

[54] **WELL BORE TEST AND SAFETY VALVE STRUCTURE**

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[58] Field of Search **166/72, 224 A, 226; 251/58, 62**

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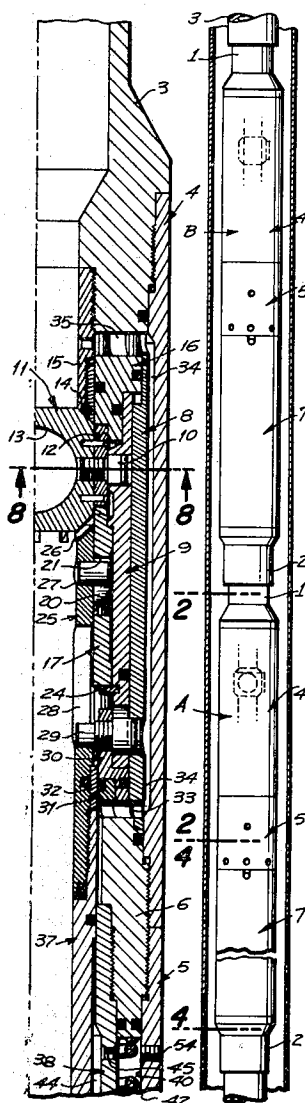
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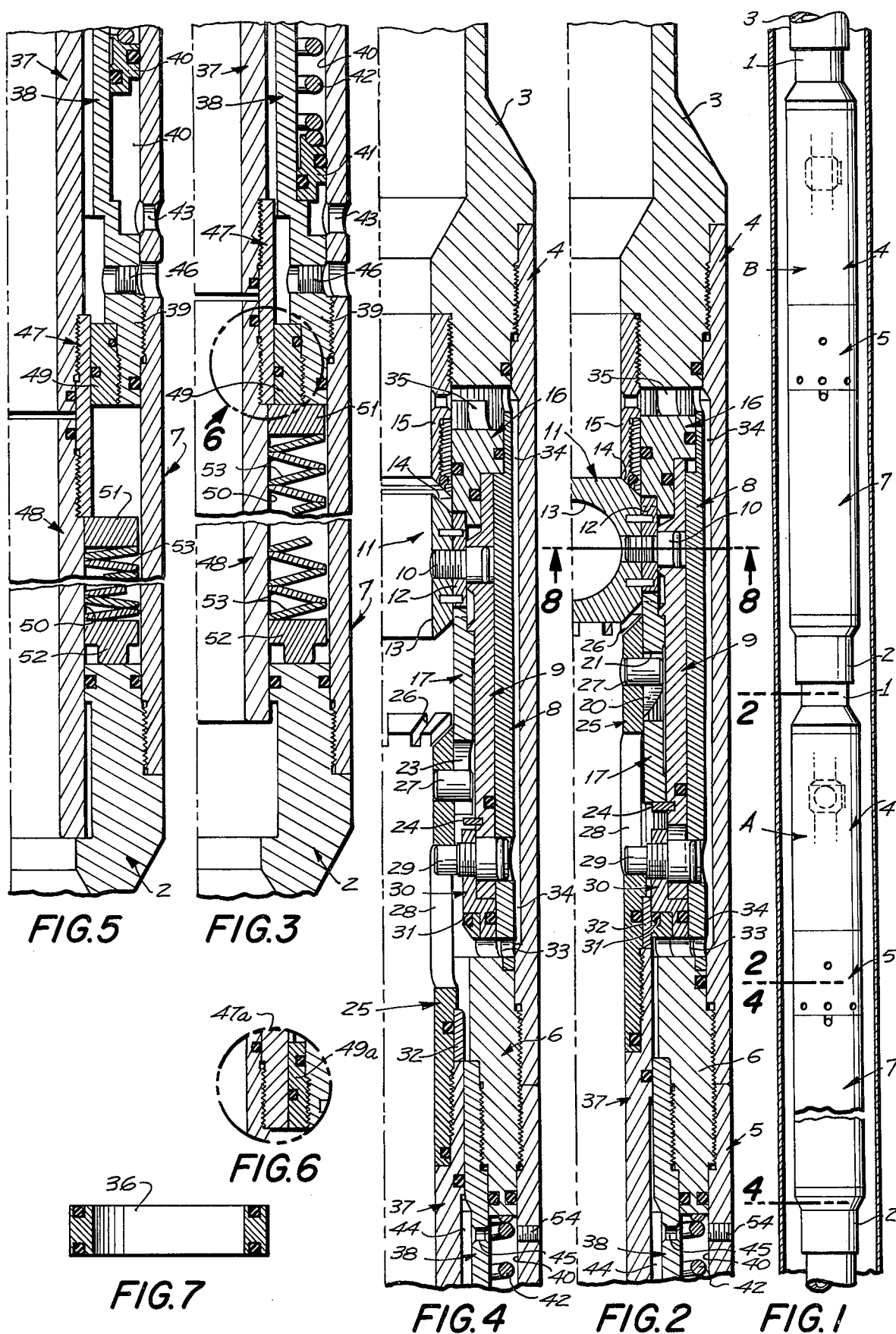
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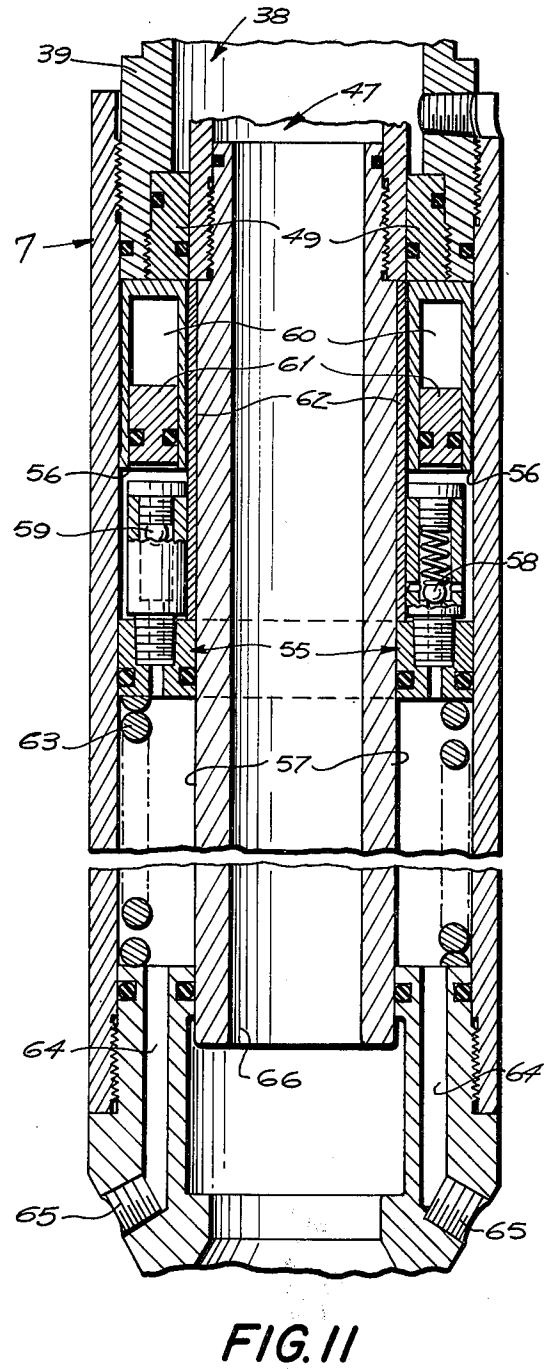
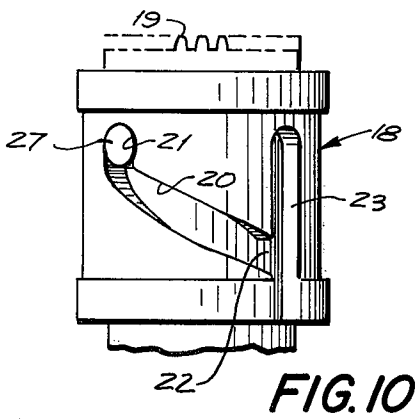
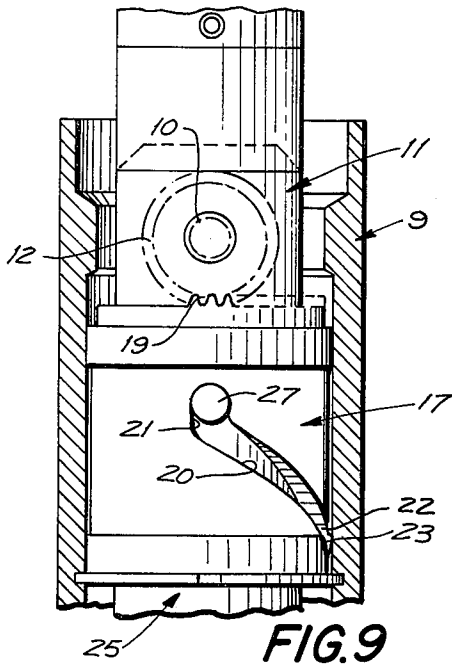
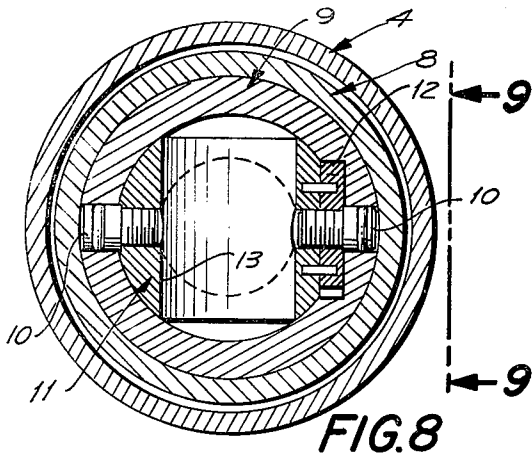
[57] **ABSTRACT**

