(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 April 2011 (14.04.2011)

(51) International Patent Classification:
E21B 23/00 (2006.01) E21B 34/14 (2006.01)

(21) International Application Number:
PCT/US2010/052017

(22) International Filing Date:
8 October 2010 (08.10.2010)

(25) Filing Language:
English

(26) Publication Language:
English

(30) Priority Data:
61/250,079 9 October 2009 (09.10.2009) US

(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 [GB/GB]; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola 1110 (VG).


(54) Title: DOWNHOLE TOOL ACTUATION DEVICES AND METHODS

(57) Abstract: According to one or more embodiments of the invention, a downhole tool includes one or more actuator apparatuses to facilitate actuation of the downhole tool. The actuation apparatus includes a piston that is dynamically coupled to a tool actuator by an actuator connector in a manner that the piston and the tool actuator necessarily move in unison in response to movement of the piston in a first direction and the piston and the tool actuator do not necessarily move in unison in response to movement of the piston in the second direction.
(71) Applicant (for all designated States except AL, AM, AU, AZ, BF, BG, BI, BY, CA, CF, CG, CI, CM, CO, CZ, DE, DK, FR, GA, GB, GN, GQ, GR, GW, HU, ID, IE, IL, IT, JP, KG, KP, KR, KZ, IT, MD, ML, MR, MX, MY, NE, NL, NO, NZ, OM, PL, RO, RU, SI, SK, SN, TD, TG, TH, TJ, TM, TN, TR, TT US, (U, ZA): PRAD RESEARCH AND DEVELOPMENT LIMITED [GB/GB]; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola 1110 (VG).

(71) Applicant (for IS only): SCHLUMBERGER TECHNOLOGY CORPORATION [US/US]; 300 Schlumberger Drive, Sugar Land, TX 77478 (US).

(72) Inventors; and


(74) Agents: CLARK, Brandon, S. et al.: Schlumberger Technology Corporation, 14910 Airline Road, Legal - IP, Building 14, Rosharon, TX 77583 (US).


Published:
— without international search report and to be republished upon receipt of that report (Rule 48.2(g))
DOWNHOLE TOOL ACTUATION DEVICES AND METHODS

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 61/250,079 filed on October 9, 2009.

BACKGROUND

[0002] This section provides background information to facilitate a better understanding of the various aspects of the present invention. It should be understood that the statements in this section of this document are to be read in this light, and not as admissions of prior art.

[0003] The present disclosure relates generally to wellbore operations and equipment and more specifically to actuation devices for downhole tools (e.g., subsurface tools, wellbore tools) and methods of operation.

[0004] Hydrocarbon fluids such as oil and natural gas are produced from subterranean geologic formations, referred to as reservoirs, by drilling wells that penetrate the hydrocarbon-bearing formations. Once a wellbore is drilled, various forms of well completion components may be installed in order to control and enhance the efficiency of producing fluids from the reservoir and/or injecting fluid into the reservoir and/or other geological formations penetrated by the wellbore. In some wells, for example, valves are actuated between open and closed states to compensate or balance fluid flow across multiple zones in the wellbore. In other wells, an isolation valve may be actuated to a closed position to shut in or suspend a well for a period of time and then opened when desired. Often a well will include a subsurface safety valve to prevent or limit the flow of fluids in an undesired direction.
It is therefore a continuing desire to provide reliable and efficient downhole tools and methods and apparatus to efficiently and reliably operate the downhole tools.

**SUMMARY**

According to one or more embodiments of the invention, an actuator apparatus for a downhole tool comprises a piston moveable in a first direction and a second direction, a tool actuator, and an actuator connector dynamically coupling the piston and the tool actuator, wherein the piston and the tool actuator necessarily move in unison in response to movement of the piston in the first direction and the piston and the tool actuator do not necessarily move in unison in response to movement of the piston in the second direction.

In some embodiments, the actuator connector can be permanently fixedly coupled to only one of the piston and the tool actuator. The actuator connector may comprise a first portion adapted to fixedly engage a portion of the piston and a second portion adapted to fixedly engage a portion of the tool actuator. In some embodiments the actuator connector is permanently fixedly connected to only one of the piston and the tool actuator and the actuator connector is temporarily fixedly connected to the other of the piston and the tool actuator in response to movement of the piston in the first direction.

