April 13, 1965 R. ROUSSIN 3,177,938

METHODS AND APPARATUS FOR OPERATING BOREHOLE EQUIPMENT

Filed Oct. 23, 1958 2 Sheets-Sheet 1

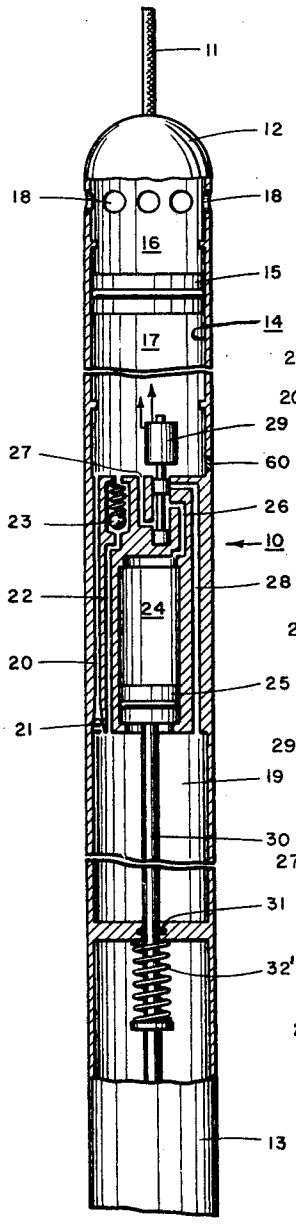


FIG. 1

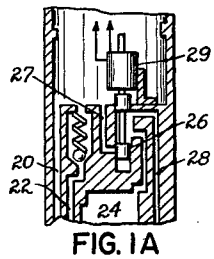


FIG. 1A

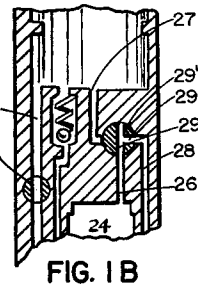


FIG. 1B

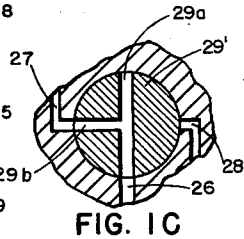


FIG. 1C

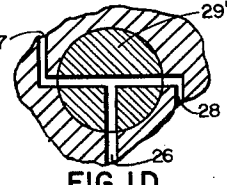


FIG. 1D

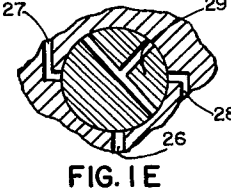


FIG. 1E

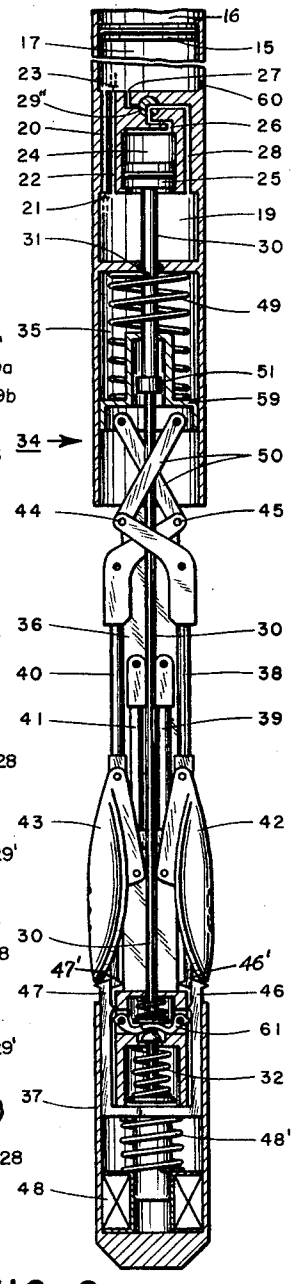


FIG. 2

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METHODS AND APPARATUS FOR OPERATING BOREHOLE EQUIPMENT

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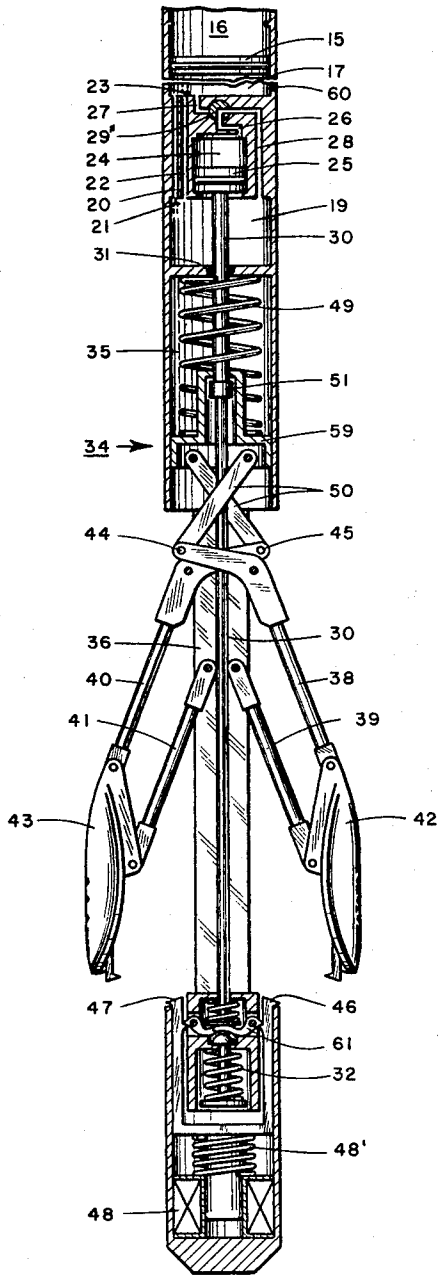


FIG. 3

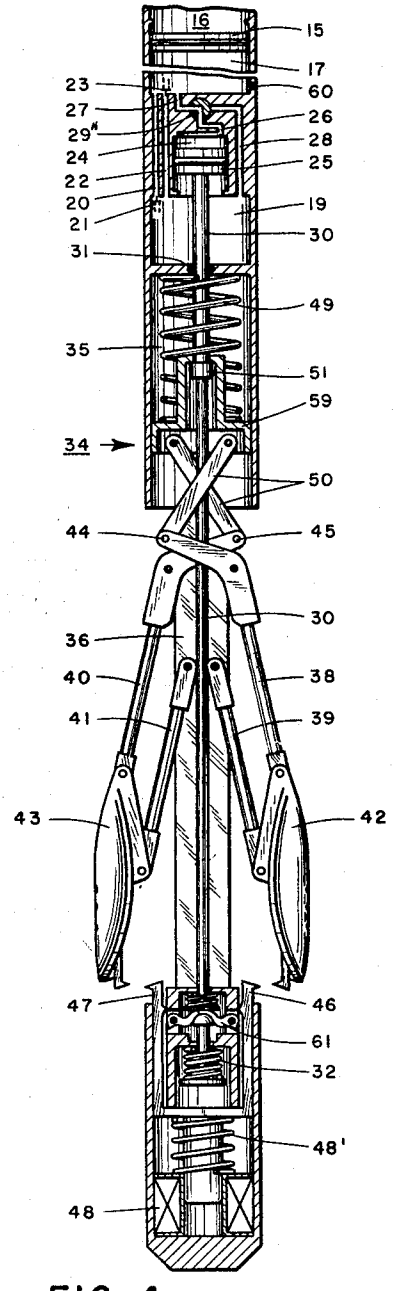


FIG. 4

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3,177,938

METHODS AND APPARATUS FOR OPERATING BOREHOLE EQUIPMENT

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Filed Oct. 23, 1958, Ser. No. 769,232
6 Claims. (Cl. 166—4)

The present invention relates to methods and apparatus for operating borehole equipment and more particularly to new and improved methods and apparatus for supplying the energy necessary to operate mechanically-activated equipment within the confines of a borehole filled with drilling liquid.

This application is a continuation-in-part of the applicant's copending application Serial No. 443,058, filed July 13, 1954, for "Methods and Apparatus for Operating Borehole Equipment," now abandoned.

Many commercial oil field tools for use in boreholes require considerable energy for proper operation of mechanical components at given levels within a borehole. Examples of such tools are apparatus for setting packers, formation fluid samplers requiring setting against the wall of the borehole, and various logging devices in which one portion of the down-hole equipment must be moved relative to another part. The energy required for mechanical operation of such tools may be supplied in a number of ways, for example, by translation from electrical energy transmitted from the surface of the earth, by translation from explosive energy generated in the borehole, or by translation from mechanical energy transmitted by way of drill pipe and the like.