A valve structure which, with minimum change in parts, may function as a test valve or as a safety valve; the valve structure including an annular valve housing containing a closed fluid system actuated by fluid pressure externally of the housing to effect, in conjunction with cam means, axial and partial rotation of a sleeve and a driving gear carried thereby; the housing journalling a tubular valve block having a driven gear engageable with the driving gear to rotate the valve block between a closed and an open position, and in doing so, the pressure differential across the valve block is first relieved. The valve housing also incorporates means for partially counterbalancing a predetermined portion of the external fluid pressure.

14 Claims, 11 Drawing Figures







WELL BORE TEST AND SAFETY VALVE STRUCTURE

SUMMARY OF THE INVENTION

The present invention is directed to an improved well bore test and safety valve structure which is summarized in the following objects:

First, to provide a valve structure for use in well bores which, with a minimum change of parts, may be used as a test valve or as a safety valve; a pair of the valve structures one arranged as a test valve and the other being arranged as a safety valve is adapted to be installed in tandem near the bottom of a tubing string.

Second, to provide a valve structure of the type indicated in the preceeding object, which incorporates a novel arranged valve block having a bore and a gear drive means for turning the valve block between its closed position and its open position.

Third, to provide a valve structure for use under high pressure in well bores wherein the pressure across the valve is relieved immediately preceeding movement from its closed position to its open position.

Fourth, to provide a valve structure wherein movement of the valve is accomplished through a closed fluid system within the valve structure subject to fluid pressure in the bore annulus around the valve structure.

Fifth, to provide a valve structure, as indicated in the other objects, which incorporates a novel means for counterbalancing a preselected portion of the pressure exerted by the surrounding well fluid, reserving a remaining pressure for operating the valve structure, and further novel means is provided to permit a pair of valve structures arranged in tandem to be responsive to different effective pressures whereby the valve structures may be operated in sequence.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of the well bore test and safety valve structure with adjacent ends of the tubing string shown fragmentarily and also showing a surrounding casing in section.

FIG. 2 is an enlarged fragmentary longitudinal half sectional view corresponding to the region between 2—2 of FIG. 1, the parts being shown in their initial position with the valve block in its closed position.

FIG. 3 is a similar fragmentary half sectional view continuing downwardly from FIG. 2 also showing the parts in their initial position.