The actuator connector may include a tubular member adapted to be positioned around the tool actuator. In some embodiments the actuator connector may include a yoke, a tubular member adapted to be positioned about the tool actuator, and an elongated member connected between the yoke and the tubular connector, wherein the yoke is axially separated from the tubular connector by the elongated member. According to one or more aspects the actuator connector may comprise a first yoke separated from a second yoke by an elongate member.
[0009] A subsurface valve according to one or more aspects of the invention comprises a piston movable in a first direction and a second direction, a flow tube, a valve closure member actuated to one of an open position and a closed position in response to movement of the flow tube in one of the first direction and the second direction, and an actuator connector connected between the piston and the flow tube, wherein the piston, the actuator connector and the flow tube necessarily move in unison in response to movement of the piston in a first direction and wherein the piston and the flow tube do not necessarily move in unison in response to movement of the piston in the second direction. According to one or more aspects of the invention the actuator connector may be permanently fixedly connected to only one of the piston and the flow tube and temporarily fixedly connected to the other of the piston and the flow tube in response to movement of the piston in the first direction.

[0010] A method of actuation a downhole tool according to one or more aspects of the invention comprises moving a piston in a first direction in response to an applied signal, moving a tool actuator in the first direction in unison with the first piston in response to the moving the piston in the first direction, moving the piston in a second direction, and releasing a fixed connection between the tool actuator and the piston in response to the moving the piston in the second direction.

[0011] The foregoing has outlined some of the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention.
BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The present disclosure is best understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of various features may be arbitrarily increased or reduced for clarity of discussion.

[0013] Figure 1 is a schematic of a well system incorporating an embodiment of a downhole tool comprising an actuator apparatus according to one or more aspects of the present disclosure.

[0014] Figure 2 is a partial cross-sectional view of an embodiment of a subsurface valve utilizing an actuator apparatus according to one or more aspects of the present disclosure illustrated in the open position.

[0015] Figure 3 is a partial cross-sectional view of a downhole tool and an actuator apparatus according to one or more aspects of the present disclosure disposed in a first operational position.

[0016] Figure 4 is a partial cross-sectional view of the downhole tool and the actuator apparatus of Figure 3 disposed in a second operational position.

[0017] Figure 5 is a cross-sectional view of the downhole tool and the actuator apparatus of Figures 3 and 4 disposed in another operational position.

[0018] Figure 6 is a cross-sectional view of a section of another embodiment a downhole tool and an actuator apparatus according to one or more aspects of the present disclosure.

[0019] Figure 7 is a schematic view of an embodiment of an actuator connector according to one or more aspects of the present disclosure.
[0020] **Figure 8** is a schematic view of another embodiment of an actuator connector according to one or more aspects of the present disclosure.

[0021] **Figure 9** is a partial cross-sectional view of another embodiment of a portion of a downhole tool and an actuator connector according to one or more aspects of the present disclosure.

[0022] **Figure 10** is an end view of the downhole tool and the actuator connector of Figure 9.

[0023] **Figure 11** is a sectional view of a downhole tool and comprising more than one actuator apparatus according to one or more aspects of the present disclosure disposed in a first operational position (e.g., closed).

[0024] **Figure 12** is a sectional view of the downhole tool and the actuator apparatus of Figure 11 disposed in a second operational position (e.g., open).

[0025] **Figure 13** is a cross-sectional view along the line I-I of Figure 11.

[0026] **Figure 14** is a cross-sectional view along the line II-II of Figure 12.
DETAILED DESCRIPTION

[0027] It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed. Moreover, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed interposing the first and second features, such that the first and second features may not be in direct contact.

[0028] As used herein, the terms "up" and "down"; "upper" and "lower"; "top" and "bottom"; and other like terms indicating relative positions to a given point or element are utilized to more clearly describe some elements. Commonly, these terms relate to a reference point as the surface from which drilling operations are initiated as being the top point and the total depth of the well being the lowest point, wherein the well (e.g., wellbore, borehole) is vertical, horizontal or slanted relative to the surface. The terms "pipe," "tubular," "tubular member," "casing," "liner," "tubing," "drill pipe," "drill string" and other like terms can be used interchangeably. The terms may be used in combination with "joint" to mean a single unitary length; a "stand" to mean one or more, and typically two or three, interconnected joints; or a "string" meaning two or more interconnected joints.
[0029] In this disclosure, "fluidicly coupled" or "fluidicly connected" and similar terms (e.g., hydraulic, pneumatic), may be used to describe bodies that are connected in such a way that fluid pressure may be transmitted between and among the connected items. The term "in fluid communication" is used to describe bodies that are connected in such a way that fluid can flow between and among the connected items. It is noted that fluidicly coupled may include certain arrangements where fluid may not flow between the items, but the fluid pressure may nonetheless be transmitted.