Another successful method of supplying energy is to allow the difference in pressure betwen the hydrostatic pressure of the drilling liquid in the borehole at the level at which the tool is to be operated and the pressure in a low pressure chamber in the tool operate a piston to supply the necessary mechanical motion. While such method is effective, it will only supply energy for one operation in a well, and since the difference in pressure will depend on the level in the well, the energy supplied may be too much or too little for proper operation.

It is an object of the present invention to provide novel methods and apparatus utilizing the hydrostatic pressure of the liquid in a borehole to supply mechanical energy to operate equipment therein.

Another object of the present invention is to provide novel methods and apparatus in accordance with the foregoing in which the tool may be operated at successive levels in the same well.

In accordance with the present invention, the energy necessary to operate a tool in a well is obtained by utilizing the differences in the hydrostatic pressure of the well liquid at different levels in the well. More particularly, the energy may be obtained by compressing gas in a chamber in said tool to the pressure of the hydrostatic head at one level in the well, and maintaining said gas at that pressure as the tool is passed to a different level. At a new level where it is desired to operate the tool, and where the hydrostatic pressure is different, the difference in pressure between the gas in the chamber and the hydrostatic pressure at the new level is utilized to supply the required energy. At the same time the gas in the chamber may be maintained compressed to the pressure of the hydrostatic pressure at the new level, the tool again moved to a different level in the well for repetition of the foregoing operation. In order that the difference in pressure between the gas in the chamber and the hydrostatic pressure may not exceed desired limits, a valve may be supplied to keep this pressure differential within a predetermined maximum.

These and other objects of the present invention may be more fully understood with reference to the accompanying drawings in which:

FIG. 1 is a view of a borehole tool incorporating a typical embodiment of the invention and employed to explain the principles of operation;

FIG. 1A is a partial view of the borehole tool shown in FIG. 1;

FIG. 1B is a partial view of another valve arrangement for the borehole tool shown in FIG. 1;

FIGS. 1C–1E illustrate various positions of a valve shown in FIG. 1B;

FIG. 2 is a view of well logging apparatus utilizing the present invention;

FIG. 3 is another view of the apparatus shown in FIG. 2, during a different period in the operation of the invention; and

FIG. 4 is yet another view of the apparatus shown in FIG. 2, during a final period in the operation of the invention.

In FIG. 1 is shown a borehole tool **10** adapted to be passed through a borehole by means of conventional electric cable **11** connected to head **12** and including an instrument **13** requiring substantial power for proper operation, at one or more levels in the borehole. Tool **10** includes a pressure transfer chamber which is formed by an elongated cylinder or container **14** in which a piston head **15** is adapted to slide, dividing cylinder **14** into an upper chamber **16** and a lower chamber **17**. Piston head **15** and cylinder **14** therefore define pressure transmitting means in the pressure transfer chamber. A plurality of ports **18** in upper chamber **16** admit borehole liquid therein and thus maintain the upper side of piston head **15** subject to the hydrostatic pressure of the well as tool **10** is passed therethrough. The lower chamber **17** of cylinder **14** contains a compressible gas such as air which is maintained at a pressure related to the hydrostatic pressure of the well as a result of the action of piston head **15**.

Tool **10** has a high pressure elongated chamber **19** filled with a compressible gas such as air. A channel **20** interconnects chamber **19** with the lower chamber **17** of cylinder **14**. A valve **21**, shown as a simple ball-stop valve, in channel **20** permits gas flow from chamber **17** to chamber **19**, but prohibits flow in the other direction. A second channel **22** interconnects chambers **17** and **19**, and a valve **23**, shown as a spring-loaded ball valve, prohibits fluid flow in channel **22** from chamber **17** to chamber **19**, but permits flow in the opposite direction if the pressure of the gas in chamber **19** exceeds the pressure of gas in chamber **17** by an amount predetermined by the loading of the spring in valve **23**.

Tool **10** further has pressure responsive actuating means which include a pressure cylinder forming a chamber **24** separated from chamber **19** by means of a piston head **25** riding in chamber **24**. Chamber **24** is also filled with a compressible gas such as air. A channel **26** extending from chamber **24**, a channel **27** extending from lower chamber **17** of cylinder **14**, and a channel **28** extending from chamber **19** meet at a switching valve **29** adapted to be electrically operated from the surface of the earth such that channel **26** may be selectively coupled to either channel **27** or channel **28** at the discretion of the operator. The electrical wires for valve **29** are connected to cable **11** in any well-known manner. In FIG. 1B, channel **26** may be coupled to channel **27** or channel **28** or both at the discretion of the operator by means of switching valve **29'**.

