

March 17, 1964

G. E. BRIGGS, JR., ETAL
HYDROSTATIC SETTING TOOL

3,125,162

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2 Sheets-Sheet 1

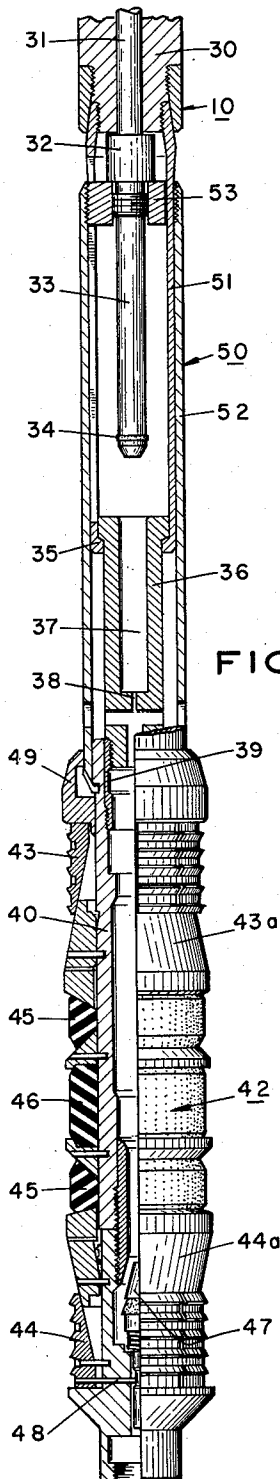


FIG. 2.

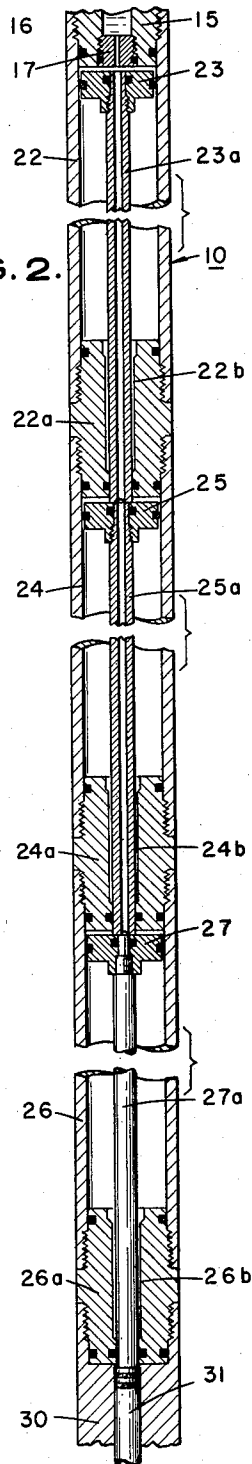
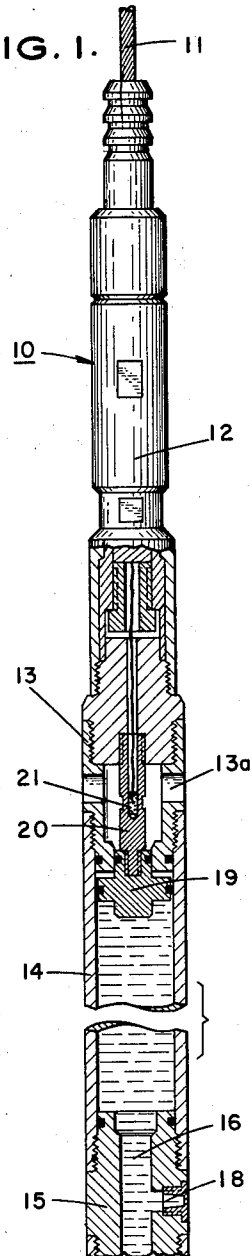


FIG. 1.



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2 Sheets-Sheet 2

FIG. 5.

FIG. 6.

