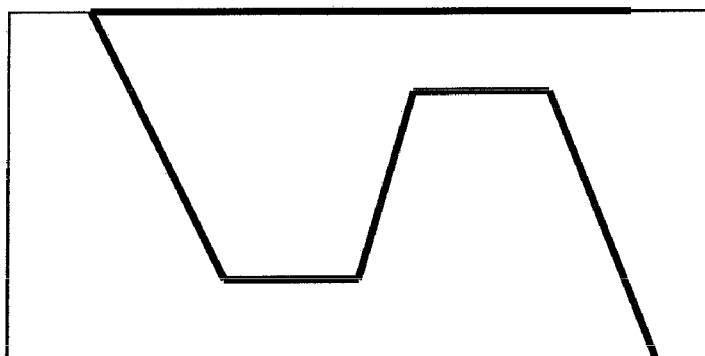
FIG. 4B



(A)



(B)



(C)

FIG. 5

MULTI-ROTATIONAL INDEXER

BACKGROUND OF INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates generally to a rotational indexing system used in a flow control valve.

[0003] 2. Background Art

[0004] The economic climate of the petroleum industry demands that oil companies continually improve their recovery systems to produce oil and gas more efficiently and economically from sources that are becoming increasingly difficult to exploit without increasing the cost to the consumer. One successful technique currently employed is the drilling of deviated wells, in which a number of horizontal wells are drilled from a central vertical borehole. In such wells, and in standard vertical wells, the well may pass through various hydrocarbon bearing zones or may extend through a single zone for a long distance. One method to increase the production of the well is to perforate the well in a number of different locations, either in the same hydrocarbon bearing zone or in different hydrocarbon bearing zones, and thereby increase the flow of hydrocarbons into the well.

[0005] One problem associated with producing from a well in this manner relates to the control of the flow of fluids from the well and to the management of the reservoir. For example, in a well producing from a number of separate zones (or from laterals in a multilateral well) in which one zone has a higher pressure than another zone, the higher pressure zone may disemboque into the lower pressure zone rather than to the surface. Similarly, in a horizontal well that extends through a single zone, perforations near the "heel" of the well, i.e., nearer the surface, may begin to produce water before those perforations near the "toe" of the well. The production of water near the heel reduces the overall production from the well.

[0006] A manner of alleviating this problem is to insert a production tubing into the well, isolate each of the perforations or laterals with packers, and control the flow of fluids into or through the tubing. However, typical flow control systems provide for either on or off flow control with no provision for throttling of the flow. To fully control the reservoir and flow as needed to alleviate the above described problem, the flow is throttled. A number of devices have been developed or suggested to provide this throttling although each has certain drawbacks. Note that throttling may also be desired in wells having a single perforated production zone.

[0007] For example, U.S. Pat. No. 6,722,439 issued to Garay et al. discloses multi-positioned sliding sleeve valve that is operable in a plurality of positions including fully open, fully closed, and positions in between. The valve uses a hydraulic control system to move the sliding sleeve a predetermined amount for a given applied control pressure. Similarly, U.S. Pat. No. 6,973,974 issued to McLoughlin et al. discloses valves for use in wells. A valve disclosed in this patent includes a choke having a plurality of orifices to allow variable flow control.

[0008] When a valve having multiple positions are used downhole, an indexing device (or indexer) is often used to provide control and indication of the various opening states. Example of indexing devices may be found, for example, in U.S. Pat. No. 6,973,974 issued to McLoughlin et al. and U.S. Pat. No. 6,948,561 issued to Myron. An indexing device

typically comprises a pin movable in a series of slots (typically, J-shaped slots or J-slots). A piston restrained to move longitudinally engages and rotates an index sleeve to allow the pin to advance into the next J-slot track. Each slot determines the position of the valve.

[0009] Existing indexing apparatus uses a plurality of J-slots arranged around the circumference of a tubing to provide the multiple control positions. However, such a design limits the number of positions that can be obtained.

SUMMARY OF INVENTION

[0010] In one aspect, embodiments of the invention relate to indexing devices for flow control. An indexing device in accordance with one embodiment of the invention includes a first cylinder having a plurality of slots disposed thereon along a path that changes rotational direction at least once before the path completes a circle around the first cylinder; and a second cylindrical member forming a concentric assembly with the first cylinder, such that an index pin disposed on the second cylindrical member is configured to move in the plurality of slots on the first cylinder when the first cylinder and the second cylindrical member move relative to each other.