[0030] According to one or more aspects of the present invention an actuator connector is configured to attach a piston type member to a tool actuator member such that movement of the piston in a first direction is transferred to the tool actuator by the actuator connector to operate the downhole tool. According to one or more aspects the invention, the actuator connector dynamically couples the piston and the tool actuator together such that a force applied in a first direction by the piston is transmitted to the actuator connector and the tool actuator urging the piston, actuator connector and the tool actuator (i.e., the actuator apparatus) to move in unison, and wherein a force applied by the piston in a second direction is not transferred to the tool actuator to necessarily move the actuator apparatus in the second direction in unison. According to at least one aspect of the invention the dynamic connection provided by the actuator connector fixedly couples the piston and the tool actuator relative to each other in response to movement of the piston in a first direction and the piston and the tool actuator are not fixedly coupled relative to one another in response to movement of the piston in a second direction. Fixedly coupled, fixedly connected and fixedly engaged are used herein to mean that the fixedly connected members necessarily move in unison as opposed to being free to move independent of one another.
In a non-limiting embodiment the downhole tool is a subsurface valve in which the tool actuator engages and opens a valve closure member (e.g., flapper, ball, sleeve, etc.). In another embodiment, the tool actuator can progressively operate a variable choke member. The tool actuator includes without limitation devices which are known in the art and commonly referred to as flow tubes and sleeves. The closure member may include various devices such as and without limitation to flappers, ball valves and sleeves. The term piston is utilized in the disclosure to refer to a device that is moved in response to a control signal to actuate a downhole tool. The signal may be, for example, an electric, mechanical, and/or fluidic signal urging the piston to move at least in a first direction. The piston and the control signal (e.g., driving force) may include without limitation a fluidic piston, an electric solenoid, a gear device, and combinations thereof.

For example, in one embodiment a fluidic signal (e.g., hydraulic pressure) can be applied to the piston urging the piston to move and apply a force in a first direction. Further, upon applying a fluidic signal, for example by reducing the fluidic pressure applied to the piston in the first direction a biasing force acting in the second direction can urge the piston to move in the second direction. According to one or more aspects of the invention, an energy source (e.g., pressurized chamber, electric motor, spring, etc.) may exert a force biasing the piston in the second direction.

Figure 1 is a schematic of a well system 10 incorporating an embodiment of a downhole tool 12 comprising an actuator apparatus 14 according to one or more aspects of the present disclosure. Depicted well system 10 includes a wellbore 16 extending from a surface 18 and lined with casing 20. A tubular string 22 is disposed in wellbore 16. Downhole tool 12 is
depicted in Figure 1 as non-limiting embodiment of a subsurface safety valve. Valve 12 is connected within tubular string 22 for selectively controlling fluid flow through tubular valve 12 and tubular string 22. For example, subsurface safety valve 12 may be used to block the flow of reservoir fluid 2 through tubular string 22 to the surface when fluid 2 flows from formation 4 through tunnels 6 and into wellbore 16 and tubular string 22 under a greater pressure than desired. As will be further described below, the present invention provides for using a plurality of actuators lending to true independent redundancy.

[0034] Depicted valve 12 is operated in this example to an open position in response to a signal (e.g., electric signal, fluidic signal, electro-fluidic signal, mechanical signal) provided via control system 24. Depicted control system 24 includes a power source 26 operationally connected to actuator apparatus 14 to operate closure member 30 from the closed position, illustrated in Figure 1, to an open position. In the non-limiting embodiment depicted in Figure 1, control system 24 is a fluidic (e.g., hydraulic) system in which fluidic pressure is provided through control line 28 to actuator apparatus 14 which applies an operational force that moves actuator apparatus in a first direction engaging and actuating closure member 30 to an open position allowing fluid in tubular string 22 to flow across closure member 30.

