United States Patent [19]

Scott

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[54] **UNDERSEA WELL TEST TREE CONTROL VALVE AND SYSTEM**

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[52] **U.S. Cl.** **137/630.19**, 137/614.11, 166/224, 251/250, 251/354

[51] **Int. Cl.**.....**F16k 31/12**

[58] **Field of Search** 137/630.19, 614.11; 166/224, 166/226

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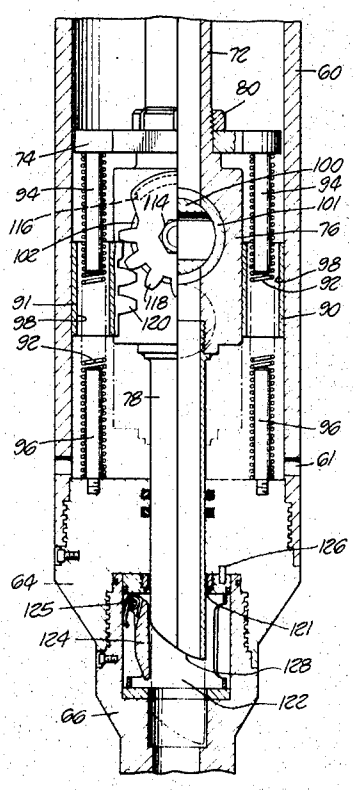
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[57] **ABSTRACT**

As part of a subsea well system, a hydraulically actuated and sequentially opening and closing control valve incorporating an upper rotary valve actuated by a rack and pinion or linear actuator arrangement coupled with a lower valve actuated by a stinger or mandrel arrangement whereby the lower valve is opened before the rotary valve is opened and the rotary valve is closed before the lower valve is closed. The lower valve may be of the flapper type. The valve incorporates a hydraulic operator actuated in one direction to open the valve by application of hydraulic pressure from a remote source, and actuated in the reverse direction to close the valve by resilient springs and/or by subsea hydrostatic pressure. The valve may also be closed by closing the rams of the blowout preventer in the subsea system above the valve and applying pressure through the kill line of such blowout preventer.

5 Claims, 6 Drawing Figures



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SHEET 1 OF 3

FIG. 1.