[0011] Another aspect of the invention relate to flow control valves. A flow control valve in accordance with one embodiment of the invention includes an indexing device, wherein the indexing device includes a first cylinder having a plurality of slots disposed thereon along a path that changes rotational direction at least once before the path completes a circle around the first cylinder; and a second cylindrical member forming a concentric assembly with the first cylinder, such that an index pin disposed on the second cylindrical member is configured to move in the plurality of slots on the first cylinder when the first cylinder and the second cylindrical member move relative to each other, wherein the plurality of slots correspond to a plurality of opening conditions of the flow control valve.

[0012] Another aspect of the invention relate to methods for controlling fluid flow downhole. A method in accordance with one embodiment of the invention includes disposing a flow control valve in a wellbore, wherein the flow control valve is equipped with an indexing device includes a first cylinder having a plurality of slots disposed thereon along a path that changes rotational direction at least once before the path completes a circle around the first cylinder; and a second cylindrical member forming a concentric assembly with the first cylinder, such that an index pin disposed on the second cylindrical member is configured to move in the plurality of slots on the first cylinder when the first cylinder and the second cylindrical member move relative to each other, wherein the plurality of slots correspond to a plurality of opening conditions of the flow control valve; and moving the index pin to one of the plurality of slots to change an opening condition of the flow control valve.

[0013] Other aspects and advantages of the invention will become apparent from the following description and attached claims.

BRIEF SUMMARY OF DRAWINGS

[0014] FIG. 1 shows a system for pumping fluid from a wellbore that may be used with embodiments of the invention.

[0015] FIGS. 2A and 2B show a conventional indexer used in controlling valves downhole.

[0016] FIGS. 3A and 3B show a pattern of J slots on a conventional indexer.

[0017] FIGS. 4A and 4B show slots of an indexer in accordance with one embodiment of the invention.

[0018] FIGS. 5A-5C show examples of paths (arrangements) of slots on indexers in accordance with embodiments of the invention.

DETAILED DESCRIPTION

[0019] Embodiments of the invention relate to indexing devices for use in flow control in downhole applications. In the following description, numerous details are set forth to provide an understanding of the present invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0020] Referring to FIG. 1, a system 20 for producing fluids from a wellbore 22 to the surface 24 is featured. In the illustrated embodiment, system 20 includes an electric submersible pumping system (ESP) 26, production tubing 28, a fluid intake valve assembly 30, a hydraulic control line 32, a hydraulic controller 34, a first packer 36, and a second packer 38. However, a pumping system need not be used. Fluid pressure may be sufficient to produce fluid to the surface without the use of a pumping system. As an additional measure, wellbore 22 is lined with casing 40.

[0021] In the illustrated embodiment, valve assembly 30 is disposed in a horizontal deviation 41 of wellbore 22. Valve assembly 30 is used to control the intake of fluid into system 20. Fluids, as referenced by arrows 42, flow from a geological formation 44 through perforations 46 in casing 40 into wellbore 22. First packer 36 and second packer 38 define a first region 48 within wellbore 22. Fluid 42 is drawn into system 20 from first region 48 through inlet ports 50 in valve assembly 30.

[0022] Valve assembly 30 is operable to control the size of the area through which fluid 42 may flow into valve assembly 30. In the illustrated embodiment, valve assembly 30 is operated by hydraulic pressure controlled from the surface 24 by a hydraulic controller 34. A control line 32 is used to apply hydraulic pressure to valve assembly 30 from hydraulic controller 34. Hydraulic controller 34 may be as simple as a pair of manually operated valves or as complex as a computer controlled system. See U.S. Pat. No. 6,973,974 issued to McLoughlin et al., which is assigned to the present assignee and is incorporated by reference in its entirety.

[0023] Multi-position valves typically are used with indexing devices (indexers) to control and indicate the various opening positions of the valves. Conventional indexing devices use J-slots arranged around the circumference of the tube shaped devices to indicate the various positions of the valves, as illustrated in FIGS. 2A-2C.

[0024] FIG. 2A shows a conventional indexer 134 assembled in a housing 66. FIG. 2B shows the indexer 134 separated from the housing 66. As shown in FIG. 2B, indexer 134 includes J-slots 176 that are arranged around the circumference of the indexer 134. The housing 66 includes a pin 178 that travels in the J-slots 176. In an alternative embodiment, an indexer may be the outer member, while the pin is disposed on an inner member. The relative movement of the housing 66 with respect to the indexer 134 determines

which J slot the pin 178 is in, which in turn controls the valve positions. The movement of the housing 66 relative to the indexer 134 may be controlled by a controller (shown as 34 in FIG. 1) mediated by a control line (shown as 32 in FIG. 1). Typically, such control is mediated by hydraulics that drives a piston, which may be linked, directly or indirectly, to the indexer 134 or the housing 66. As the piston is driven up or down, the relative movement between the housing 66 and the indexer 134 will be guided by indexer pin 178 acting on J-slot 176 of indexer 134.

