

Sept. 28, 1965

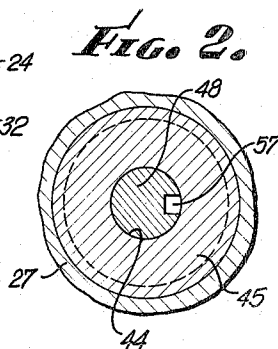
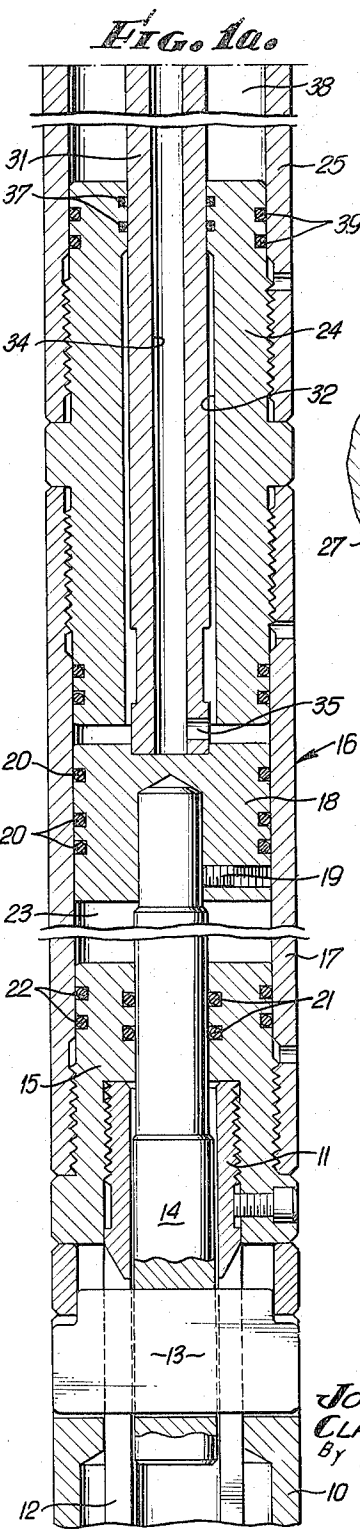
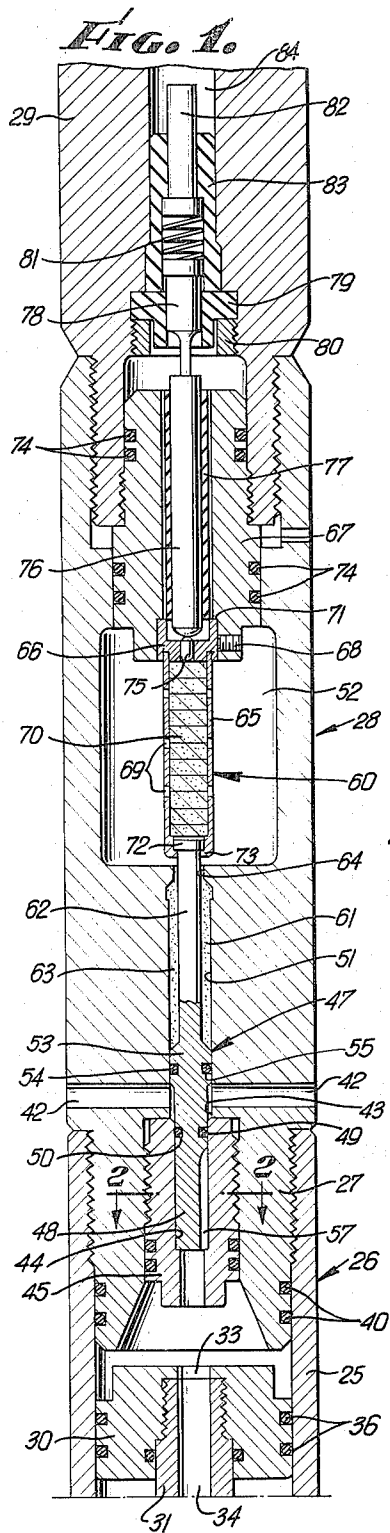
J. R. BAKER ETAL

3,208,355

HYDROSTATIC PRESSURE OPERATED APPARATUS

Filed Sept. 14, 1960

2 Sheets-Sheet 1



INVENTORS.
JOHN R. BAKER
CLAUDE A. HOUCK
 By *Mellin and Hanscom*
 ATTORNEYS.