FIGS. 4 and 5 are enlarged fragmentary half sectional views corresponding respectively to FIGS. 2 and 3 showing the parts as they appear upon movement of the valve to its open position.

FIG. 6 is a sectional view taken within circle 6 of FIG. 3 illustrating a modification whereby the effective area of a piston is increased.

FIG. 7 is a sectional view of a ring intended for insertion in a vent passageway to close off flow there-through.

FIG. 8 is a transverse sectional view taken through 8—8 of FIG. 2 showing the valve in its closed position.

FIG. 9 is a fragmentary side view taken from 9—9 of FIG. 8 with outer portions of the housing structure removed to expose the drive means for the valve when used as a test valve structure.

FIG. 10 is a similar side view of a modified drive means for the valve when used as a safety valve structure.

FIG. 11 is a fragmentary full sectional view corresponding to the region shown in FIG. 3, but showing a modified form of a counterbalancing structure.

As indicated by its title the well bore test and safety valve structure does in fact involve two structures namely, a test valve structure A and a safety valve structure B. These two structures may be in most respects identical. Stated otherwise, by making minor changes in the test valve structure, it becomes the safety valve structure.

Each valve structure includes an upper adaptor fitting 1 and a lower adaptor fitting 2. To place the two structures in tandem relation, the upper adaptor fitting 1 of the test valve structure is secured to the lower adaptor fitting of the safety valve structure. The upper adaptor fitting of the safety valve structure is joined to a tubing string 3 while the lower adaptor fitting of the test valve structure is for suitable devices (not shown) intended for use with the valve structures.

Each valve structure includes an upper outer case 4 joined to its upper adaptor fitting 1. An intermediate outer case 5 is joined by an internal coupling 6 to the upper outer case. A lower outer case 7 is joined to the lower adaptor fitting 2 and extends upwardly into confronting relation with the intermediate outer case 5.

Secured within the upper outer case 4 between the upper adaptor fitting 1 and internal coupling 6, is a spacer tube 8. Within the spacer tube 8 is a carrier tube 9. Journalled within the carrier tube is a pair of diametrically disposed rotary trunnion pins 10 which are screwthreadedly connected to a valve block 11 at one radial end of which is a driven gear 12. The valve block 11 forms a bore 13 and is provided at its axially upper end with a conical valve seat 14.

Secured within the upper adaptor fitting 1 is a tubular sealing assembly 15 which engages the valve seat 14 mounted between the sealing assembly 15 and the upper portion of the spacer tube 8 is a valve unseating piston 16 which engages the carrier tube 9. As will be later disclosed in more detail, the piston 16 moves the carrier tube 9 downwardly a short distance to space the valve seat 14 from the sealing assembly 15.

Journalled within the carrier tube 9 of the test valve structure A is a cam sleeve 17 whereas the safety valve structure B is provided with a modified cam sleeve 18. Each cam sleeve is provided with a segmental drive gear 19 and a helical cam slot 20. The upper ends of the cam slot 20 have axially extending portions 21. The cam slot 20 of the test valve structure terminates in a short axial lower end 22. The lower end of the cam slot in the safety valve structure B is provided with an axially extending return slot 23 which intersects the lower end of its helical cam slot, all as shown best in FIGS. 9 and 10.

In order to retain the cam sleeve 17 or 18 in place there is provided a lock ring 24 fitted in the carrier tube 9. Disposed below the valve block 11 and forming a portion of the inner bore of the valve structure is a cam driver tube 25 the upper end of which is internally beveled and slotted as indicated by 26. The cam driver tube 25 is provided with an outwardly extending cam engaging pin 27 initially received in the upper end 21 of the helical cam slot 20.

The cam driver tube 25 is provided with an axial slot 28 which receives an alignment pin 29 extending radially inward from the spacer tube 8. The alignment pin includes a screwthreaded portion which extends through a seal holder ring 30 disposed within the lower end of the carrier tube 9. The seal holder ring 30 protrudes below the carrier tube 9 and is provided with a seal ring 31 and retainer which in the initial position of the valve structure engages an unloader ring 32 carried by the lower portion of the cam driver tube 25.