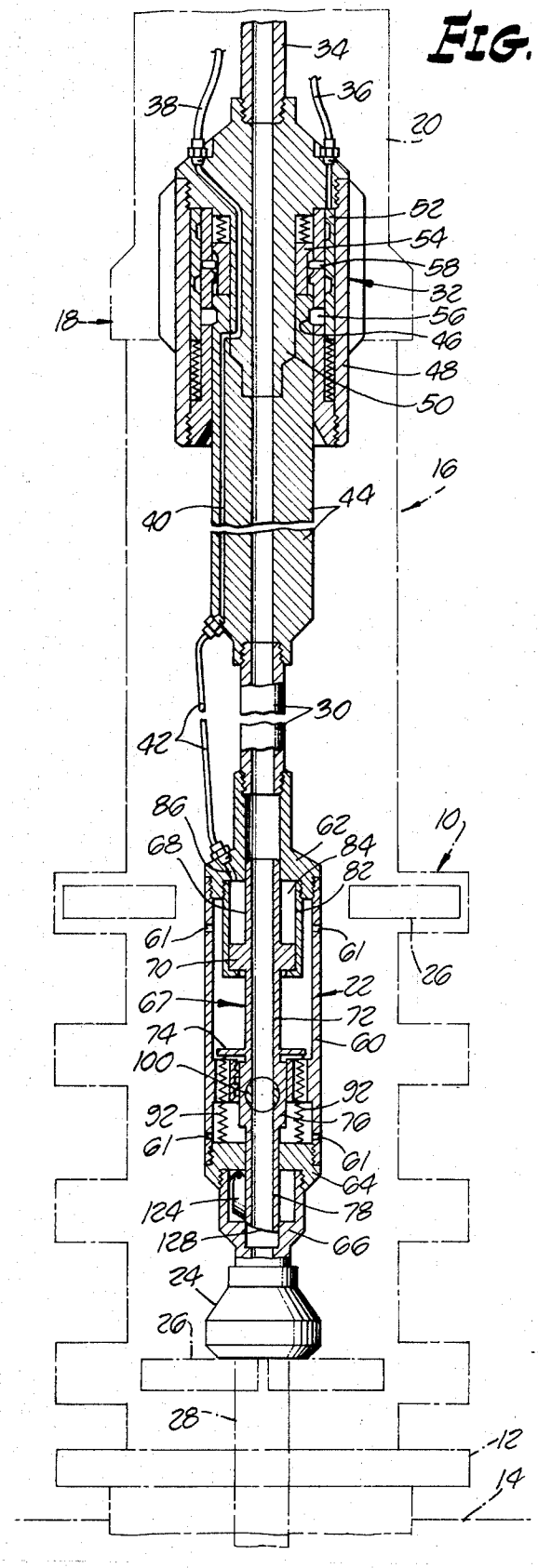
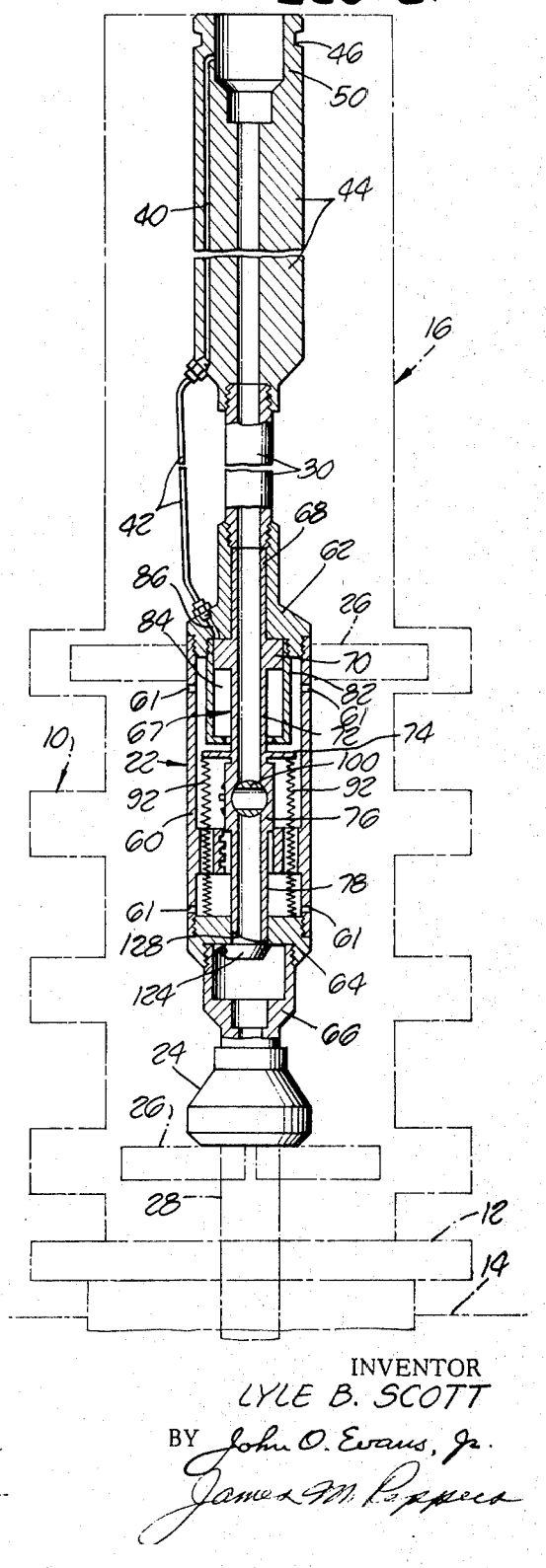
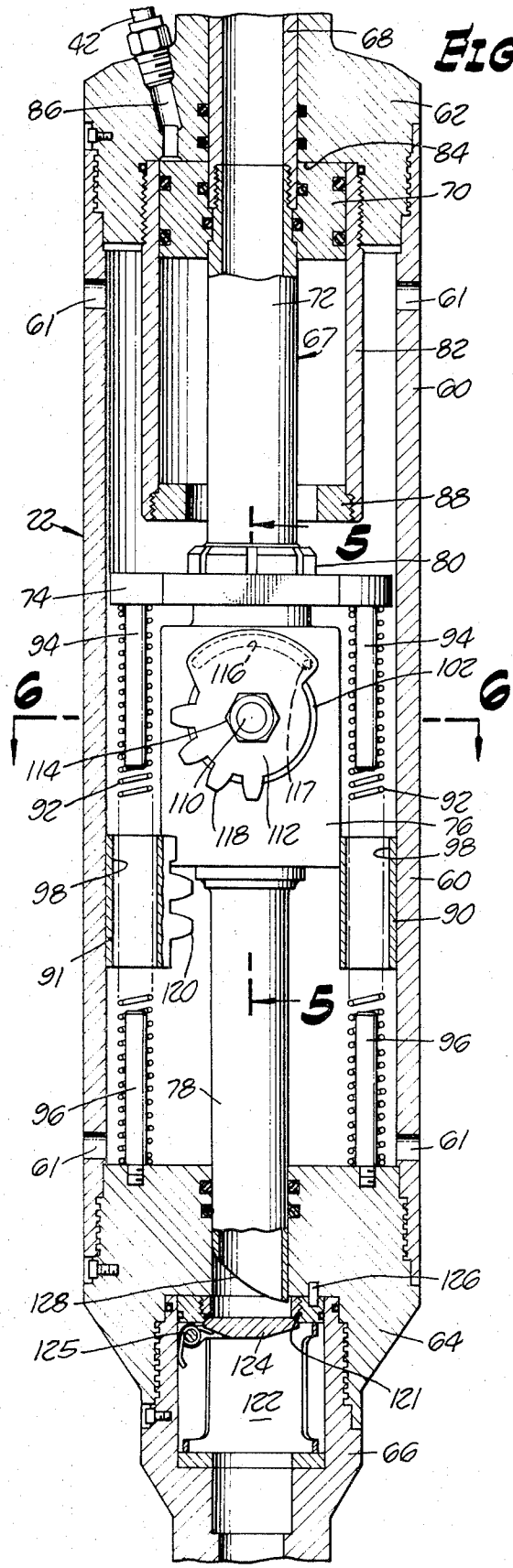