Sept. 28, 1965

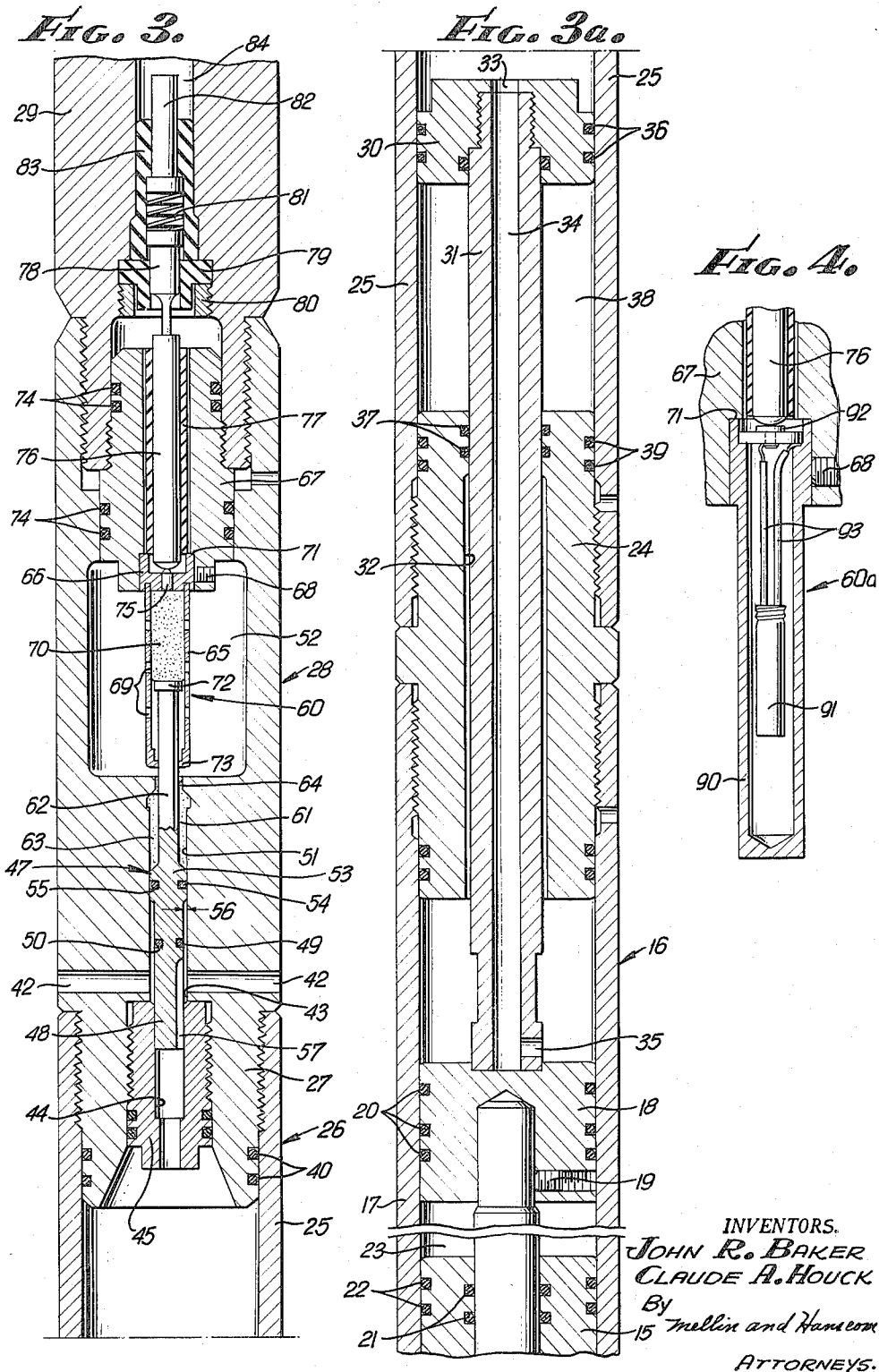
J. R. BAKER ETAL

3,208,355

HYDROSTATIC PRESSURE OPERATED APPARATUS

Filed Sept. 14, 1960

2 Sheets-Sheet 2



1

3,208,355

HYDROSTATIC PRESSURE OPERATED APPARATUS

John R. Baker, Pasadena, and Claude A. Houck, South Pasadena, Calif., assignors to Baker Oil Tools, Inc., Los Angeles, Calif., a corporation of California
Filed Sept. 14, 1960, Ser. No. 87,518
(Filed under Rule 47(b) and 35 U.S.C. 118)
10 Claims. (Cl. 91-411)

The present invention relates to subsurface well bore equipment, and more particularly to subsurface apparatus for setting well packers and bridge plugs in well bores, and for performing other specific operations therewithin.