A radially extending vent passage 33 is formed between the upper end of the coupling 6 and the lower end of the spacer tube 8 and seal holder ring 30. The vent passage 33 communicates with an annular recess 34 formed within the upper outer case 4 and extending upwardly to the lower end of the upper adaptor fitting 1. Here there is provided a second radially extending vent passage 35 formed between the upper adaptor fitting 1 and the valve unseating piston 16 and including a hole in the sealing assembly 15. The vent passages and annular recess form a bypass passage around the valve block 11 of the test valve structure A, however, the vent passage is not used in conjunction with the safety valve structure, instead a closure ring 36 shown in FIG. 7 is substituted for the seal ring 31 and its retainer.

Secured to the lower end of the cam driver tube 25, is an upper mandrel 37 forming a continuation of the bore of the valve structure. The mandrel 37 is surrounded by a sleeve 38 having an enlarged lower end 39 screwthreaded and sealed to the upper portion of the lower outer case 7. Between its enlarged lower end 39, and the lower end of the internal coupling 6, the sleeve 38 forms with the lower portion of the intermediate outer case 5 an outer annular pressure chamber 40 which receives at its lower end an annular piston 41 urged downwardly by a spring 42. The lower end of the chamber 40 is provided with an external pressure fluid inlet 43.

Formed between the upper mandrel 37 and sleeve 38 is an inner annular pressure chamber 44 connected to the outer pressure chamber 40 by a port 45 in the sleeve 38. A radial port normally closed by a filler plug 46 is formed in the lower end 39 of the sleeve 38 and is accessible through an opening provided in the upper end of the lower outer case 7.

Screwthreaded and sealed to the upper mandrel 37 is a differential piston 47 which also functions as a coupling to join the upper mandrel 37 to a lower mandrel 48. The lower portion of the differential piston confronts a differential sleeve 38 and having a seal ring sealingly engaging the differential piston 47.

The effective area of the differential piston 47 is determined by the difference in diameter of the mandrel 37 and the piston 47 by increasing the diameter of the lower portion of the piston 47 as indicated by 47a in FIG. 6 and by correspondingly enlarging the internal diameter of the differential cylinder 49 as indicated by 49a in FIG. 6, the effective area of the piston 47 may be increased.

Below the lower end 39 of the sleeve and the differential cylinder 49 is a spring chamber 50 defined between the lower mandrel 48 and lower outer case 7 which extends to the lower adaptor fitting 2. The lower mandrel 48 fits slidably within the fitting 2. The lower mandrel and differential piston are adapted to respond to pressure within the inner pressure chamber 44 to

move downwardly past the differential cylinder 49 and engage an upper collar 51. Between the collar 51 and a lower collar 52 engaging the lower adaptor fitting 2, is a set of conical spring disks 53 which may be in the nature of bellville springs.

Operation of the test valve structure A is as follows:

The parts are assembled as shown in FIGS. 2 and 3. The pressure chambers 40 and 44 are filled with a liquid care being taken to remove as much air as possible. One or more vent plugs 54 being provided to minimize entrapped air. The spring disks 53 are compressed so that a preselected upper force is maintained on the differential piston 47.

In order to run the test valve structure, it is desirable to know the approximate bottom hole pressure in the region between the test valve structure and the surrounding casing when the test valve structure is in position in the bottom of the well bore or whatever location it is desired to compensate for the bottom hole pressure that is, the static pressure of a column of liquid extending to the head of the well. At the well head, means not shown, provided for applying additional pressure. The static pressure and the additional pressure is transmitted from the inlet 43 to the differential piston 47 through the annular piston 41 and the liquid contained in the chambers 40 and 43. By preselection of the diameter of the differential piston 47 the surface pressure at which the valve may be moved from a closed position to an open position can be predetermined.