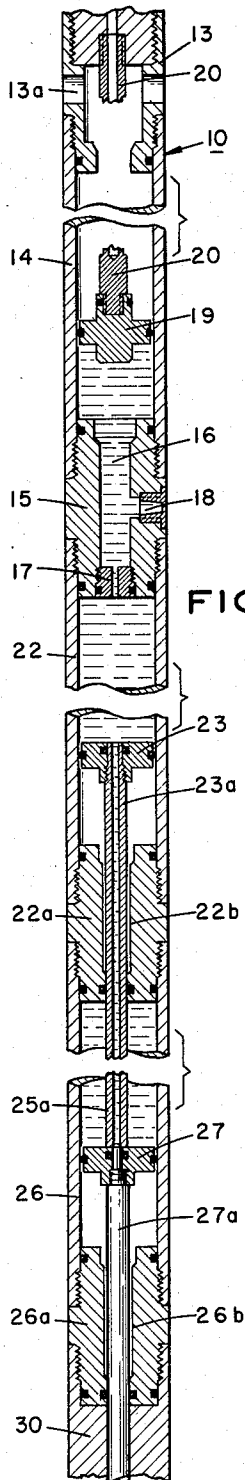
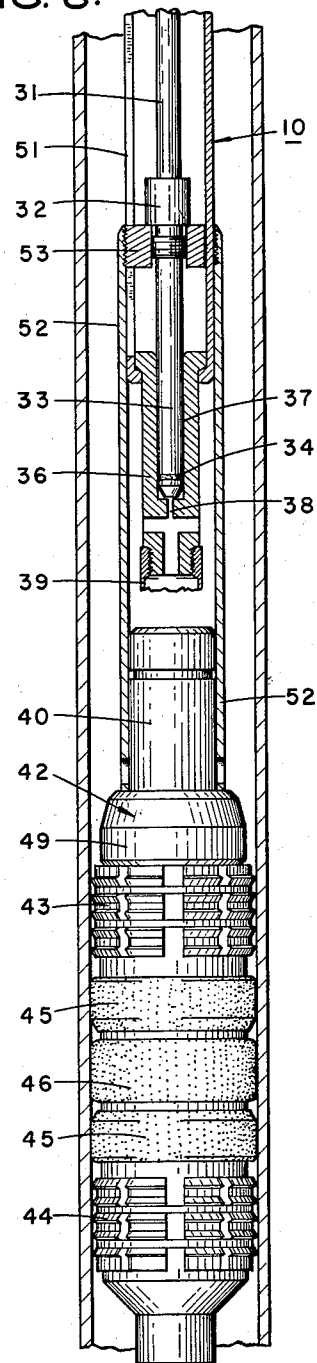
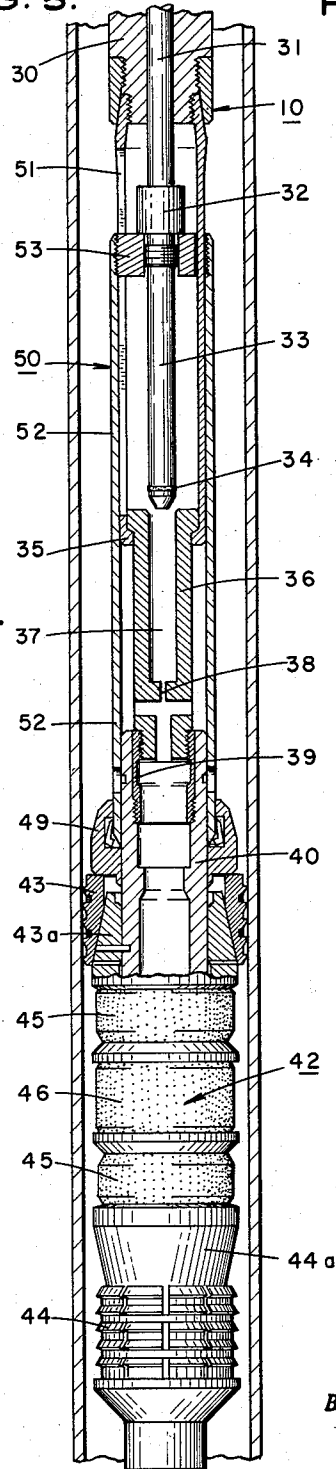


FIG. 4.



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3,125,162

HYDROSTATIC SETTING TOOL

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6 Claims. (Cl. 166—123)

The present invention is directed to an assembly for use in well bores and more particularly to subsurface equipment useful in performing operations in oil wells.

In its more particular aspect, the present invention is directed toward an assembly for setting such tools as bridge plugs, packers and the like in a well bore.

Various methods and means are presently being used to set such tools. One such method involves the manipulation of a pipe string, the bottom of which is connected to the packer or bridge plug to be set. This method involves the time consuming and manual running, manipulation and removal of the pipe string. On such operations which require the setting of such tools at great depths in the borehole it is obvious that this method is far from economical.