Operations have been undertaken in well bores that require the use of an explosive, or of a power charge or powder propellant, or both, to initiate the particular operation or to effect its full performance. As an example, setting apparatus is disclosed in United States Patent 2,640,547, in which a slow burning powder charge or propellant is ignited by a cartridge or the like to generate a gas under pressure for the purpose of operating subsurface well equipment, such as a bridge plug or well packer. Although many thousands of operations have been performed successfully through use of equipment of the type disclosed in the aforesaid patent, difficulties are encountered in securing proper operation of the equipment in very hot well bores, as are sometimes encountered in very deep wells (of the order of 18,000 to 20,000 feet), in which the temperatures may be of the order of 400 degrees F. to 450 degrees F. The powder charges or propellants, as well as ignition devices, like cartridges or a match compound, which are operable properly at lower temperatures may fail to ignite or may not burn satisfactorily if ignited because of their deterioration under high temperature conditions. The result is failure of the operation or its partial success only.

Accordingly, it is an object of the present invention to provide improved subsurface apparatus for operating equipment in a well bore that is not adversely affected by very high temperatures that might be encountered in the well bore.

Another object of the invention is to provide a subsurface hydrostatically operated apparatus for performing an operation in the well bore, in which the application of hydrostatic pressure to the apparatus is determined by a valve mechanism controlled from the top of the well bore.

A further object of the invention is to provide a subsurface hydrostatically operated apparatus for performing an operation in a well bore, in which the hydrostatic pressure can shift the valve mechanism that controls the application of hydrostatic pressure to an open condition, and in which shifting of the valve mechanism is initially resisted by a disruptable device capable of withstanding comparatively high temperatures and forces without deteriorating. In a more limited sense, the disruptable device includes material capable of burning away to permit removal of restraint from the valve mechanism and its hydrostatic shifting to open position, the burnable material being capable of withstanding high temperatures.

An additional object of the invention is to provide apparatus of the character indicated in which the valve apparatus can move to a fully open condition at a relatively slow rate to avoid the imposition of sudden or shock loads on the equipment by the hydrostatic pressure.

Yet another object of the invention is to provide subsurface fluid pressure operated apparatus for performing an operation in the well bore, in which the fluid pressure is caused to operate on an improved tandem arrangement of cylinders and pistons for multiplying the total force exerted by the apparatus in performing its operation.

2

This invention possesses many other advantages and has other objects which may be made more clearly apparent from a consideration of several forms in which it may be embodied. Such forms are shown in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIGURES 1 and 1a are longitudinal sections through an apparatus embodying the invention, FIG. 1a constituting a lower continuation of FIG. 1, with the parts in their initial position;

FIG. 2 is an enlarged cross section taken along the line 2-2 on FIG. 1;

FIGS. 3 and 3a are longitudinal sections corresponding to FIGS. 1 and 1a, FIG. 3a constituting a lower continuation of FIG. 3, showing parts of the apparatus in another relative position of operation;

FIG. 4 is a longitudinal section through another embodiment of a portion of the apparatus disposed in FIG. 1 and adapted to be used in the apparatus shown in FIGS. 1 to 3a, inclusive.

The apparatus particularly illustrated is intended specifically for use in setting a bridge plug or well packer in a well casing or open well bore. Actually, the lower portion of the apparatus disclosed in FIG. 1a is connectible to a bridge plug or well packer (not shown) in the same manner as illustrated in the aforesaid United States Patent 2,640,547. As described in this patent, a piston operated device acts downwardly upon the upper slips (not shown) of the packer and the cylinder portion of the apparatus exerts an upward force on the body of the well packer apparatus, the opposite direction of movement and the opposite forces exerted by the piston and cylinder portion of the mechanism effecting a full setting of the plug or packer in the well bore, and also releasing the setting apparatus from the packer or bridge plug.

As shown in the present drawings, a setting sleeve 10 is slidably mounted on a setting mandrel 11 having a pair of diametrically opposed longitudinally extending slots 12 therein, through which a cross-over piece or anvil 13 extends, which is connected to the setting sleeve 10 and which passes through the lower end of a piston rod 14 extending upwardly through a lower cylinder head 15 of a lower cylinder 16. The head 15 is threadedly secured to the upper end of the setting mandrel 11 and also to the lower end of a lower cylinder sleeve 17. A lower piston 18 is piloted over and attached to the upper end of the piston rod 14, as through use of a set screw 19, and is slidable in the lower cylinder sleeve 17. Its relative downward movement in the lower cylinder 16 moves the lower piston rod 14 downwardly, exerting a downward force on the setting sleeve 10. Reactively, the cylinder 16 moves in an upward direction to pull the setting mandrel 11 upwardly, which is releasably connected to the body of the well packer or bridge plug (not shown). With the setting sleeve 10 exerting a downward force on the upper slips (not shown) of such bridge plug or well packer and the mandrel 11 an upward force on the packer body, full setting of the bridge plug or well packer and release of the setting tool therefrom is accomplished.