[0025] J-slots 176 and indexer pin 178 cause indexer 134 to rotate about its axis, thereby the valve assembly is shifted from one position to the next. Indexer 134 makes one complete revolution as valve assembly 30 transits from the closed position to the fully open position and back to the closed position. In some conventional indexers, a portion of the outer surface 180 of indexer 134 may be configured with a toothed surface 182. A latch 184, secured to indexer housing 66, may be used with toothed surface 182 to ensure that indexer 134 rotates about its axis in only one direction. This ensures that J-slot 176 cooperates with indexer pin 178 to produce the desired motion of indexer 134.

[0026] The indexing device (or indexer) 134 in FIG. 2B has a plurality of J slots 176 arranged around the circumference of the tube in a spiral path. A "path" as used herein refers to an imaginary line that connects the bottom portions of the J slots. In this configuration, the beginning and the end of the spiral path may be connected by a longitudinal (along the axis direction of the tube-shaped indexer) slot (not shown) such that the pin 178 can come back to the beginning when it rotates around a complete circumference. When the J slots 176 are arranged in a spiral path, as shown in FIG. 2B, the "height" (from the top to the bottom of each "J") of each J slot may be the same.

[0027] A alternative configuration of an indexer may have the J slots 176 arranged around the circumference of the indexer without the spiral path, i.e., in a circle around the indexer at the same longitudinal location, as shown in FIG. 3A. FIG. 3B shows the indexing sleeve of FIG. 3A opened up into a flat sheet to illustrate the arrangement of the J slots 176. In this alternative configuration, the "height" of each J slot may be different such that when an indexer pin 178 rests against the "top" (closed end) of the J slot, the axial location of the indexer pin 178 has a correlation with its rotation position.

[0028] As shown in FIG. 3B, the axial locations ($z_1, z_2, \dots, z_n$) of the closed ends of the J slots directly correlate with the rotational (azimuthal) locations ($x_1, x_2, \dots, x_n$) of the slots. This relationship can be maintained whether the J slots are arranged on a spiral path (as shown in FIG. 2B) or a non-spiral path (as shown in FIG. 3B). With this relationship, knowledge of the axial location of the indexer pin (shown as 178 in FIG. 2A) can provide the rotational (azimuthal) location of the indexer pin, and vice versa. That is, the axial locations (z_i) of an indexer pin is indexed by the rotational (azimuthal) location (x_i) of the indexer pin. Therefore, if the axial locations of the indexer pin correspond to different openings of a valve (e.g., a sliding valve), then one can obtain this information from the rotational locations of the indexer pin, and vice versa.

[0029] As illustrated in FIG. 3B, the number of J slots in an indexer determines how many opening positions a valve can be operated. Since the circumference is limited by the diameter of the indexer 134, the width of the slots deter-

mines how many J slots **176** may be provided in the indexer. The width of the slots in turn is determined by the indexing pin **178** that travels in these slots. For reliable operation, the indexing pin **178** needs to withstand significant impact forces without breaking. Therefore, the indexing pin **178** cannot be made too thin. As a result, the number of J slots **176** around a fixed circumference is often limited.

[0030] Embodiments of the invention provide indexers that can have more slots (J-shaped slots or other-shaped slots) than the conventional indexers because the slots of an indexer of the invention are not arranged in a fashion that is limited by the circumference. For example, in accordance with embodiments of the invention, the slots may be arranged in a path that reverses its rotational (azimuthal) direction before finishing a complete circle around the circumference. Such indexers may be referred to as “multi-rotational” indexers.

[0031] As shown in FIG. 4A and FIG. 4B, an indexer **400** of the invention may include a plurality of slots (grooves) **402** or other appropriate shaped grooves. As shown in FIG. 4B, the plurality of slots **402** are disposed along a path that forms a closed loop on the circumference of the indexer. This closed loop path is more clearly illustrated in FIG. 5A. An indexer pin traveling along the closed loop path shown in FIG. 5A will change its rotational (azimuthal) direction before it completes a circle around an indexer. That is, the indexer pin will not travel in a single rotational direction. Instead, it will reverse its rotational direction at least once. This closed loop path has a length that is longer than the circumference of the indexer, making it possible to have more slots included on the indexer. Other examples of closed loop paths that may provide more slots on an indexer in accordance with embodiments of the invention are shown in FIGS. 5B-5C. One of ordinary skill in the art would appreciate that these examples are for illustration only and other modifications are possible without departing from the scope of the invention.