Another method which has proved very satisfactory is the use of a setting tool assembly which is run and operated on an electrical cable. The upper end of the tool carries its own potential power, that is a gaseous medium contained in the tool which, when released or set off, supplies enough pressure to perform the operations required to set a bridge plug or packer. After the plug has been set, the pressure still increasing, releases the setting tool from the packer or plug and the setting tool can be removed from the borehole by the cable. Such tools require the use of expanding gases which are generated by igniting a powder charge or propellant, the burning of which creates the required gas pressure.

It is the primary object of the present invention to provide a setting tool whereby the hydrostatic pressure of the fluids contained in a borehole can be utilized to supply the pressure necessary to perform the setting operations.

It is also an object of the present invention to provide a wire line setting tool utilizing the power supplied by the well fluids to automatically perform the operations necessary and to also automatically release the tool for removal once the packer or plug is set.

It is a further object of the present device to provide means for metering the power of the hydrostatic pressure so that setting operations can be performed efficiently and accurately.

Briefly described, the present invention comprises an elongated tubular body which is adapted to be suspended in a well bore by an electrical cable. The body is divided into a succession of vertically aligned cylindrical chambers in each of which is positioned a piston and rod assembly. Inasmuch as the piston rod of each chamber extends into a successive chamber and abuts the piston therein, the succession of chambers and the relationship of the pistons and piston rods therein may be said to provide a cascade force amplifying system for amplifying the force of a fluid.

The lowermost piston rod extends from the bottom of the body. A pair of telescoping sleeves, one of which is connected to the extending piston rod and the other to the lower end of the body, operably connect the tool to the packer or plug to be set. The pistons and their re-

2

spective rods are releasably retained in an upper position by means operable from the earth's surface. The upper sides of all of the pistons are subject to the hydrostatic pressure of the well bore. Release of the pistons allows the well pressure to be exerted upon the pistons to supply the power and movement necessary to perform the setting operation. As all of the pistons are subject to well pressure, the original well pressure can be doubled or tripled, i.e., amplified, according to the number of pistons used in the assembly.

The structure and operations of the present invention will be more clearly understood by reference to the following description and illustrations in which:

FIGS. 1, 2, and 3 illustrate the upper, intermediate, and lower sections of the device of the present invention connected to a bridge plug and suspended by an electrical cable;

FIGS. 4 and 5 illustrate the position of various parts of the device during the initial portion of the setting operation; and

FIG. 6 shows the bridge plug fully set in the casing and the lower portion of the setting tool disconnected for removal.

Referring now to the drawings and particularly to FIGS. 1, 2, and 3, the setting tool of the present invention generally designated by the numeral 10 is shown connected to a bridge plug 42 and suspended by a cable 11.

The upper portion 12 of the tool 10 is comprised of a cable connector head and a firing or power release section. Connected to the lower end of portion 12 by a suitable threaded connection is a ported sleeve 13 provided with fluid entry ports 13a. Connected to sleeve 13 is a fluid reservoir cylinder 14 provided with a spacer sub 15 on its lower end. A fluid metering plug 17 is positioned in the central bore 16 of sub 15. A threaded fill up port 18 closable by a suitable plug is also provided in sub 15.

Positioned in the upper end of cylinder 14 is a piston member 19 which is retained in the upper position as shown by means of a frangible tube 20. The tube 20 contains a powder squib 21 which can be fired when desired by an electrical signal applied through an electrical lead contained in cable 11.

Connected to the lower end of sub 15 are shown a plurality of power cylinders 22, 24, and 26, each provided with spacer subs 22a, 24a, and 26a. The subs are each provided with bores 22b, 24b, and 26b, respectively.

Power pistons 23, 25, and 27 are slidably arranged in power cylinders 22, 24, and 26, respectively. Connected to the underside of the power pistons 23, 25, and 27, respectively, are piston rods 23a, 25a, and 27a. As shown, the rod 23a extends through the bore 22b of sub 22a and abuts against the power piston 25 of cylinder 24. Likewise, the rod 25a extends through the bore 24b of sub 24a and abuts against the piston 27 of cylinder 26. Rod 27a as shown extends through the bore 26b of sub 26a and abuts against a piston 31 which is slidably arranged in a thick-walled sleeve 30 connected to the lower end of sub 26a.

Each of the sub members 22a, 24a, and 26a is provided with sealing means such as "O rings" which sealingly engage the piston rods passing therethrough. Each of the pistons is also provided with seal rings which sealingly engage the wall of their respective cylinders.