The lower piston has side seal rings or piston rings 20 on its periphery adapted to slidably seal along the wall of the lower cylinder sleeve 17. The lower cylinder head 15 has rod packing or seal rings 21 slidably sealing against the periphery of the piston rod 14. Such seals, accompanied by external seals 22 on the lower cylinder head sealing against the wall of the lower cylinder sleeve 17,

provide a confined space 23 in the lower cylinder 16 between the piston 18 and lower cylinder head 15 into which the well bore fluid cannot pass, such that this space initially contains air at atmospheric pressure.

The upper end of the lower cylinder sleeve 17 is threadedly attached to an intermediate cylinder head 24, which is, in turn, threadedly secured to the lower end of an upper cylinder sleeve 25 forming part of an upper cylinder 26. This upper cylinder sleeve is threadedly secured to an upper head portion 27 of a valve body 28, the upper end of which is, in turn, threadedly attached to a firing head 29 suitably secured, directly or indirectly, to a wire line (not shown) extending to the top of a well bore, and which has a conductive element therewithin adapted to conduct electricity to the apparatus, as described hereinbelow.

Disposed in the upper cylinder 26 below its upper head 27 is an upper piston 30 which is threadedly or otherwise suitably secured to a tubular thrust rod or upper piston rod 31 that extends downwardly through the upper cylinder sleeve 25 and through the central bore 32 in the intermediate cylinder head 24, the lower end of the tubular rod 31 engaging the upper end of the lower piston 18. The upper end of the upper piston 30 has an inlet port 33 for allowing fluid under pressure to pass downwardly through the central passage 34 in the upper piston rod, such fluid then passing outwardly through an outlet port 35 in the lower portion of the tubular rod into the lower cylinder 16 above the lower piston 18. Leakage of fluid around the upper piston 30 is prevented by suitable piston rings 36 mounted in its peripheral portion and slidably sealing against the wall of the upper cylinder sleeve 25. Similarly, rod packing 37 is mounted in the intermediate cylinder head 24 which is adapted to slidably seal against the upper piston rod or thrust rod 31, thereby providing an upper confined cylinder space 38 between the upper piston 30 and the intermediate cylinder head 24 into which the well bore fluid cannot pass, this upper confined cylinder space initially containing air at substantially atmospheric pressure. Leakage of fluid between the intermediate cylinder head 27 and upper cylinder sleeve 25 is prevented by suitable side seal rings 39 mounted on the intermediate cylinder head and engaging the inner wall of the upper cylinder sleeve. Similarly, leakage of fluid between the upper head 27 and the upper cylinder sleeve 25 is prevented by suitable side seal rings 40 mounted in the upper head and engaging the wall of the upper cylinder sleeve 25.

Initially, the lower and upper pistons 30, 18 are located in the upper portions of the lower and upper cylinders 26, 16, respectively. Inasmuch as the apparatus is intended for use in a well bore containing fluid, the pistons are to be shifted relatively downwardly in their respective cylinders by the fluid under hydrostatic pressure externally of the apparatus. Such fluid under hydrostatic pressure, when permitted to do so, can pass through lateral inlet ports 42 to the central passage or cylinder 43 of the valve body, then passing downwardly through the central passage 44 in a valve guide 45 threadedly secured in the upper cylinder head 27 into the upper cylinder 26 for downward action upon the upper piston 30. The fluid under hydrostatic pressure will also pass through the upper inlet port 33 into the central passage 34 through the upper piston rod 31, and out through its outlet port 35 into the lower cylinder 16 for downward action upon the lower piston 18. The upper and lower pistons 30, 18 move downwardly together to exert their combined force on the lower piston rod 14 and through the cross-over piece 13 on the setting sleeve 10 surrounding the setting mandrel 11.

The fluid under hydrostatic pressure also acts upwardly over the effective cross-sectional areas of the upper and intermediate cylinder heads 27, 24, to exert a combined force on the lower cylinder sleeve 17 and lower cylinder head 15, which is transmitted to the setting mandrel 11, urging it in an upward direction and thereby exerting the

upward pull on the well packer or plug body (not shown). Since the well bore fluid cannot enter the confined upper cylinder space 38 below the upper piston 30 and the confined lower cylinder space 23 below the lower piston 18, the undersides of these pistons have only air at substantially atmospheric pressure, or slightly above such pressure as the pistons move downwardly, acting upon them, whereas the hydrostatic forces acting on the upper sides of the upper and lower pistons is proportional to the hydrostatic head of fluid externally of the equipment. If, for example, the apparatus is used in a very deep well, with the setting operation being performed at about 20,000 feet below the top of the well bore, the unit hydrostatic pressure available for action on the upper and lower pistons 30, 18 will be of the order of about 10,000 p.s.i. Such relatively high pressures operating over the substantial areas of the upper and lower pistons makes a very great total setting force available for the appropriate setting or operation of the equipment secured to the lower portion of the apparatus illustrated.