FIG. 2.



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FIG. 3.



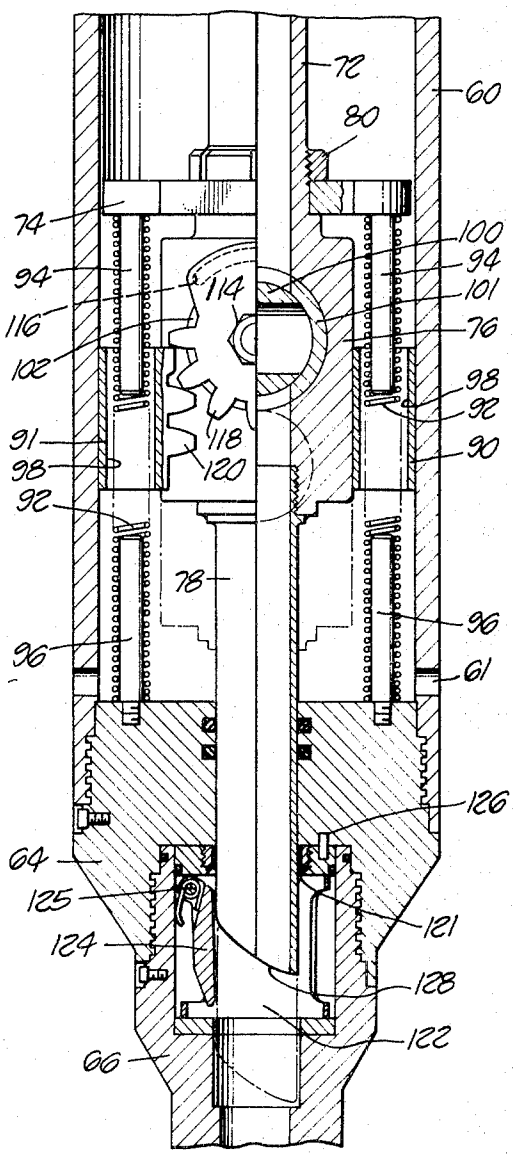


FIG. 4.

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FIG. 5.