A piston rod **30** connected to piston head **25** passes out of chamber **19** through pressure seal **31** into instrument **13** for which power to operate is desired. Piston rod **30** and thus piston head **25** may be biased downwardly by means of compression spring **32'**.

In operation, with tool **10** at the surface, valve **29** is set so that channel **26** is connected to channel **28** as shown in FIG. 1A. The tool is then lowered into the well filled with liquid, such as drilling mud, and as the depth increases the hydrostatic pressure in upper chamber **16** of cylinder **14** increases, forcing piston head **15** downwardly and thus maintaining the gas in lower chamber **17** of cylinder **14** at the hydrostatic pressure of the drilling mud at the level of tool **10**. As a result of interconnecting channels **26** and **28** and the presence of channel **20**, as the pressure in chamber **17** increases, the pressure of the gas in chambers **19** and **24** increases similarly.

The tool is then lowered to a level considerably lower than that at which mechanical energy is desired to be supplied to instrument **13**. At this point, chambers **17, 19** and **24** are all at the same relatively high hydrostatic pressure at such lower level. The tool is then raised to the desired level. During the raising, the hydrostatic pressure in chamber **16** decreases and likewise the air pressure in chamber **17** decreases but due to the action of valve **21** the pressure in chambers **19** and **24** remains at the previous high level. If, however, the difference in pressure between chambers **17** and **19** exceeds a predetermined safe amount, valve **23** will reduce the differential to the desired value.

When the proper level is reached, the operator activates valve **29**, disconnecting chamber **24** from chamber **19** and connecting chamber **24** to chamber **17**. The pressure in chamber **24** is thus reduced, creating a pressure differential across piston head **25** and driving head **25** upwardly into chamber **24**. Piston rod **30** thereupon supplies the mechanical energy necessary to operate instrument **13**. Thus, piston head **25** in chamber **24** are pressure responsive actuating means.

Upon completion of the operation, valve **29** may be returned to its starting point thus interconnecting channels **26** and **28** bringing chambers **19** and **24** in communication which permits equalization of the pressure in chambers **19** and **24** across piston head **25** and movement of the piston head in a downward direction due to the action of spring **32**.

With the valve **29'** as shown in FIG. 1B, operation is similar to the above in that the tool is lowered into the well filled with liquid and as the depth increases the pressure of the gas in chambers **17, 19** and **24** is increased. Valve **29'** is a rotatable valve member actuated by means well known in the art (not shown) between a plurality of rotative positions. Valves **29** and **29'** and means for operating the valves are conventional as illustrated, for example, in pages 1608–1610 of "Tool Engineers Handbook" 1st ed., 1949. A T type fluid conduit in valve **29'** includes a channel **29*b*** extending diametrically through valve **29'** and a channel **29*a*** extending radially and perpendicularly to channel **29*b*** and interconnected therewith. The channels **29*b*, 29*a*** of valve **29'** provide interconnection of channels **26** and **28** in the position shown in FIG. 1B and the presence of channel **20** permits interconnecting of chambers **17, 19** and **24** so that as the pressure in chamber **16** increases, the pressure of the gas in chambers **17, 19** and **24** is also increased.

The tool is lowered to a level considerably lower than that at which mechanical energy is desired to be supplied to instrument **13**. At this point the gas in chambers **17, 19** and **24** are all equally pressured by the same relatively high hydrostatic pressure at such lower level. The tool is then raised to the desired level. During the raising the hydrostatic pressure in chamber **16** decreases, and likewise the air pressure in chamber **17** decreases but due to the action of valve **21** the pressure in chambers **19** and **24** remains at the previously high level. With valve **29'** in position as shown in FIG. 1B, when the proper level is reached, valve **29'** is actuated to rotate 180° counterclockwise to the position shown in FIG. 1C, disconnecting chamber **24** from chamber **19** and connecting chamber **24** to chamber **17**. The pressure in chamber **24** is thus reduced, creating a pressure differential across piston head **25** and driving head **25** upwardly into chamber **24**. Piston rod **30** thereupon supplies the mechanical energy necessary to operate instrument **13**.