Operation of the apparatus until it has been lowered to the desired depth in the well bore is prevented by maintaining the inlet ports 42 in a closed condition, so that the hydrostatic head of fluid cannot enter the cylinders 26, 16 for action upon the pistons 30, 18 and the cylinder heads 27, 24. As disclosed, the ports are closed by a differential valve rod or piston 47. The lower portion 48 of the rod below the inlet ports 42 is disposed within the valve guide 45 and has a suitable seal ring 49, such as a rubber or rubber-like O ring, in a ring groove 50, sealing against the inner wall of the guide to prevent passage of fluid pressure downwardly through the guide and into the cylinders 26, 16 therebelow. The hydrostatic fluid under pressure is prevented from passing in an upward direction through an upper cylinder or central passage 51 that opens into an enlarged release chamber 52 in the valve body 28. The upper portion 53 of the valve rod is adapted to slidably seal in the central cylinder 51, leakage of fluid between the rod and the cylinder wall being prevented by a suitable side seal ring 54, such as a rubber or rubber-like O ring, disposed in a peripheral groove 55 in the valve rod and engaging the cylinder wall 51 above the inlet port.

The upper portion 53 of the valve rod 47 is constituted as a piston having a larger diameter, and preferably only slightly larger, than the diameter of a smaller piston portion 48 that slides in the lower guide 45. Because of the difference in areas between the upper and lower piston portions 53, 48 of the valve on opposite sides of the inlet ports 42, the hydrostatic head of fluid is acting in an upward direction over the outer annular part 56 of the large piston and tends to shift such large piston 53 in an upward direction within its cylinder 51.

When the valve rod 47 is permitted to move upwardly, the lower seal ring 49 moves upwardly out of the guide 45, whereupon the hydrostatic fluid under pressure can then pass from the inlet ports 42 into a longitudinal groove or flute 57 running along the external portion of the valve rod below its seal ring 49, and into the cylinder 26 therebelow. The single groove 57 is provided so that the fluid under pressure can only pass at a relatively slow rate into the cylinders 26, 16, to avoid the imposition of sudden or shock loads on the apparatus. The valve rod 47 can shift upwardly to an extent at which its lower end is disposed above the ports, then providing a full opening for the hydrostatic fluid under pressure to pass into the central guide 45 and then into the cylinders 26, 16 for action upon the upper and lower pistons 30, 18, in the manner described above.

It is to be noted that the valve rod 47 extends upwardly from the larger piston 53 through the cylinder 51 and projects into the release chamber 52. This release chamber has a retainer or holding device 60 which at first is engaged by the upper end of the valve rod 47 to prevent the latter from moving upwardly to a position opening

the inlet ports 42. When the retainer or holding device 60 is released, then the hydrostatic head of fluid moves the valve rod 47 upwardly. However, such upward motion is retarded by filling the annular space 61 between the upper portion 62 of the valve rod and the cylinder wall 51 with grease 63, requiring the upper piston 53 to force such grease through a relatively small annular orifice 64 at the entrance to the release chamber 52, provided by decreasing the internal diameter of the cylinder at its upper portion. Such smaller internal diameter is only slightly greater than the external diameter of the upper portion 62 of the valve rod. The necessity for the grease to be forced through the annular orifice 64 and into the release chamber 52 retards the rate at which the valve rod 47 can be shifted upwardly by the hydrostatic head of fluid to a fully opened position, thereby allowing time for the fluid to pass through the relatively narrow area flute or groove 57 in the lower portion of the valve rod and into the cylinder 26, in order to gradually build up the pressure in the upper and lower cylinders 26, 16 for action upon the upper and lower pistons 30, 18 and the upper and intermediate cylinder head 27, 24.