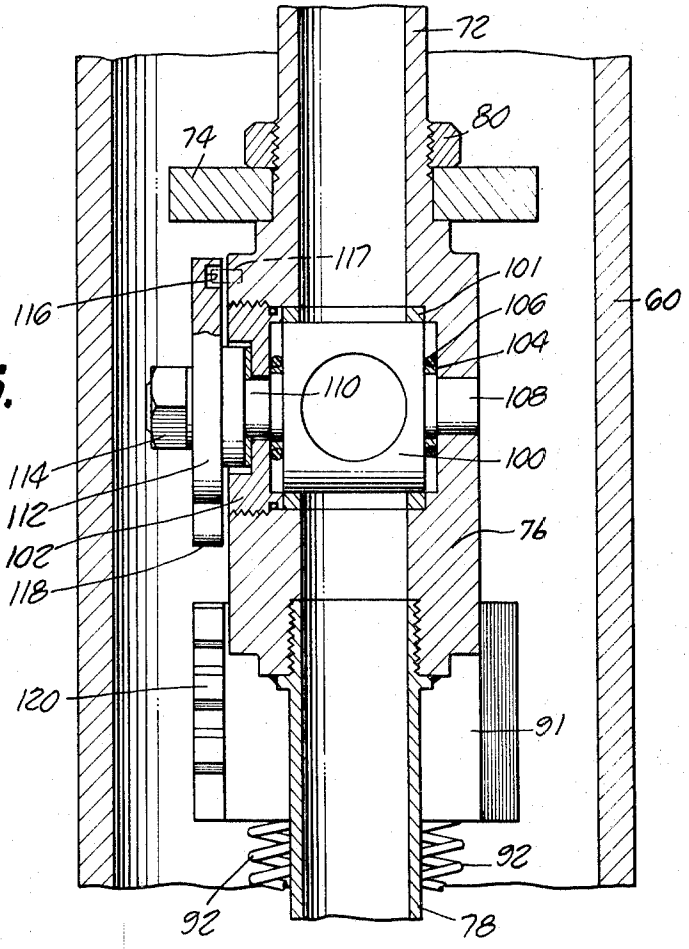
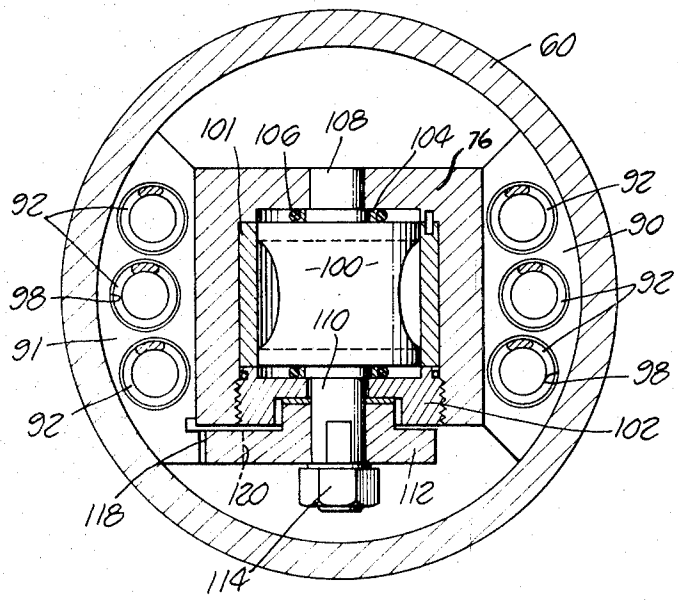


FIG. 6.



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UNDERSEA WELL TEST TREE CONTROL VALVE AND SYSTEM

BACKGROUND OF THE INVENTION

This invention generally concerns drill stem testing and the like from a floating drilling vessel and more particularly to a subsea test tree including an improved safety control valve, commonly referred to as a fail-safe valve, having valve elements actuated in sequence or tandem.

Operations such as drill stem testing require a reliable and safe shut down technique to rapidly disconnect from a subsea well and secure the well should it become necessary to move the surface vessel off the well location due to bad weather or other adverse conditions. In such operations a fail-safe valve is located in the pipe string within or slightly below the subsea blowout preventer stack assembly. This valve is held open with hydraulic pressure and should automatically close when such pressure is released. It is desirable that the fail-safe valve include at least two valve elements with one such valve element serving as "back up" for the other valve element. Since the well may be flowing fluids containing particulate and sometimes abrasive materials when shut-off or opening is effected, it is desirable that the valve elements be actuated sequentially so that one of such valve elements initially effects such shut-off, requiring exposure to the erosive effects of the flowing fluid, and the other of such valve elements follows into positively sealing position after fluid flow has completely or substantially terminated.

For rapid disconnection of the suspended well pipe string from the subsea equipment and ready reconnection of the pipe string to the subsea equipment, a suitable quick release-reconnect coupling is provided such as shown in U.S. Pat. No. 3,488,031, such a coupling being incorporated in combination with this invention as disclosed herein.

Background information for apparatus relating to this invention may be found, for example, by reference to pages 2810; 3511–3517; 3790–3791, and 4155–4162 of the 1970–71 COMPOSITE CATALOG of Oil Field Equipment and Services, published by Gulf Publishing Company, Box 2608, Houston, Texas, 77001.