Upon completion of the operation, valve **29'** may be set at an intermediate point by rotating 90° counterclockwise from the position shown in FIG. 1C to the position shown in FIG. 1D, thus interconnecting channels **26, 27, 28**, again bringing chambers **19** and **24** to the hydrostatic pressure in chamber **16**. Since the pressure on both sides of piston head **25** is equalized, spring **32** will retract piston rod **30** and piston head **25** into their previous position, readying instrument **13** for the next operation. Valve **29'** is again adjusted to interconnect channels **26** and **28** by rotating 90° counterclockwise from the position shown in FIG. 1D to the position shown in FIG. 1B, and the tool is ready to be raised to a new level to repeat the previous operation.

In accordance with the invention the foregoing operation may be made on descent rather than ascent. For this manner of operation, an additional control valve **20'** is inserted in channel **20** permitting the channel to be selectively opened and closed at the surface. With valve **29'** set to interconnect channels **26** and **28 (FIG. 1B)**, the tool is lowered to a point above the level at which operation of instrument **13** is desired, the gas in chambers **17, 19** and **24** being at a pressure related to the hydrostatic pressure of the liquid at that level. The valve **20'** in channel **20** is then closed by means operable at the surface (not shown) and the tool lowered to the new level, whereby the pressure in chamber **17** is increased substantially over the pressure in chambers **19** and **24**. At the new lower level, valve **29'** is activated to rotate 45° counterclockwise from the position shown in FIG. 1B to the position shown in FIG. 1E, disconnecting chamber **24** completely and the valve **20'** in channel **20** opened increasing the pressure in chamber **19** to the higher pressure in chamber **17** due to the higher hydrostatic pressure at the new level. Piston head **25** will again supply the necessary motion to activate instrument **13**.

Obviously many other arrangements of valves, chambers and channels may be employed to accomplish the desired result. In addition, it is apparent that valve arrangements may be supplied to permit operation either after ascent or descent with the same tool.

In FIGS. 2, 3 and 4 are shown three views of a well tool **34** constructed in accordance with the disclosure in copending application Serial No. 419,678, filed March 30, 1954, by Saurenman and Lebourg, entitled "Borehole Apparatus" and assigned to the assignee of the instant application, now Patent No. 2,876,413. Tool **34** has been modified to incorporate the present invention, elements in FIGS. 2, 3 and 4 that are similar to elements in FIG. 1 bearing the same numerical designations.

In FIG. 2, piston rod **30** extends through pressure seal **31** into a cylindrical housing, through an open frame **36** into base plug **37** wherein rod **30** is normally maintained downwardly by means of a spring **32**. Connected to frame **36** by means of support arms **38** and **39**, and **40** and **41** are pads **42** and **43**, respectively. A downward pressure on arms **38** and **40** at points **44** and **45** respectively is adapted to force pads **42** and **43** outwardly from frame **36** against the wall of a borehole, an upward force retracting same.

Pads **42** and **43** are normally retained inwardly by means of latches **46** and **47** forced upward by a spring **48'** over latch members **46', 47'** attached to the respective pads **42, 43**. Latches **46, 47** are adapted to be pulled downwardly by means of electromagnet **48** and latched in the downward position by dogs **61**. However, a compression spring **49** in housing **35**, through which rod **30** passes, tends to force pads **42** and **43** outwardly by means of slidable means **59** and links **50**. An enlarged section **51** on piston rod **30** tends when pulled upwardly to withdraw means **59** and thus collapse spring **49**, and retract pads **42** and **43**.

Typical characteristics of tool **34** may be as follows: With piston head **15** in its fully upward position chambers **17, 19** and **24** have an initial volume of 306 cubic inches.

At the surface, chambers 17, 19 and 24 are loaded with an initial pressure of 1,000 pounds per square inch through valve 60. Safety valve 23 is set so that the maximum differential pressure between chambers 19 and 17 will be 600 pounds per square inch. Spring 49 is a 500 pound compression spring, and a retraction of 1.3 inches will completely retract pads 42 and 43. With these characteristics the tool will operate down to 16,000 feet in a borehole filled with drilling mud; at 16,000 feet, the hydrostatic pressure will be approximately 10,000 pounds per square inch. Piston rod 30 may be activated every 1,000 feet as the tool is raised, the difference in hydrostatic pressure between two levels 1,000 feet apart being approximately 600 pounds per square inch.