Upward movement of the valve rod 47 by the hydrostatic head of fluid is at first prevented by a material which is capable of being disintegrated. As shown, a substantially cylindrical casing 65 is disposed coaxially in the release chamber 52, the upper end of this casing being secured to a head 66 which is, in turn, attached to a sleeve 67 threadedly secured to the firing head 29. The retainer head 66 is attached to the sleeve 67 by a set screw 68, or the like. The casing or tubular retainer member 65 has a plurality of perforations 69 extending through its wall and contains a material 70 that is capable of burning away. Prior to its ignition and burning away, this material 70 has substantial compressive strength, and is well capable of resisting relatively large hydrostatic heads of fluid tending to shift the valve rod 47 in an upward position. As shown, the material 70 fills the casing 65, being formed as a plurality of superimposed collars or discs, the lower one of which engages the upper end of the valve rod 47, the upper one of which engaging the retainer head 66 which, in turn, bears against a downwardly facing shoulder 71 of the sleeve 67. As a result, upward force on the valve rod 47 is transmitted through the pellets or discs 70, through the head 66 and thence through the sleeve 67, which is connected through the firing head 29 to the valve body 28. Accordingly, the valve rod 47 cannot shift upwardly at this time. For convenience of assembly, the valve rod may be prevented from dropping from the retainer casing 65 by a flange 72 on the upper end of the rod engaging an inwardly directed shoulder 73 therebelow constituting the lower end of the casing 65.

When the proper depth in the well bore is reached at which the apparatus is to be operated, the material 70 within the casing 65 is ignited and will either burn or melt away, flowing outwardly through the perforations 69 into the release chamber 52, which contains air at substantially atmospheric pressure. Leakage of fluid into this chamber from the exterior of the apparatus is prevented by the seal ring 54 on the upper valve rod piston 53 and also by side seals 74 on the sleeve engaging the adjacent wall of the valve body 28 and the adjacent wall of the firing head 29. As the material 70 burns away or melts, the products of combustion or the molten material itself flows out through the perforations 69 into the chamber 52. The hydrostatic head can then force the valve rod 47 upwardly into the cylinder 51, the upper portion 62 of the rod then moving into the casing 65.

The material 70 in the casing can be ignited by providing a suitable igniter or match compound 75 in the head. This igniter or match compound has a suitable filament (not shown), one end of which is grounded,

the other end of which making contact with a conductor rod 76 extending into the sleeve 67 and insulated therefrom by a suitable surrounding insulating sleeve 77. The upper end of this rod 76 engages a conductive terminal 78 extending through an insulating washer 79 held in place within the firing head 29 by a suitable threaded nut 80. The conductive terminal 78 is engaged by a conductive coil spring 81 which engages a conductor rod 82, the terminal spring and rod being contained within an insulating sleeve 83 in the central firing head passage 84. The conductor rod 82 is connected in a known manner to the central conductive core of a wire line (not shown), which is attached directly or indirectly to the firing head, in a known manner.

When current is caused to pass downwardly through the conductive wire line and the several conductive elements 82, 81, 78, 76 to the igniter or match compound 75, the latter is ignited and will initiate combustion of the adjacent material 70 in the casing 65. Such material either burns away or assumes a molten state, whereby the valve rod 47 is moved upwardly by the hydrostatic head of fluid in the casing, bringing the flute or passage 57 in the valve rod 47 below its seal 49 in communication with the inlet ports 42, allowing the hydrostatic head of fluid to enter the cylinders 26, 16 for action upon the pistons 30, 18 and set the bridge plug, well packer, or the like, connected to the setting tool. The fluid pressure effects a full setting of the equipment therebelow, and its release from the setting tool in a known manner, as more specifically described in the aforesaid United States Patent 2,640,547.

The pellets or discs 70 are preferably made of a material which is not adversely effected by relatively high temperatures encountered in some well bores, which, as indicated above, may be of the order of 400 to 450 degrees F. One such material is a photoflash mixture. For example, it may consist of 55% by weight of magnesium, 36% by weight of sodium nitrate, which functions as an oxidizer, and about 9% by weight of a resin binder. Another material that can be used is that found in incendiary bombs, which may consist of 48% by weight of a 50-50 magnesium-aluminum alloy and 52% by weight of barium nitrate.

The material just referred to, when ignited, will burn away and will not be available for the offering of resistance to upward movement of the valve rod 47 in the valve body 28. However, such materials have sufficient compressive strength prior to ignition to prevent upward movement of the valve rod from its position closing the inlet ports 42.

In lieu of the materials just referred to, a thermite material can be used in the casing, which consists of a mixture of aluminum and ferric oxide. When ignited by the match compound 75, such material will melt and will flow through the perforations 69 into the release chamber 52 surrounding the casing 65, its ejection through the perforations in the casing being aided by the fact that the rod 47 is being urged upwardly by the hydrostatic head of fluid externally of the apparatus.

The aforementioned materials prior to ignition all have ample compressive strength to prevent the rod 47 from being moved upwardly. It is only upon their ignition that they will either burn to a gaseous form and pass through the perforations 69 into the release chamber 51, permitting upward movement of the rod in the casing 65, or they will develop a sufficiently high temperature as to melt (like the thermite material), then flowing out through the perforations 69, being assisted in such movement by the upward passage of the valve rod 47 into the perforated casing 65.