As illustrated, the rods 23a and 25a are hollow throughout their length and extend through the pistons 23 and 25, respectively, to which they are affixed. The lowermost rod 27a is solid. The hollow rods 23a and 25a, as can be seen, provide a fluid passageway which extends from the fluid reservoir formed by cylinder 14 to the upper side of each of the power pistons 23, 25, and 27.

The piston 31 is of slightly larger diameter than the piston rod 27a which abuts against the top of it. As can be seen, the piston 31 extends a substantial distance out the lower end of the sleeve 30. The piston 31 is provided with sealing means such as "O rings" about its upper end. The rod 31 is provided with an enlarged annular shoulder 32 which, as shown in FIG. 3, abuts against the lower end of sleeve 30. The lower end 33 of rod 31 is provided with an annular seal ring 34.

A telescopic assembly generally designated by the numeral 50 connects the power portion of the setting device just described to the bridge plug 42. The assembly 50 is comprised of an inner sleeve 51 which is connected to the lower end of the power section or sleeve member 30 and an outer sleeve 52 which is slidably mounted on the sleeve 51. The outer sleeve 52 is connected to the rod 31 just below the annular shoulder 32 by means of a spider connection 53. The sleeves 51 and 52 are slotted so that relative vertical movement can be had between the two.

Inner sleeve 51 is somewhat shorter in length than the outer sleeve 52 and has suspended from its lower end by an annular shoulder 35 a downwardly extending shock absorber cylinder 36. Member 36 is provided with a central bore 37 which is coaxially aligned with the lower end 33 of piston 31. The bore 37 is adapted to sealingly receive the lower end 33 of the piston 31. The lower end of the bore 37 is formed to provide a metering orifice 38. As shown, the orifice 38 is in fluid communication with a cross bore extending through the cylinder 36.

The lower end of the shock absorber cylinder 36 is releasably connected to the inner sleeve or mandrel 40 of plug 42 by a threaded frangible tension collar 39. The collar 39 is adapted to break or shear when a predetermined tension is applied to it.

The lower end of outer sleeve 52 extends downwardly and is slidably arranged about the upper end of the plug mandrel 40 and is positioned as shown to abut against a movable slip setting collar 49 of the bridge plug 42.

The bridge plug 42 is provided with upper slip members 43 which are operated by downward movement of the collar 49 and lower slip members 44 operable by upward movement of the mandrel or sleeve 40. The bridge plug 42 is also provided with packing elements 45 and 46 which are adapted to be compressed into contact with the casing wall upon operation of the present device. Slips 43, when set against the casing, prevent upward movement of the bridge plug and the slips 44 prevent downward movement of the plug assembly.

The central bore of the plug mandrel 40 is provided with a closure valve 47 which is spring biased to close the mandrel bore upon setting of the plug assembly. As shown, the valve 47 is held in the open position by a pin 48 which is attached to the lower slip assembly 44. Movement of the slip assembly 44 outwardly from the mandrel 40 releases the valve 47 and allows it to close the bore of the mandrel under bias of the spring. It will be understood that the bridge plug 42 is only one of many used in the art and is only used herein as an example to illustrate the operation of the setting tool of the present invention.

Operation

In operation of the device as described the tool 10 is assembled as shown in FIGS. 1, 2, and 3 and connected to the upper end of a plug member such as 42. The fluid reservoir of cylinder 14 is filled with a noncompressible fluid such as, for example, hydraulic fluid or some suitable oil and the fill up port 18 is closed.

The assembly is then lowered in the casing to the depth at which the bridge plug is to be set. Now consider the principle under which the present device operates. The tool is lowered to a depth at which the hydrostatic pressure of the fluid column in the casing is, for example, 1000 pounds per square inch. If the cross-sectional area of the piston 19 of reservoir cylinder 14 is, for example, 10 square inches, then there will be a total pressure force of 10,000 pounds acting against the upper surface of the piston 19 and against the fluid below the piston 19. The pressure against the upper side of piston 19 is applied by the well fluids entering through the ports 13a of the sleeve 13.

When it is desired to set the plug 42, an electrical signal is applied through the cable 11 from the earth's surface to explode the powder squib 21. Exploding the squib 21 causes the shearing or breaking of the frangible tube 20, thereby releasing the piston 19 for downward movement under the pressure of the well fluids.

Downward movement of the piston 19 forces the hydraulic fluid in the cylinder 14 to be forced out through the orifice plug 17 and against the upper surface of the piston 23. The purpose of the orifice in plug 17 is to meter the passing fluid and prevent any jolting action during the operation and also to allow the bridge plug to be set in the correct sequence for which it was designed.