[0032] An indexer of the invention may be used with a housing having an indexer pin as shown in FIG. 2A. In an alternative embodiment, an indexer of the invention may be used with an inner member having an indexer pin disposed inside the indexer. In the latter case, the inner member may be a sleeve, a hollow cylinder, or a solid cylinder. The relative movement between the indexer and the outer housing or the inner member determines the various openings of a valve. Indexers of the invention may be used with any downhole valves that need to be operated in multiple opening positions. Such valves, for example, include a pressure-actuated circulation valve, a flow-actuated circulation valve, and a differential valve.

[0033] Advantages of the current invention include one or more of the following. An indexer of the invention may have any number of index grooves (or slots) for finer flow control, not limited by the circumference of the indexing device. Additionally, the reversal of rotational direction of the slots may allow multiple gradational opening and closing of flow control valves in traversing the full circumference of the indexing sleeve.

[0034] While the invention has been described with respect to a limited number of embodiments, those skilled in the art will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims.

What is claimed is:

1. An indexing device for flow control, comprising:
 - a first cylinder having a plurality of slots disposed thereon along a path that changes rotational direction at least once before the path completes a circle around the first cylinder; and
 - a second cylindrical member forming a concentric assembly with the first cylinder, such that an index pin disposed on the second cylindrical member is configured to move in the plurality of slots on the first cylinder when the first cylinder and the second cylindrical member move relative to each other.
2. The indexing device of claim 1, wherein the second cylindrical member forms an outer cylinder of the concentric assembly.
3. The indexing device of claim 1, wherein the second cylindrical member forms an inner member of the concentric assembly.
4. The indexing device of claim 1, wherein the indexing device is connected to a control line that controls relative movement between the first cylinder and the second cylindrical member.
5. The indexing device of claim 1, wherein the plurality of slots are J-shaped slots.
6. A flow control valve having an indexing device, wherein the indexing device comprises:
 - changes rotational direction at least once before the path completes a circle around the first cylinder; and
 - a second cylindrical member forming a concentric assembly with the first cylinder, such that an index pin disposed on the second cylindrical member is configured to move in the plurality of slots on the first cylinder when the first cylinder and the second cylindrical member move relative to each other, wherein the plurality of the slots correspond to a plurality of opening conditions of the flow control valve.
7. The flow control valve of claim 6, wherein the flow control valve is at least one selected from a pressure-actuated circulation valve, a flow-actuated circulation valve, and a differential valve.
8. The flow control valve of claim 6, wherein the plurality of slots are J-shaped slots.
9. The flow control valve of claim 6, further comprising a control line configured to control the indexing device.
10. The flow control valve of claim 6, wherein the second cylindrical member forms an outer cylinder of the concentric assembly.
11. The flow control valve of claim 6, wherein the second cylindrical member forms an inner member of the concentric assembly.
12. A method for controlling fluid flow downhole, comprising:
 - disposing a flow control valve in a wellbore, wherein the flow control valve is equipped with an indexing device comprising:
 - a first cylinder having a plurality of slots disposed thereon along a path that changes rotational direction at least once before the path completes a circle around the first cylinder; and
 - a second cylindrical member forming a concentric assembly with the first cylinder, such that an index pin disposed on the second cylindrical member is

configured to move in the plurality of slots on the first cylinder when the first cylinder and the second cylindrical member move relative to each other, wherein the plurality of slots correspond to a plurality of opening conditions of the flow control valve; and moving the index pin to one of the plurality of slots to change an opening condition of the flow control valve.

13. The method of claim **12**, wherein the moving the index pin is performed through a control line connected to the flow control valve.

14. The method of claim **12**, wherein the plurality of slots are J-shaped slots.

15. The method of claim **12**, wherein the flow control valve is at least one selected from a pressure-actuated circulation valve, a flow-actuated circulation valve, and a differential valve.

16. The method of claim **12**, wherein the second cylindrical member forms an outer cylinder of the concentric assembly.

17. The method of claim **12**, wherein the second cylindrical member forms an inner member of the concentric assembly.

* * * * *