The form of invention disclosed in FIG. 4 can be employed in the release chamber 52 in lieu of the perforated casing 65 and the material 70 contained therewithin. As shown, a frangible valve retainer or holder 90, which, for example, may be made of cast iron, extends up-

wardly into the sleeve 67, bearing against the shoulder 71 and being retained in place by a set screw 68, or the like. This frangible housing or retainer 90 extends downwardly within the release chamber 51 to substantially the same extent as the perforated casing 65 illustrated in FIGS. 1 and 3, the lower end of the housing 90 being closed and engaging the upper end of the valve rod 47. Thus, the frangible retainer 90, by engaging the rod, prevents the latter from moving upwardly to a position opening the inlet ports 42.

Contained within the hollow housing or retainer 90 is a blasting cap 91 capable of withstanding comparatively high temperatures, which, for example, may be of the order of 500 degrees F. This blasting cap is electrically connected to the conductor rod 76 through an intervening contact 92 and conductive wiring 93, one wire being grounded.

When the proper location in the well bore is reached at which the apparatus is to be operated, the electric circuit through the blasting cap 91 is completed, the latter exploding and shattering the frangible housing 90, the pieces thereof then moving freely into the release chamber 52, which is of a substantially greater diameter than the outside diameter of the frangible retainer itself. As a result, restraint to upward movement of the valve rod 47 is removed and the hydrostatic head can then shift the latter upwardly to a position opening the inlet ports 42, thereby permitting operation of the apparatus in the manner described above.

We claim:

1. In apparatus adapted to be disposed in a well bore: upper and lower cylinders secured together; lower piston means in said lower cylinder and having a portion extending outwardly therefrom; upper piston means in said upper cylinder and having a portion extending outwardly therefrom into said lower cylinder in engagement with said lower piston means; means preventing entry of well bore fluid externally of said cylinders into said cylinders below said upper and lower piston means; said upper and lower cylinders containing a gaseous medium below said upper piston means and lower piston means, respectively, when disposed in a well bore containing a surrounding liquid; means for conducting well bore fluid under pressure from the exterior of said upper cylinder into said upper cylinder for direct action upon the upper side of said upper piston means to shift said upper piston means relatively downwardly in said upper cylinder; means for conducting such fluid under pressure from said upper cylinder into said lower cylinder for action upon the upper side of said lower piston means to shift said lower piston means relatively downwardly in said lower cylinder; valve means above and separate from said upper piston means initially closing said well bore fluid conducting means to prevent well bore fluid from being exerted upon any and all portions of said upper piston means; and means for shifting said valve means in a direction away from said upper piston means to open position.

2. In apparatus adapted to be disposed in a well bore: upper and lower cylinders secured together; lower piston means in said lower cylinder and having a portion extending outwardly therefrom; upper piston means in said upper cylinder and having a portion extending outwardly therefrom into said lower cylinder in engagement with said lower piston means; means preventing entry of well bore fluid externally of said cylinders into said cylinders below said upper and lower piston means; said upper and lower cylinders containing a gaseous medium below said upper piston means and lower piston means, respectively, when disposed in a well bore containing a surrounding liquid; means for conducting well bore fluid under pressure from the exterior of said cylinder into said upper cylinder for direct action upon said upper piston means; means for conducting such fluid under pressure from said upper cylinder into said lower cyl-

inder for action upon said lower piston means; valve means above and separate from said upper piston means initially closing said well bore fluid conducting means to prevent well bore fluid from being exerted upon any and all portions of said upper piston means; means responsive to fluid pressure externally of said upper cylinder for shifting said valve means in a direction away from said upper piston means to open position; means preventing such shifting of said valve means; and means for releasing said preventing means.

3. In apparatus adapted to be disposed in a well bore: cylinder means; piston means in said cylinder means; means for conducting fluid under pressure into said cylinder means for action upon said piston means; valve means initially closing said conducting means to prevent passage of fluid under pressure into said cylinder means for exertion upon any and all portions of said piston means; means associated with said valve means and responsive to the pressure of fluid in the well bore for shifting said valve means to open position in a direction away from said piston means; means engageable with said valve means to prevent shifting of said valve means to open position under the action of fluid pressure; and means for releasing said preventing means to permit said shifting means to shift said valve means to open position under the action of the fluid pressure.

4. In apparatus adapted to be disposed in a well bore: cylinder means; piston means in said cylinder means; means for conducting fluid under hydrostatic pressure externally of said cylinder means into said cylinder means for action upon said piston means; valve means initially closing said conducting means to prevent said fluid under external hydrostatic pressure from being exerted upon any and all portions of said piston means; means associated with said valve means and exposed to and responsive to hydrostatic fluid pressure externally of said cylinder means for shifting said valve means to open position in a direction away from said piston means; disruptable means for preventing such shifting of said valve means; and means for disrupting said disruptable means to permit such shifting of said valve means.