In operation, with chambers 17, 19 and 24 initially loaded with air at 1,000 lbs./in.^{2}, with valve 29 in the position shown, and with arms 42 and 43 latched against frame 36, tool 34 may be lowered to opposite the lowermost portion of a well where it is desired to have pads 42 and 43 extended. When tool 34 has been lowered past the point where the hydrostatic pressure in the well is 1,000 lbs./in.^{2}, piston head 15 will begin to compress the air in chambers 17, 19, and 24, so that the air in such chambers will be at the same relatively high hydrostatic pressure of the drilling mud at such lowermost point.

Electromagnet 48 is now activated, pulling latch means 46 and 47 downwardly and releasing pads 42 and 43. As shown in FIG. 3, spring 49 operating against driving means 59 forces pads 42 and 43 outwardly against the wall of the borehole. Tool 34 may now be raised, pads 42 and 43 remaining pressed against the borehole wall. While tool 34 is being raised, the pressure in chamber 17 is continuously decreasing, while the pressure in chambers 19 and 24 remains at the relatively high hydrostatic pressure of the lowermost point to which tool 34 was lowered. However, when the pressure in chamber 17 decreases by 600 lbs./in.^{2} below the pressure in chambers 19 and 24, valve 23 will maintain the pressure differential at 600 pounds.

When tool 34 has been raised past that section of the well against which it is desired to have pads 42 and 43 pressed, pads 42 and 43 should be retracted against frame 36. If tool 34 has been raised between two levels having at least 600 lbs./in.^{2} pressure differential, the retraction operation may be begun at once; otherwise the tool must be raised until the required pressure differential has been reached.

At this point, rotatable valve 29'' is switched to the position shown in FIG. 4, and thus the pressure in chamber 24 above piston head 25 is suddenly reduced to the pressure in chamber 17. The difference in pressure across piston head 25 forces piston rod 30 upwardly, enlarged section 51 pulling driving mechanism 59 upwardly against the counter pressure of spring 49, and retracting pads 42 and 43. The upward movement of rod 30 also releases dogs 61, whereupon spring 48' forces latches 46 and 47 into their upward position. When latches 46', 47' on retracting pads 42 and 43 reach latches 46 and 47 respectively, these pads are securely latched against frame 36. The tool is now ready to be quickly withdrawn from the borehole.

However, if additional operations are required at a higher level, valve 29'' is operated as explained in connection with valves 29 and 29' to regulate the pressures in chambers 17, 19 and 24 with respect to the hydrostatic pressure of the mud at the new level. When the pressure in chambers 24 and 19 becomes equal, spring 32 pulls rod 30 downwardly and withdraws piston head 25 to the position shown in FIG. 2. Tool 34 may now be raised to a new level, and the pad extending and retracting operations repeated, if desired.

It will be understood that the embodiments disclosed herein are merely illustrative, and should not be considered as limiting the claims appended hereto.

I claim:

1. Apparatus for operating equipment in a well bore containing a column of liquid comprising: a housing adapted to be passed through a well bore; a pressure transfer chamber in said housing containing a compressible fluid; a high pressure chamber in said housing containing a compressible fluid; pressure responsive actuating means in said housing comprising a piston and pressure cylinder, said pressure cylinder being fluidly connected at one end to said high pressure chamber thereby to expose one side of said piston to any fluid pressure in said high pressure chamber; means connecting said pressure transfer and high pressure chambers including a first valve operable to control the passing of said compressible fluid under pressure from said pressure transfer chamber to said high pressure chamber; means fluidly connecting said pressure transfer chamber and the opposite end of said pressure cylinder including a second valve selectively operable to expose the remaining side of said piston to fluid pressure in said pressure transfer chamber so that said piston may be displaced as a result of a difference in pressures occurring in said pressure transfer and said high pressure chambers; means mechanically connecting said piston to equipment to be operated in the well bore; and pressure transmitting means in said pressure transfer chamber responsive to variations in the pressure of the column of liquid opposite said housing as said housing is passed through the well bore to transmit corresponding pressure variations to the compressible fluid in said high pressure chamber and said pressure cylinder.

2. Apparatus as in claim 1 including a passageway interconnecting said pressure transfer and high pressure chambers, and valve means in said passageway prohibiting the difference in fluid pressures between said pressure transfer and high pressure chambers from exceeding a predetermined maximum.