Rotary valves of the kind actuated by a rack and pinion arrangement such as is incorporated in the preferred embodiment of the invention as disclosed herein are shown in the following U.S. Pats., for example:

No. 2,238,609	No. 2,785,755	No. 3,035,808
3,283,835		

Rotary valves which are variously related to the rotary valve incorporated in the invention as disclosed herein are shown in the following U.S. Pats., for example:

No. Re. 25,471	No. 2,894,715	No. 2,998,070
2,959,187	3,126,908	3,189,044
3,233,860	3,236,255	3,292,706
3,310,114	3,457,991	3,509,913

Flapper check valves of the kind incorporated in the invention as disclosed herein are shown in the following U.S. Pats., for example:

No. 2,786,535	No. 2,798,561	No. 2,831,539
2,841,171	2,921,601	3,016,914

3,045,760	3,092,135	3,318,387
3,332,495		

Related apparatus incorporating both a rotary valve and a flapper check valve are shown in the following U.S. Pats., for example:

No. 2,908,330	No. 3,356,145	No. 3,494,417

Other related apparatus incorporating check valves and/or rotary valves are shown in the following U.S. Pats. for example:

No. 2,912,216	No. 3,094,170	No. 3,035,641
3,265,134	3,412,806	3,411,576
3,398,762	3,200,837	2,998,077
3,332,497	3,218,024	3,107,080
3,104,862	2,963,260	

Structures considered as most pertinent examples to an understanding of the invention as disclosed herein are shown in U.S. Pats. No. 3,488,031 and No. 3,502,913, and on pages 3790–3791 of the COMPOSITE CATALOG referenced above.

SUMMARY OF THE INVENTION

An object of this invention is to provide a fail-safe control valve having at least two valve elements operative in succession or sequence so that at least one of such valve elements is protected from fluid erosion while maintaining the safety features of multiple valves.

Another object of this invention is to provide a fail-safe valve which may be closed in an emergency by any or all of three separate means of closure.

A further object of this invention is to provide a valve comprised of common and simple components for relatively inexpensive manufacture and maintenance.

The foregoing and other conditions and objects are met with a control valve apparatus for use in subsea operations having a tubular valve body adapted for connection into a well pipe, a mandrel member extending through the body and providing a flow passage through the well pipe, a first and a second valve element mounted within the valve body to be operative between an open and a closed position responsive to axial movement of the mandrel within the body, the first and said second valve element being mounted within the body with means responsive to axial movement of the mandrel to (a) first completely open the first valve element while the second valve element remains closed, then to completely open the second valve element and (b) to close the first element while the second valve element remains open, then to close the second valve element, and hydraulic actuating means connected with the mandrel to axially move the mandrel and thereby actuate the first and the second valve element between open and closed positions.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an elevational, partly sectional, view of a pipe string suspended from the water surface (not shown) and connected to a subterranean well pipe through a release-reconnect coupling and through a control valve shown in open position which is mounted within a schematically shown blowout preventer stack assembly.

FIG. 2 is the elevational view of FIG. 1 wherein the coupling has been disconnected and the control valve moved to a closed position.

FIG. 3 is a longitudinal sectional view of a major portion of the control valve of the invention shown in closed position.

FIG. 4 is a longitudinal sectional view of a portion of the control valve of the invention shown in an intermediate position as found during the closing cycle or the opening cycle of the valve.

FIG. 5 is a longitudinal sectional view taken along the line 5—5 of FIG. 3.

FIG. 6 is a transverse sectional view taken along the line 6—6 of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, there is shown subsea apparatus 10 mounted on a well head 12 extending from the sea floor 14. Subsea apparatus 10 includes a blowout preventer stack assembly 16 having removably mounted thereon a riser latch assembly 18. Riser latch assembly 18 is connected to a riser or conductor pipe 20 which extends upwardly to floating surface equipment (not shown).

A control valve 22, hereinafter described, is threadedly connected at its lower end to a landing collar 24 which is supported by one set of a plurality of rams 26 mounted within blowout preventer stack 16. Landing collar 24 is threadedly connected to a well pipe 28 which extends into connection with well head equipment (not shown) mounted within well head 12. The set of rams 26 supporting landing collar 24 is also closed around well pipe 28 and effects a seal between the interior of well head 12 and blowout preventer stack 16. The upper end of control valve 22 is threadedly connected through a conduit sub 30 into a quick type release coupling member 32. Coupling 32 is threadedly connected to the lower end of a pipe string 34 which extends upwardly to such floating surface equipment and is suspended therefrom.