The force required to open the valve block depends upon the pressure differential across the valve block. However, by releasing this pressure before actually moving the valve the amount of force required may be minimized. Initial downward movement of the differential piston; mandrel 37 and cam driver tube 25 causes the closure ring 36 to disengage the seal ring 31 bleed or vent fluid below the valve through passages 33, 34 and 35 and at the same time moving the valve unseating piston 16 downward due to pressure build-up above the piston 16. This downward movement also moves the carrier tube 9 and the valve downward as shown in FIG. 4 so that the valve block 11 is free to rotate. Continued downward movement of the differential piston and cam driver tube 25 causes the cam sleeve 18 to rotate about a vertical axis which through the gears 19 and 12 rotates the valve block 11 about a horizontal axis from the closed position shown in FIG. 2 to the fully open position shown in FIG. 4. The length of the axial slot 28 or other means may be used to insure that the valve block when opened is disposed within the bore 13 in complete alignment with the bore through the sealing assembly 15 as well as the tube 25 and mandrels 37 and 48. Release of the pressure applied at the well head permits the spring to return the cam driver tube 25 and mandrels 37 and 48 to their original position which causes the valve block to return from its open position to its closed position and engage the sealing assembly 15.

The operation of the safety valve structure B is essentially the same except that the valve block 11 is initially placed in its open position so that operation of the driver tube 25 moves the valve to its closed position. It is desirable that, the vent passages 33, 34 and 35 be sealed by the closure ring 36 placed to close the passage 33. Also the proportions of the differential piston 47 and its cylinder 49 are such that a greater surface

pressure at the well head is required than is required to operate the test valve structure A. When the greater pressure is applied the cam driver tube 25 turns the cam sleeve 18 to cause the valve block 11 to close. When closed, the pin 27 is in alignment with the axial slot 28 and the valve block is locked in its closed position irrespective of what external pressures may be applied.

In order to provide more accurate control, of the counterbalancing force than is possible by use of a stack of springs, it is preferred to use a hydraulic counterbalancing unit. This is accomplished as shown in FIG. 11 by placing in the chamber 50, an annular piston 55 dividing the chamber into an upper pressure chamber 56 and a lower pressure chamber 57. The annular piston 55 carries a high pressure transfer valve 58 permitting liquid transfer from the lower chamber to the upper chamber when the pressure differential is above a predetermined value. This pressure differential is related to the static pressure of the well fluid surrounding the tubing string and may be in the order of several thousands of pounds if the well bore is deep and the surrounding liquid is water or a heavier liquid. The piston 55 also carries a low pressure transfer valve 59 which operates in the opposite direction to the valve 58. The upper pressure chamber 56 is provided with an annular air cylinder 60 having an annular piston 61 and a connecting sleeve 62 extends from the annular piston 55 to the differential piston 47 in order to provide space for the valves 58 and 59 as well as the air cylinder 60.

A spring 63 initially holds the annular piston 55 in its upper position as shown in FIG. 11 and appropriate filler and vent ports 64 are provided in the lower adaptor fitting 2 and are closed by suitable plugs 65. Both chambers 56 and 57 are filled with a liquid, some cushioning is permitted as determined by the air cylinder 60 and the air piston 61. The lower pressure chamber 57, however, is completely filled with liquid at a pressure calculated to equal the static head of liquid between the valve structure and the well head. When the well head pressure is increased for the purpose of moving the valve block, liquid is bypassed through the high pressure transfer valve 58 permitting the differential piston 47 to force the sleeve 62 and piston 55 downward. A sleeve 66 provides mechanical connection between the differential piston 47 and the piston 55.

Having fully described my invention it is to be understood that I am not to be limited to the details herein set forth, but that my invention is of the full scope of the appended claims.

I claim:

1. A tubing string supported valve structure for use in a well bore and operated by fluid pressure from a source other than the tubing string controlled from the well head, said valve structure comprising:
 - a. an annular housing structure depending from the tubing string and having a bore communicating with the interior of the tubing string;
 - b. a valve block within the housing structure bore and rotatable about an axis transverse thereto between a position closing the housing structure bore and a position in alignment therewith;
 - c. a driven gear carried by the valve block;
 - d. an annular drive means journaled in the housing structure and including an arcuate drive gear con-

centric with the housing structure and engageable with the driven gear;