[0035] Figure 2 is a partial cross-section view of an embodiment of downhole valve 12a that includes a contemporary actuation assembly 3. An example of a downhole valve 12a is disclosed in U.S. Patent 5,058,682, which is incorporated herein by reference. Depicted valve 12a includes a body 32 (e.g., housing) forming a fluid passageway 34, closure member 30, and a biasing energy source 35 (e.g., fluidic force, electrical force, mechanical force) depicted as a spring in this embodiment. The depicted contemporary actuation assembly 3 comprises piston
36 which is permanently fixedly connected to tool actuator 38 (e.g., flow tube) by a fixed connecting device 5. In other words, the permanent fixed connection of actuation assembly 3 dictates that the members (i.e., piston 36, flow tube 38 and connecting device 5) of actuation assembly 3 move in unison in response to movement of piston 36 in the first direction and movement of piston 36 in the second direction. In the depicted embodiment, connecting device 5 is a tongue and groove connection.

[0036] In an example of operation of tool 12a, a control signal such as hydraulic pressure is applied to piston 36 which applies a force in a first direction 50a to flow tube 38 through connection 5. Piston 36, flow tube 38 and connecting device 5 necessarily move in unison when the force applied in the first direction 50a overcomes the biasing force of biasing source 35 acting in the second direction 50b causing flow tube 38 to engage and actuate closure member 30 to the open position as depicted in Figure 2. When the operational force applied by piston 36 in the first direction 50a is released or reduced, the biasing force of energy source 35 acts on actuation assembly 3 in the second direction 50b moving permanently fixedly coupled piston 36 and flow tube 38 in unison in the second direction 50b.

[0037] Figure 3-5, 6 and 9-10 are partial cross-sectional views of portions of a downhole tool 12 illustrating the dynamic connection of an actuator apparatus 14 according to one or more aspects of the invention. In the embodiments depicted in Figures 3-6 and 9-10, downhole tool 12 is illustrated and described as a valve 12 having a central bore 34 depicted by the center-line "X". Various aspects of valve 12a depicted in Figure 2, except for the fixed connection of actuation assembly 3, can be included in the embodiments of valve 12.
[0038] Actuator apparatus 14 is illustrated disposed with body 32 (e.g., housing) of valve 12. Actuator apparatus 14 includes piston 36, flow tube 38 and one or more actuator connectors 40. Actuator connector 40 dynamically couples piston 36 and flow tube 38 together such that piston 36 and flow tube 38 are fixedly coupled relative to one another and move unison in response to movement of piston 36 in a first direction 50a, and wherein piston 36 and flow tube 38 are not fixedly coupled or engaged to one another in response to movement of piston 36 in a second direction 50b opposite from the first direction relative to flow tube 38. Piston 36 and flow tube 38 are not permanently fixedly connected to one another, but fixedly connected to one another in response to piston 36 being moved in only one of the first or the second direction.

[0039] In the embodiments of Figures 3-6, actuator connector 40 comprises a first portion 42 adapted to fixedly engage a portion 43 of piston 36 and a second portion 44 adapted to fixedly engage a portion 45 of flow tube 38. Actuator connector 40 can be described as floating relative to piston 36 and/or flow tube 38. In some embodiments, actuator connector 40 can float relative to both piston 36 and flow tube 38 and selectively fixedly couple piston 36 and flow tube 38 together in response to movement of the piston in one of the first direction or the second direction. In some embodiments, actuator connector 40 can be fixedly coupled, e.g., permanently fixedly coupled, to one of piston 36 or flow tube 38 and releasably fixedly coupled to the other of piston 36 and flow tube 38. Actuator connector 40 cannot be permanently fixedly coupled to both piston 36 and flow tube 38.

[0040] In the embodiment depicted in Figures 3-5, actuator connector 40 does not float relative to piston 36 but instead is permanently fixedly coupled to piston 36 and therefore moves in unison with piston 36. In the depicted embodiment, actuator connector 40 floats relative to flow
tube 38 and actuator connector 40 releasably fixedly couples with flow tube 38 in response to
movement of piston 36 in the first direction 50a; thus, when piston 36 is urged in the second
direction 50b relative to flow tube 38, the releasable fixed coupling between actuator connector
40 and flow tube 38 is released as depicted in Figure 5. The depicted actuator connector 40 is
disposed between piston 36 and flow tube 38 and first portion 42 and second portion 44 are
located on opposing sides from one another. Portion 43 of piston 36 can be described in the
depicted embodiments as a recessed portion or pocket having opposing shoulders 46a, 46b
depicted in Figure 5. Actuator connector 40 can be disposed in recessed portion 43 in a manner
that opposing ends 48a, 48b (Figure 5) of actuator connector 40 contact shoulders 46a, 46b
respectively in response to movement of piston 36 in the first direction and in the second
direction.