A flexible hydraulic conduit 36 is connected at its lower end to the upper end of coupling 32 and at its upper end to a surface source of fluid pressure. Hydraulic fluid pressure is also supplied into the top of control valve 22, later described, through a flexible hydraulic conduit 38 extending from a surface pressure source and connected to the upper end of coupling 32, through a passageway 40 longitudinally defined through coupling 32 and through a flexible hydraulic conduit 42 connected between the lower end of coupling 32 in communication with passage 40 and the upper end of control valve 22 to provide fluid communication into valve 22.

Briefly described, coupling member 32 includes a mandrel member 44 provided with a latch recess 46 and threadedly connected to sub 30 as shown and a sleeve member 48 threadedly connected to pipe string 34 and fitted about mandrel 44. When fitted as shown, a stinger member 50 extends into mandrel 44 and complementary portions of passageway 40, defined in each of members 44 and 48, are joined in fluid communication. Coupling member 32 also includes a latch sleeve 52 and a lug sleeve 54 mounted as shown with appropriate recesses to accommodate a latch dog 56 and a lug 58, mounted as shown. As provided, sleeve 48 is releasably latched to mandrel 44, after being slipped over the mandrel, and the sleeve is subsequently released for removal from the mandrel when actuated by application of fluid pressure through conduit 36 onto the upper area of latch sleeve 52. Apparatus such as coupling member 32 is disclosed in detail in U.S. Pat. No. 3,488,031, specifically incorporated herein by reference.

Referring additionally to FIGS. 3–6, control valve 22 has a generally tubular body 60 including an upper connection member 62 and a lower connection member 64. Upper connection member 62 is threadedly connected to conduit sub 30 and lower connection member 64 is threadedly connected through a valve retainer sub 66 to landing collar 24. Ports 61 provide fluid communication between the interior and exterior of body 60.

Extending through valve 22 is a composite hollow mandrel member 67 comprising an upper seal mandrel 68, a piston 70, a driving mandrel 72, a spring return plate 74, a valve body 76 and a lower actuating mandrel or stinger 78. Piston 70 is mounted on driving mandrel 72 and retained in operative position by threaded connection of seal mandrel 68 with driving mandrel 72. Driving mandrel 72 and valve body 76 are shown as being integral in structure but may be separate components with threaded connection if desired. Retainer plate 74 is mounted with valve body 76 and fastened into position by threaded connection of a spanner nut 80. Piston 70 is fitted into a cylinder 82 which cylinder is concentrically mounted and threadedly connected into upper connection member 62. Connection member 62, seal mandrel 68, piston 70 and cylinder 82 as provided cooperate to define a hydraulic chamber 84 which is in fluid communication with hydraulic line 42 through a passageway 86 defined in connection member 62. Appropriate seals such as O-rings are provided about seal mandrel 68, piston 70 and driving mandrel 72 to confine fluids under pressure within chamber 84 and also to seal the interior of mandrel assembly 67 from the exterior of valve body 22.

To limit downward movement of piston 70 within cylinder 82, a limit bushing 88 is mounted in threaded connection within the lower end of cylinder 82. As provided, the extreme upper and lower positions of piston 70, and consequently the entire mandrel assembly 67, is limited in predetermined relation within valve 22 by upper connection member 62 and limit bushing 88, respectively.

Valve body 76 may be generally a hexahedron in shape as shown and is supported against rotation within body 60 by valve guides 90 and 91 which guides are mounted within body 60 by means such as cap screws (not shown). When valve 22 is assembled, mandrel assembly 67 is forcibly urged to its upper position within body 60 by means of springs 92 longitudinally mounted in compression between return plate 74 and lower connection member 64. Springs 92 are maintained in longitudinal position by means of guide rods 94 projecting from return plate 74, by guide rods 96 projecting from connection member 64 and by guide holes 98 defined through guides 90 and 91 as shown in FIGS. 3 and 6.

Referring to FIGS. 1–6, valve body 76 is shown to house a rotary valve member or plug 100 which plug is

adapted to be rotated between an open position and a closed position. Plug **100** is retained in operative position within body **76** by means of a retainer bushing **102** having threaded connection within body **76**, as shown in FIGS. **5** and **6**. Plug **100** is fitted within an intermediate seal sleeve **101** mounted within body **76**. Seal means such as O-ring guides **104** and O-rings **106** are mounted about plug support shafts **108** and **110** extending from plug **100** and between the plug and body **76**. Plug shaft **110** is fitted with an operator **112** which is secured thereon by a threaded nut **114**.