The fluid under pressure then passes through the passageway provided by the hollow piston rod 23a and against the upper side of piston 25, through the hollow piston rod 25a and then against the upper surface of piston 27.

The area of the upper surface of pistons 23, 25, and 27 as shown are the same as the cross-sectional area of the piston 19 of the cylinder 14. If there is a total pressure force of 10,000 pounds acting on piston 19 and the reservoir fluid below it, there is also 10,000 pounds of pressure force acting against the upper surface of piston 23.

As the fluid is forced down rod 23a, it acts against the upper surface of piston 25 which, being of the same cross-sectional area as piston 23, adds another 10,000 pounds of downward acting force to the abutting rod and piston assemblies. The fluid pressure then is forced through the hollow rod 25a and hence against the upper surface of piston 27. As the piston 27 is of the same cross-sectional area as the other pistons, it affords another 10,000 pounds of downwardly acting force. As the piston rod 27a is solid, the fluid pressure is retained in the chamber formed above the lower piston 27. With the device as illustrated there is 10,000 pounds of pressure acting on the piston 23. The addition of piston 25 and rod 25a adds another 10,000 pounds of downwardly acting force and the piston 27 still another 10,000 pounds. With the three piston assemblies abutting against one another there is a total force of 30,000 pounds acting against the upper end of the piston 31 which extends from the bottom of the sleeve 30. The only counteracting force is the pressure of the well fluids acting upwardly against the cross-sectional area of the piston 31 and piston rods 25a and 23a. It is obvious that the areas described are for the sake of example only and can be varied as desired to fit various operation procedures and conditions.

As the rod 31 is forced downwardly, the outer sleeve 52 connected thereto is also moved down. As the sleeve 52 is abutting against the upper slip setting collar 49, the collar is also moved down on the mandrel 40 and thereby forces the upper slips 43 down against the wedge surface 43a and out against the casing wall as shown in FIG. 5. At this time, the extreme lower end of the rod section 33 is positioned just above the bore 37 of the shock absorber sleeve 36.

When the slips 43 are set against the casing wall, further downward movement of the outer sleeve 52 and rod 31 is prevented. This causes the setting tool 10 to actually move up on the rod 31 as pressure is still being applied.

As the tool 10 is moved up the inner sleeve 51 also moves up and applies an upward pull on the plug mandrel 40 through the frangible tension collar 39. As the mandrel 40 is pulled up the upper slips 43 are wedged more tightly against the casing wall and the packing elements 45 and 46 are compressed until they are tightly squeezed against the casing wall.

The mandrel 40 continues to move under power of the fluid pressure until the packers are tightly compressed and the lower slips 44 are forced outwardly by the wedge surface 44a against the casing wall. After the plug 42 has been set satisfactorily, it will then resist upward movement of the mandrel 40. The upward pull of the tool 10 is then entirely exerted on the tension collar 39.

As the mandrel 40 was pulled up, the shock absorber cylinder 36 was also pulled up, forcing the rod section 33 and sealing element 34 into the bore 37. Well fluids trapped in the bore 37 below the piston 31 were forced out through the metering orifice 38.

When the tension sleeve 39 breaks the shock absorber sleeve 36 cooperating with the rod section 33 prevents the tool from jumping upwardly in the casing. This action prevents possible damage to the setting tool and also possible kinking of the electrical cable 11. The tool is now in position to be removed from the casing by the cable 11.

As the pressure below the pistons 23, 25, and 27 is atmospheric, it is compressed by downward movement of the pistons until it reaches a point where it will somewhat cushion and finally resist extreme downward movement of the pistons. This cushioning effect also prevents the lower end of the rod section 33 from being pushed against the lower end of the shock absorber cylinder 36 by the extreme power of the tool.

It will be evident from the foregoing description and illustrations that the size and number of pistons such as 19, 23, 25, and 27 can be varied as desired. It may be advantageous to decrease or increase the number to perform operations at various depths or with various tools.

The purpose of the fluid reservoir is to afford a clean operating fluid to the system and to provide a more efficient tool. As far as the principle of the operation is concerned, the well fluids could be exerted directly against the upper end of the piston 23. The piston 23 could be restrained and released in the same manner as is the piston 19 of cylinder 14.

It is evident from the foregoing description and illustrations that the previously stated objects of the present invention have been accomplished. The present device provides a tool for setting packers and plugs and the like, which is entirely operable by the force afforded by the pressure of the well fluids.