- e. an axially movable operating means within the housing structure and responsive to said fluid pressure source;
- f. a cam and pin means connecting the drive means and axially movable means for causing the drive gear to turn the driven gear and valve block upon axial movement of the operating means.
2. A valve structure as defined in claim 1, which further comprises:
 - a. a yieldable means for applying a predetermined counterforce on the operating means approximating the force exerted by the static head of the pressure fluid whereby predetermined added force may be applied at the well head to effect movement of the valve block.
3. A valve structure as defined in claim 2, wherein:
 - a. the yieldable means is a spring assembly.
4. A valve structure as defined in claim 2, wherein:
 - a. the yieldable means is a pressurized hydraulic assembly.
5. A valve structure as defined in claim 1, wherein:
 - a. means is provided to form a bypass externally of the valve block and relieve the pressure differential across the valve block upon initial movement from its closed position.
6. A valve structure as defined in claim 1, wherein:
 - a. said valve block occupies an initially closed position;
 - b. said cam means is a helical slot to effect movement of the valve block from its initially closed position to an open position upon first operation of the operating means and to effect closure of the valve block upon return movement of the operating means.
7. A valve structure as defined in claim 1, wherein:
 - a. said block occupies an initially open position;
 - b. said cam means is a helical slot, said slot being joined at one end to an axial slot whereby, upon first operation of the operating means, the valve block is moved from its initially open position to its closed position, whereupon the pin of the cam and pin means is received in the axial slot rendering the valve block inoperative to further movement of the operating means.
8. A valve structure, as defined in claim 1, wherein:
 - a. a chamber is formed in the housing structure;
 - b. a first piston exposed to the chamber is connected to the operating means;
 - c. a second piston exposed to the chamber is also exposed to said pressure fluid source;
 - d. the chamber is filled with a force transmitting liquid whereby change in the force exerted at said pressure fluid source is transmitted to the first piston and operating means.
9. A valve structure, as defined in claim 8, wherein:
 - a. a yieldable means is carried within the housing structure and exerts a force on the operating means in opposition to the force exerted at said pressure fluid source, to effect return movement of the operating means upon predetermined reduction in force exerted at said pressure fluid source.
10. A valve structure, as defined in claim 9, wherein:
 - a. the yieldable means, is a precompressed spring means.
11. A valve structure, as defined in claim 9, wherein:

- a. the yieldable means is a closed pressure fluid chamber divided by a piston bypassed by valve means operable at a preselected pressures.

12. A valve structure adapted to be suspended from a tubing string within a well bore and responsive to static fluid pressure externally of the tubing string supplemented by a variable fluid pressure supply means applied at the well head, said valve structure comprising:

- a. an annular valve housing depending from the tubing string and having a bore communicating with the interior of the tubing string;
- b. a valve block within the valve housing bore and rotatable about an axis transverse thereto between a position closing the housing bore and a position in alignment therewith;
- c. an axially movable drive means for rotating the valve block between its open and closed positions; said drive means including a first piston, means operatively connecting the first piston and valve block, a second piston exposed to the fluid pressure externally of the tubing string, and a chamber formed within the valve housing closed by the pistons and filled with a force transmitting liquid to effect movement of the valve block in one direction; upon a predetermined increase of pressure at the well head fluid supply means;
- d. and yieldable means carried by the valve housing, engaging the drive means to effect opposing movement of the valve block upon predetermined reduction of pressure at the well head fluid supply

means.

13. A valve structure, as defined in claim 12, wherein:

- a. means forming a pressure equalizing bypass around the valve block is provided, said bypass means being operated by the drive means immediately prior to movement of the valve block from its closed position.

14. A testing and safety means adapted to be suspended from a tubing string within a well bore and responsive to fluid pressure externally of the tubing string supplemented by a variable pressure supply means applied at the well head, said means comprising:

- a. a lower valve structure and an upper valve structure;
- b. each valve structure including a valve housing having a bore communicating with the bore of the tubing string, a valve in each bore, the lower valve being initially in a closed position, the upper valve being initially in an open position;
- c. each valve structure including a valve operating means responsive to fluid pressure externally of the tubing string, the valve operating means being operable at different fluid pressures;
- d. the operating means for the lower valve structure adapted to open and close the corresponding valve repeatedly;
- e. and the operating means for the upper valve structure being adapted to close the corresponding valve and lock the valve in its closed position.

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