An arcuate slot **116** is developed in a portion of operator **112** which accommodates a limit pin **117** connected into valve body **76**, as shown in FIGS. **3—5**. The slot **116** and pin **117** function to limit plug **100** between a fully open and a fully closed position. Another portion of operator **112** is developed into a segment of a gear pinion **118**, as shown in FIGS. **3–6**. Gear pinion **118** is adapted to engage a gear rack **120** which is developed as a portion of guide **91**. As mandrel **67** is moved downwardly, pinion **118** initially engages rack **120**. Further movement to the position limit established by limit bushing **88** causes meshing of the gears and rotation of operator **112** which rotates plug **100** from the closed to the open position. It is to be noted that mandrel assembly **67** must be moved downwardly a predetermined distance before pinion **118** and rack **120** mesh and become operable to cause rotation of plug **100**.

As best shown in FIGS. **3** and **4**, actuating stinger **78** is adapted to extend through lower connector member **64**. Appropriate seal means such as O-rings are mounted between stinger **78** and member **64** to effect a seal between the interior of mandrel assembly **67** and the outside of valve **22**. Stinger **78** is threadedly connected into valve body **76** as shown and tack welded or otherwise fixed in arcuate orientation with respect to the valve body.

A valve cage assembly **122** is mounted in intermediate relation by and between valve retainer sub **66** and connection member **64**. Cage assembly **122** has pivotally mounted therein a swing type valve member **124** mounted by means of a spring and pivot assembly **125**. Cage assembly **122** includes a valve seat **121** with an appropriate seal such as an O-ring. Valve cage **122** and valve **124** is arcuately oriented with respect to connection member **64**, and consequently with respect to valve body **76** and stinger **78**, by means of an alignment dowell pin **126** fitted into adjacent portions of cage **122** and member **64**. A curved bevel **128** is developed across the lower end of stinger **78** which purpose is to engage valve member **124** across from pivot assembly **125** then push valve **124** from the closed to the open position in a rolling and sliding fashion as stinger **78** is moved downwardly into valve cage **122**.

OPERATION OF THE PREFERRED EMBODIMENT

In operation, valve **22**, landing collar **24** and release coupling **32** are installed within blowout preventer **16** with lower rams **26** closed as shown in FIG. **1**. Hydraulic fluid is forced under pressure into chamber **84** through conduits **38**, **40** and **42**, causing piston **70** and mandrel assembly **67** to move from their upper position to their lower position established by limit bushing **88**. Initial downward movement of assembly **67** and stinger **78** causes valve member **124** to move from its closed position to its open position (FIG. **4**). At this stage plug **100** has not been actuated and remains in closed position. Continued downward movement of mandrel assembly **67** causes pinion **118** to mesh with rack **120** then rotate plug **100** from its closed to its open position, whereupon further movement of mandrel assembly **67** is stopped by contact of piston **70** with limit bushing **88**.

It is to be noted that such structure and operation as described permits valve **124** to be fully opened and thus to be exposed to a minimum of abrasive flow contact with possibly erosive fluids flowing through well pipe **28** before any such flow is permitted by subsequent opening of valve plug **100**. Any fluid caused erosion thus will be confined to plug **100** and to some extent to sleeve **101**.

When it is desired to release sleeve member **48** and latch assembly **18** from the remainder of the subsea installation, as caused by an emergency or for any other reason, pressure is released from chamber **84** of valve **22** through conduit **38**, or subsequent disconnection of coupling **32**, and fluid pressure is applied through conduit **36** to bear on latch sleeve **52** and unlock sleeve member **48** from mandrel member **44**. Latch assembly **18** and pipe string **34** including sleeve member **48** is thereafter removed from stack assembly **16**.

When closure of valve **22** is desired, three features are available to insure closure of the valve. The first closing feature is the compression springs **92** which forcibly urge the valve to a closed position when fluid pressure in chamber **84** is reduced. As a second closing feature, when fluid pressure through conduit **38** is released and before coupling **32** is disconnected, the hydrostatic pressure of the sea water around valve **22** is greater than that of the hydraulic fluid in chamber **84** and such pressure is communicated through body parts **61** to the underside of piston **70** to urge the valve closed. As a third feature in closing the valve, one of the upper set of rams **26** may be closed about the top of valve **22** (FIG. **2**) and fluid pressure may be introduced into blowout preventer stack **16** through its control system (not shown) which fluid pressure is communicated through ports **61** to the underside of piston **70** to close the valve.