[0041] The dynamic coupling, e.g., releasable fixed connection between actuator connector 40,
and therefore piston 36, and flow tube 38 in the embodiment of Figures 3-5, is now described
with reference to Figure 5. Portion 42 of actuator connector 40 is adapted to fixedly couple to
portion 45 of flow tube 38 in response to movement of piston 36 in the first direction 50a shown
in Figures 3 and 4. When piston 36 is moved in the second direction 50b, the fixed coupling
between actuator connector 40, and therefore piston 36, and flow tube 38 is released. In this
embodiment, portion 44 of actuator connector 40 is described as a back angled surface adapted to
engage with the portion 45 of flow tube 38 which protrudes toward piston 36.

[0042] As will be recognized by those skilled in the art with benefit of the present disclosure,
actuator connector 40 may comprise various geometric shapes, engaging portions 42, 44 and the
like. For example, Figure 6 depicts an actuator connector 40 having a different geometric
configuration than the embodiment of Figures 3-5. In this embodiment, second portion 44 of actuator connector 40 is a shoulder which engages portion 45 (e.g., shoulder) of flow tube 38 causing piston 36 and flow tube 38 to move in unison in response to piston 36 moving in the first direction 50a.

[0043] Figures 3-5 illustrate a non-limiting embodiment of an actuator apparatus 14 and downhole valve 12 in different operational positions. In Figure 3, valve 12 is depicted in a first operational position from which piston 36 is actuated in a first direction 50a. With reference to Figures 1 and 2, the first operational position is described as valve 12 and closure member 30 being in the closed position, and first direction 50a is described as being the direction that operates closure member 30 from the closed position toward the open position.

[0044] Figure 4 depicts valve 12 in a second operational position associated with piston 36 being moved a distance in first direction 50a relative to the position of Figure 3. With reference to Figures 1-3, a signal applied to piston 36 causes piston 36 to move in the first direction 50a. As piston 36 moves in first direction 50a it is fixedly engages actuator connector 40 which fixedly engages flow tube 38 causing flow tube 38 and actuator connector 40 to move in unison with piston 36. Continued movement of actuator apparatus 14 in the first direction causes flow tube 38 to engage closure member 30 and move it to an open position as depicted in Figure 2 for example.

[0045] Figure 5 depicts an operational position in which piston 36 has been moved and/or is moving in the second direction 50b independent of the movement of flow tube 38. In some embodiments, the force acting on piston 36 in first direction 50a can be released or reduced permitting piston 36 to move in the second direction, for example in response to a biasing force
of energy source 35 (Figure 2), independent of the movement of flow tube 38. Thus, flow tube 38 is not necessarily moved (e.g., actuated) in response to movement of piston 36. Disconnecting piston 36 from flow tube 38 when closure member 30 (Figures 1 and 2) is in the open position, for example, can reduce or eliminate friction and/or forces acting on flow tube 38 and closure member 30 when closure member 30 is closing in response to an undesired condition.

[0046] Figures 7 and 8 are schematic isometric views of additional embodiments of actuator connector 40 according to one or more aspects of the invention. In both embodiments, actuator connector 40 comprises a yoke 40a and a tubular connector 52. The depicted embodiments can provide stability to actuator connector 40 and may limit movement of actuator connector 40 along the flow tube as may occur in other embodiments. Yoke 40a can be disposed relative to the piston and flow tube 38 as described with reference to Figures 1-6 for example with tubular connector 52 disposed over flow tube 38. In Figure 8, yoke 40a is positioned laterally away from tubular connector 52 by an extension arm 54. In some embodiments yoke 40a can be permanently fixedly connected to the piston and the tubular connector 52 disposed about the flow tube such that yoke 40a fixedly engages portion 45 of flow tube 38 as depicted in Figures 3-6 when piston 36 is moved in the first direction.