Having fully described and illustrated the structure and operation of the device of the present invention, what is claimed is:

1. An actuation device of the character described comprising: a body adapted to be suspended in the hydrostatic fluid pressure environment of a well bore by means of a wireline; said body comprising a succession of chambers including a last chamber; a succession of pistons, one in each of said chambers defining first and second chamber portions therein; a separate piston rod associated with each of the penultimate and preceding ones of said succession of pistons and extending through the second chamber portion defined thereby, through a chamber end wall in sealed slidable relation therewith, and into the first chamber portion of a successive chamber; said rod extending into said successive chamber adapted for transmission of force from its associated piston to the piston in said successive chamber; a last piston rod associated with the last chamber of said succession of chambers extending through the second chamber portion thereof, through an end wall thereof in sealed slidable relation therewith, and externally of said body; all the pistons, including their respectively

associated piston rods; respectively associated with the penultimate and preceding chambers of said succession of chambers being provided with fluid passageways intercommunicating the first chamber portions of each chamber of said succession of chambers; means in said device for application of well bore fluid pressure to said intercommunicated first chamber portions and to effective areas of the pistons respectively defining said first chamber portions; and all said pistons, by virtue of said transmission of force by said rods and upon said application of well bore fluid pressure, being cooperatively adapted to further extend said last piston rod from said last chamber with a force capability which varies as a function of the product of the applied well bore fluid pressure and the effective area of all said pistons.

2. A device of the character described comprising: a body adapted to be suspended in the hydrostatic fluid pressure environment of a well bore by means of a wireline; said body comprising a succession of chambers, including a last chamber; a succession of pistons, one in each of said chambers defining first and second chamber portions therein; a separate piston rod associated with each of the penultimate and preceding ones of said pistons and extending through the second chamber portion defined thereby, through a chamber end wall in sealed slidable relation therewith, and into the first chamber portion of a successive chamber; said rod extending into said successive chamber adapted for transmission of force from its associated piston to the piston in said successive chamber; a last piston rod associated with the last chamber of said succession of chambers extending through the second chamber portion thereof, through an end wall thereof in sealed slidable relation therewith, and externally of said body; means in said device for application of well bore fluid pressure to said first chamber portions and to the effective areas of the pistons respectively defining said first chamber portions; and all said pistons, by virtue of said transmission by said rods and upon said application of fluid pressure, being cooperatively adapted to further extend said last piston rod from said last chamber with a force capability which varies as a function of the product of the applied fluid pressure and the effective areas of all said pistons.

3. A device in accordance with claim 2 wherein said means in said device for application of well bore fluid pressure comprises a fluid reservoir communicated with well bore fluid pressure and in communication with all said first chamber portions, a reservoir piston in said reservoir, and releasable means adapted to initially fix said reservoir piston in said reservoir to thereby effectively isolate said well bore fluid pressure from a portion of said fluid reservoir and in response to control from the earth's surface to free said reservoir piston and effectively communicate said well bore fluid pressure to all said first chamber portions.

4. A device in accordance with claim 3 wherein said means for application of well bore fluid pressure, in addition, comprises means for metering the fluid from said reservoir to all said first chamber portions.

5. A device for actuating and setting a plug in the hydrostatic fluid pressure environment of a well bore comprising: a body adapted to be suspended in a well bore by means of a wireline; said body comprising a succession of chambers; a piston in each of said chambers defining first and second chamber portions therein; a separate piston rod associated with each of the penultimate and preceding ones of said pistons and extending through the second chamber portion defined thereby, through a chamber end wall in sealed slidable relation therewith, and into the first chamber portion of a successive chamber; said rod extending into said successive chamber adapted for transmission of force from its associated piston to the piston in said successive chamber; a last piston rod associated with the last chamber of said succession of chambers extending through the second

7

chamber portion thereof, through an end wall thereof in sealed slidable relation therewith, and externally of said body; a working fluid reservoir in said device for application of a working fluid to said first chamber portions and to the effective areas of the pistons respectively defining said portions; all said pistons, by virtue of said transmission by said rods and upon said application of working fluid being cooperatively adapted to further extend said last piston rod with a force capability which varies as a function of the product of the pressure of said working fluid and the effective area of all said pistons; and means depending from said body and means depending from said last piston rod adapted for relative movement in response to further extension of said last piston rod

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and cooperatively adapted to receive a plug and impart said relative movement and said force capability of said last piston rod thereto for actuation and setting thereof.

6. The device of claim 5 wherein the pistons and piston rods associated with the penultimate and preceding chambers of said succession of chambers are provided with passageways intercommunicating all of said first chamber portions.

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