It is to be noted, while the flapper type valve cage assembly is disclosed herein as a preferred embodiment, that other properly spaced valve means actuated by mandrel assembly **76** could be provided. As an example, a second properly spaced rotary valve, pinion and rack assembly such as shown herein could be provided. The desirable features to be provided by this invention are the sequential opening and closing of at least two valve elements along with positive means to close the valve when necessary.

While only one embodiment of the invention is shown and described herein, other embodiments and variations thereof will become apparent to be included in the spirit of the invention as herein set forth.

That being claimed is:

1. A subsea control valve comprising:

a. an elongated valve body adapted for connection into a conduit;

b. actuating fluid flow mandrel means mounted within said body for movement between first and second positions within said body;

c. hydraulic actuating means connected with said body and said mandrel means and operative to move said mandrel means between said first and said second positions;

d. first valve means mounted within said body and operative to be opened by movement of said mandrel means from said first position to said second position;

e. second valve means mounted within said body and operative to remain closed until said first valve means has been fully opened by movement of said mandrel means then to be opened in sequence by continued movement of said mandrel means from said first position to said second position;

f. said mandrel means being operative first to fully close said second valve means and then to close said first valve means in sequence upon movement of said mandrel means from said second position to said first position;

g. return means mounted between said mandrel means and said body which is operative to urge said mandrel means from said second position to said first position; and

h. wherein said first valve means includes a flapper type valve mounted within said valve body and adapted to be opened by said mandrel means.

2. A subsea control valve comprising:

a. an elongated valve body adapted for connection into a conduit;

b. actuating fluid flow mandrel means mounted within said body for movement between first and second positions within said body;

c. hydraulic actuating means connected with said body and said mandrel means and operative to move said mandrel means between said first and said second positions;

d. first valve means mounted within said body and operative to be opened by movement of said mandrel means from said first position to said second position;

e. second valve means mounted within said body and operative to remain closed until said first valve means has been fully opened by movement of said mandrel means then to be opened in sequence by continued movement of said mandrel means from said first position to said second position;

f. said mandrel means being operative first to fully close said second valve means and then to close said first valve means in sequence upon movement of said mandrel means from said second position to said first position;

g. return means mounted between said mandrel means and said body which is operative to urge said mandrel means from said second position to said first position;

h. wherein said second valve includes a rotary valve body mounted with said mandrel means, a rotary valve member mounted for rotation within said rotary valve body, and rotary actuating means to rotate said valve between opened and closed positions in response to movement of said mandrel means within said body; and

i. wherein said first valve means includes a flapper type valve mounted within said valve body to be pushed open by an extension of said mandrel means.

3. The control valve of claim 2 wherein said rotary actuating means includes a gear pinion mounted with said rotary valve member adapted to mesh with a gear rack mounted with said elongated valve body.

4. A subsea control valve comprising:

a. an elongated valve body adapted for connection into a conduit;

b. actuating fluid flow mandrel means mounted within said body for movement between first and second positions within said body;

c. hydraulic actuating means connected with said body and said mandrel means and operative to move said mandrel means between said first and said second positions;

d. first valve means mounted within said body and operative to be opened by movement of said mandrel means from said first position to said second position;

e. second valve means mounted within said body and operative to remain closed until said first valve has been fully opened by movement of said mandrel means then to be sequentially opened by continued movement of said mandrel means from said first position to said second position and vice versa whereby said first valve means and said second valve means are sequentially opened and sequentially closed upon movement of said mandrel means between said first position and said second position;

f. wherein return means is provided between said mandrel means and said body which is operative to urge said mandrel from said second position to said first position; and

g. wherein said first valve means includes a flapper type valve mounted on said valve body adapted to be opened by said mandrel means and wherein said second valve means includes a rotary valve body mounted with said mandrel means, a rotary valve member mounted for rotation within said body, and rotating means to rotate said valve between opened and closed positions in response to movement of said mandrel means within said body said rotating means including a gear pinion mounted with said rotary valve member and adapted to mesh with a gear rack mounted with said elongated valve body.

5. The control valve set forth in claim 4 wherein said return means includes compression springs.

* * * * *