5. In apparatus adapted to be disposed in a well bore: cylinder means; piston means in said cylinder means; means for conducting fluid under hydrostatic pressure externally of said cylinder means into said cylinder means for action upon said piston means; valve means initially closing said conducting means to prevent said fluid under external hydrostatic pressure from being exerted upon any and all portions of said piston means; said valve means having a portion providing a differential area subject to hydrostatic fluid pressure externally of said cylinder means tending to shift said valve means to open position in a direction away from said piston means; disruptable means engaging said valve means for preventing such shifting of said valve means; and means for disrupting said disruptable means to permit such shifting of said valve means.

6. In apparatus adapted to be disposed in a well bore: cylinder means; piston means in said cylinder means; means for conducting fluid under hydrostatic pressure externally of said cylinder means into said cylinder means for action upon said piston means; valve means initially closing said conducting means to prevent said fluid under external hydrostatic pressure from being exerted upon any and all portions of said piston means; means associated with said valve means and exposed to and responsive to hydrostatic fluid pressure externally of said cylinder means for shifting said valve means to open position in a direction away from said piston means; combustible means engaged by said valve means for preventing such shifting of said valve means; and means for igniting said combustible means to effect its burning and to remove restraint from said valve means whereby said valve means is shiftable to open position.

7. In apparatus adapted to be disposed in a well bore:

cylinder means; piston means in said cylinder means; means for conducting fluid under hydrostatic pressure externally of said cylinder means into said cylinder means for action upon said piston means; valve means initially closing said conducting means to prevent said fluid under external hydrostatic pressure from being exerted upon any and all portions of said piston means; means associated with said valve means and exposed to and responsive to hydrostatic fluid pressure externally of said cylinder means for shifting said valve means to open position in a direction away from said piston means; frangible means engaged by said valve means for preventing such shifting of said valve means; and explosive means for disrupting said frangible means to remove restraint from said valve means whereby said valve means is shiftable to open position.

8. In apparatus adapted to be disposed in a well bore: cylinder means; piston means in said cylinder means; means for conducting fluid under hydrostatic pressure externally of said cylinder means into said cylinder means for action upon said piston means; valve means slidable in and initially closing said conducting means; means providing a release chamber into which said valve means is adapted to move; said valve means having a portion providing a differential area subject to hydrostatic fluid pressure externally of said cylinder means tending to shift said valve means into said release chamber and to open position; disruptable means in said release chamber engaged by said valve means for preventing shifting of said valve means to open position; and means for disrupting said disruptable means to permit shifting of said valve means into said release chamber and to open position.

9. In apparatus adapted to be disposed in a well bore: cylinder means; piston means in said cylinder means; means for conducting fluid under hydrostatic pressure externally of said cylinder means into said cylinder means for action upon said piston means; valve means slidable in and initially closing said conducting means; means providing a release chamber into which said valve means is adapted to move; said valve means having a portion providing a differential area subject to hydrostatic fluid pressure externally of said cylinder means tending to shift

said valve means into said release chamber and to open position; combustible means in said release chamber engaged by said valve means for preventing shifting of said valve means to open position; and means for igniting said combustible means to effect its burning in said chamber and to remove restraint from said valve means to permit shifting of said valve means into said release chamber and to open position.

10. In apparatus adapted to be disposed in a well bore: cylinder means; piston means in said cylinder means; means for conducting fluid under hydrostatic pressure externally of said cylinder means into said cylinder means for action upon said piston means; valve means slidable in and initially closing said conducting means; means providing a release chamber into which said valve means is adapted to move; said valve means having a portion providing a differential area subject to hydrostatic fluid pressure externally of said cylinder means tending to shift said valve means into said release chamber and to open position; frangible means in said release chamber engaged by said valve means for preventing shifting of said valve means to open position; and means for disrupting said frangible means to permit shifting of said valve means into said release chamber and to open position.

References Cited by the Examiner

UNITED STATES PATENTS

2,279,676	4/42	Hart	166—63
2,308,004	1/43	Hart	166—63
2,377,249	5/45	Lawrence	166—98
2,595,014	4/52	Smith et al.	166—98
2,807,325	9/57	Webb	166—63
2,815,816	12/57	Baker	166—63
2,829,716	4/58	Stewart	166—98
2,978,028	4/61	Webb	166—63
2,979,904	4/61	Royer	166—123
3,125,162	3/64	Briggs et al.	166—123

40 BENJAMIN HERSH, *Primary Examiner*.

BENJAMIN BENDETT, *Examiner*.