3. Apparatus for operating equipment in a well bore containing a column of liquid comprising: a housing having a pressure-transfer chamber containing a compressible fluid and a high-pressure chamber; means to permit the liquid in the well bore to act upon the pressure transfer chamber; pressure transmitting means in said pressure transfer chamber to isolate said compressible fluid from said well bore liquid and transmit corresponding pressure variations to the compressible fluid therein; means fluidly interconnecting said pressure transfer and high pressure chambers including a first valve operable to control the passing of said compressible fluid under pressure from said transfer chamber to said high pressure chamber; said housing further having a portion defining a pressure cylinder fluidly connected at one end to said high pressure chamber; a piston movably positioned in said pressure cylinder and adapted to be connected to a load; means for fluidly interconnecting said pressure transfer chamber with the opposite end of said pressure cylinder and with said high pressure chamber, said means including a second valve selectively operable to connect either said high pressure chamber to said opposite end of said pressure cylinder or to connect said opposite end of said pressure cylinder to said transfer chamber.

4. Apparatus for operating equipment in a well bore containing a column of liquid comprising: a housing adapted to be passed through a borehole, a pressure transfer chamber in said housing; a pressure transfer piston in said pressure transfer chamber; means in said housing to admit liquid in the well bore to one side of said pressure transfer piston, the portion of the transfer chamber to the other side of said pressure transfer piston being filled with a compressible fluid, whereby the column of liquid in the well bore maintains the compressive fluid in said pressure transfer chamber at substantially the same pressure as the hydrostatic pressure of

the liquid in the well bore opposite said housing as said housing is passed through the well bore; a high pressure chamber and pressure cylinder in said housing; a slidable piston head in said pressure cylinder; said pressure cylinder and high pressure chamber being filled with a compressible fluid, said pressure cylinder being fluidly connected at one end to said high pressure chamber thereby to expose one side of said piston head to any fluid pressure in said high pressure chamber, means fluidly interconnecting said pressure transfer and high pressure chambers and including a first valve operable to control the passing of said compressible fluid under pressure from said pressure transfer chamber to said high pressure chamber; means for fluidly connecting said high pressure chamber and the opposite end of said pressure cylinder to one another and for fluidly connecting said pressure transfer chamber and said pressure cylinder to one another and including second valve means, said second valve means being operable either to connect said high pressure chamber and said pressure cylinder to one another or to connect said pressure transfer chamber and said pressure cylinder to one another; and means connected to said piston head for translating movement thereof to mechanical power.

5. Apparatus for operating equipment in a well bore containing a column of liquid comprising: a housing adapted for passage through a well bore, said housing having a pressure transfer chamber, a high pressure chamber and a pressure cylinder each containing a compressible fluid; said pressure cylinder opening to said high-pressure chambers; a piston received in said pressure cylinder and a piston rod secured to said piston for movement therewith to actuate equipment in a well bore; said pressure transfer chamber having an opening to the exterior of the housing, pressure transmitting means in said transfer chamber separating the liquid in the well bore from the compressible fluid in said transfer chamber, said pressure transmitting means being responsive to the pressure of the liquid in the well bore to transmit the hydrostatic pressure of the well bore liquid to the compressible fluid; first passage means fluidly interconnecting said pressure transfer chamber to said high pressure chamber; second passage means fluidly interconnecting said high pressure chamber to said pressure cylinder; one way valve means in said first passage means arranged to control the passing of said compressible fluid under pressure from said transfer means to said high pressure chamber and maintain the pressure of the compressible fluid in said high pressure chamber and the pressure of the compressible fluid in said pressure cylinder at the highest attained value; third passage means for fluidly interconnecting said pressure transfer chamber, said pressure cylinder and said second passage means, and valve means in said third passage means selectively operable to couple either said pressure cylinder to said second passage means or to couple said pressure cylinder to said pressure transfer chamber.

6. A method for operating mechanically driven apparatus at different levels in a well bore containing a column of liquid comprising: the step of subjecting a body of fluid in said apparatus to the hydrostatic pressure in said column of liquid at one level in the well bore; the step of isolating a portion of said body of fluid in said apparatus from the hydrostatic pressure in said column of liquid at said one level, the step of moving said apparatus to a second level in the well bore where the hydrostatic pressure of the column of liquid is different from that at said one level so that the remaining portion of said body of fluid in said apparatus is subjected to the hydrostatic pressure in said column of liquid at a second level in the borehole, and the step of subjecting pressure responsive actuating means to the pressure of said isolated portion of said body of fluid and the pressure of said remaining portion of said body of fluid and utilizing the difference in pressure to develop instantaneous kinetic energy to operate the said apparatus.

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