[0047] Figure 9 is a partial cross-section view of a portion of a downhole tool 12 revealing a portion of the actuation apparatus 14 according to one or more aspects of the present disclosure. Figure 10 is an end view of the embodiment depicted in Figure 9. In this embodiment, the actuator connector 40 comprises a first yoke 40a and a second yoke 40b which are spaced axially apart and connected to one another by an elongated member 56. In this embodiment, first yoke
40a engages piston 36 (Figure 10) which is shown through piston hole 62 and second yoke 40b engages portion 45 of flow tube 38 facilitating operational movement of actuator apparatus 14 as described with reference to Figures 1 and 3-6. Elongated connecting member 56 is aligned substantially parallel to and laterally offset from piston 36. Connecting member 56 is disposed in a bore 58 provided in body 32. The offset relationship of piston 36 and elongated member 56 and/or the axial separation of the engagement portions of piston 36 and flow tube 38 can provide a further reduced profile connection between the piston and flow tube.

[0048] In the embodiment of Figure 9 and 10, elongated member 56 (e.g., connecting rod) is connected to first yoke 40a which is disposed in a bore 58 formed in body 32 (e.g., housing), and the distal end 56b of elongated member 56 extends outside of bore 58 where it is coupled to second yoke 40b. In this particular embodiment, second yoke 40b is illustrated retracted and disposed in a cavity 60 located at the end of body 32 exterior of bore 58.

[0049] The present invention facilitates the utilization of a plurality of actuators in a downhole tool 12. An embodiment of a downhole tool 12 comprising two actuators is now described with reference to Figures 11-14. Figure 11 is a sectional view of an embodiment of a downhole tool comprising multiple actuators according to one or more aspects of the present disclosure. Tool 12 is depicted in the closed position in Figures 3 and 11. Depicted tool 12 includes two actuator apparatuses, which are generally denoted by the numerals 114 and 214. The first actuator apparatus 114 comprises an actuator connector 140 dynamically coupling flow tube 38 and first piston 136 together for example as described with reference to Figures 3-6. Second actuator apparatus 214 comprises an actuator connector 240 dynamically coupling flow tube 38 and
second piston 236 together, for example as described with reference to Figures 3-6. A cross-sectional view along the line I-I of Figure 11 is provided in Figure 13.

[0050] Referring now to Figure 12, valve 12 is depicted in the open position in response to actuating second actuator apparatus 214 in the first operational direction 50a. A cross-sectional view along the line II-II is provided in Figure 14. As will be understood by those skilled in the art with benefit of the present disclosure, pistons 136 and 236 may be operated independently or in unison in various embodiments. For example, with reference to Figure 1, control system 24, including for example control line 28, can be configured to apply a signal, such as hydraulic pressure, independently to the pistons or a single signal to both pistons. For example, in some embodiments multiple actuator apparatus 14 may provide redundancy so that tool 12 is actuated by second actuator apparatus 214 if piston 136 was stuck.

[0051] Various benefits and advantages provided by the actuator apparatus of the present invention will be understood by those with benefit of the present disclosure. For example, according to one or more aspects of the invention, the dynamical coupling of the actuator apparatus eliminates angular constraints (e.g., the piston is not angularly fixed) of contemporary devices providing for rotational freedom. With reference to Figures 13 and 14, freedom is provided to manufacture housing (body) 32 with the piston holes 162 and 262 in desired locations due to looser required tolerances, which results in cost savings. In Figures 13 and 14 the piston holes 162, 262 are depicted 180 degrees apart, however, the angular spacing can be varied as desired. As previously noted, the system can also have more than the two actuators illustrated. The actuator assemblies depicted herein provide a tight geometry for the piston to actuator coupling bounded both uphole and downhole. The present invention may allow for
thinner walled components (e.g., housing, flow tube, etc.) to be utilized. Different materials of constructions and/or coatings may be available, for example to provide anti-galling, high strength, and the like. The make-up of two components is not blind, for example as compared to the blind connection of lining up the piston holes and connecting a collet to the lower flow tube of a contemporary device.

[0052] The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. For example, the terms piston, flow tube, yoke are utilized herein for purposes of concisely describing the invention with regard to particular, non-limiting embodiments so that the invention as a whole can be better understood and realized. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure. The scope of the invention should be determined only by the language of the claims that follow. The term "comprising" within the claims is intended to mean "including at least" such that the recited listing of elements in a claim are an open group. The terms "a," "an" and other singular terms are intended to include the plural forms thereof unless specifically excluded.
WHAT IS CLAIMED IS:

1. An actuator apparatus for a downhole tool, the actuator apparatus comprising:
   a piston moveable in a first direction and a second direction;
   a tool actuator; and
   an actuator connector dynamically coupling the piston and the tool actuator, wherein the
   piston and the tool actuator necessarily move in unison in response to movement
   of the piston in the first direction and the piston and the tool actuator do not
   necessarily move in unison in response to movement of the piston in the second
   direction.

2. The actuator apparatus of claim 1, wherein the actuator connector is permanently fixedly
   coupled to only one of the piston and the tool actuator.

3. The actuator apparatus of claim 1, wherein the actuator connector comprises a first
   portion adapted to fixedly engage a portion of the piston and a second portion adapted to
   fixedly engage a portion of the tool actuator.

4. The actuator apparatus of claim 1, wherein the actuator connector is permanently fixedly
   connected to only one of the piston and the tool actuator and the actuator connector is
   temporarily fixedly connected to the other of the piston and the tool actuator in response
   to movement of the piston in the first direction.
5. The actuator apparatus of claim 1, wherein the actuator connector comprises a tubular member adapted to be positioned around the tool actuator.

6. The actuator apparatus of claim 5, wherein the actuator connector is permanently fixedly connected to only one of the piston and the tool actuator and the actuator connector is temporarily fixedly connected to the other of the piston and the tool actuator in response to movement of the piston in the first direction.

7. The actuator apparatus of claim 1, wherein the actuator connector comprises:
   a yoke;
   a tubular member adapted to be positioned about the tool actuator; and
   an elongated member connected between the yoke and the tubular connector, wherein the yoke is axially separated from the tubular connector by the elongated member.

8. The actuator apparatus of claim 7, wherein the actuator connector is permanently fixedly connected to only one of the piston and tool actuator and the actuator connector is temporarily fixedly connected to the other of the piston and the tool actuator in response to movement of the piston in the first direction.

9. The actuator apparatus of claim 1, wherein the actuator connector comprises a first yoke separated from a second yoke by an elongate member.
10. The tool actuator of claim 9, wherein the actuator connector is permanently fixedly connected to only one of the piston and tool actuator and the actuator connector is temporarily fixedly connected to the other of the piston and the tool actuator in response to movement of the piston in the first direction.

11. A subsurface valve, the valve comprising:
   a piston movable in a first direction and a second direction;
   a flow tube;
   a valve closure member actuated to one of an open position and a closed position in response to movement of the flow tube in one of the first direction and the second direction; and
   an actuator connector connected between the piston and the flow tube, wherein the piston, the actuator connector and the flow tube necessarily move in unison in response to movement of the piston in a first direction and wherein the piston and the flow tube do not necessarily move in unison in response to movement of the piston in the second direction.

12. The valve of claim 11, wherein the actuator connector is permanently fixedly connected to only one of the piston and the flow tube and temporarily fixedly connected to the other of the piston and the flow tube in response to movement of the piston in the first direction.
13. The valve of claim 11, wherein the actuator connector comprises a tubular member positioned around the flow tube.

14. The valve of claim 13, wherein the actuator connector is permanently fixedly connected to only one of the piston and the flow tube and the actuator connector is temporarily fixedly connected to the other of the piston and the flow tube in response to movement of the piston in the first direction.

15. The valve of claim 11, wherein the actuator connector comprises:
   a yoke;
   a tubular member positioned about the flow tube; and
   an elongated member connected between the yoke and the tubular connector, wherein the yoke is axially separated from the tubular connector by the elongated member.

16. The valve of claim 11, wherein the actuator connector comprises a first yoke separated from a second yoke by an elongate member.

17. The valve of claim 16, wherein the elongated member is positioned substantially parallel to the piston and laterally offset from the piston.

18. A method of actuation a downhole tool, comprising:
   moving a piston in a first direction in response to an applied signal;
moving a tool actuator in the first direction in unison with the first piston in response to
the moving the piston in the first direction;
moving the piston in a second direction; and
releasing a fixed connection between the tool actuator and the piston in response to the
moving the piston in the second direction.

19. The method of claim 18, further comprising dynamically connecting the piston and the
tool actuator with an actuator connector.

20. The method of claim 18, wherein the actuator coupler is permanently fixedly connected
to only one of the piston and tool actuator and the actuator connector is temporarily
fixedly connected to the other of the piston and the tool actuator in response to movement
of the piston in the first direction.