Sept. 26, 1961 L. B. SCOTT 3,001,584

APPARATUS FOR TREATING WELLS

Filed April 11, 1957 4 Sheets-Sheet 1

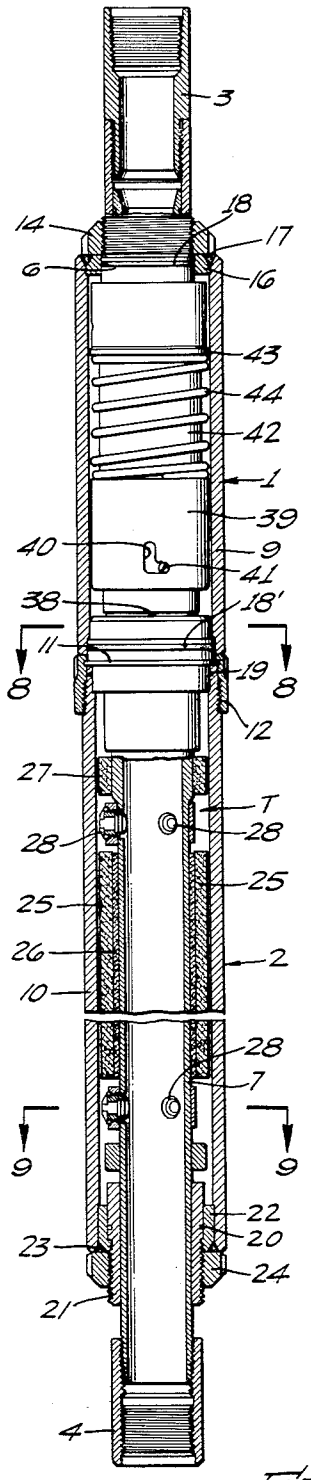


FIG. 1.

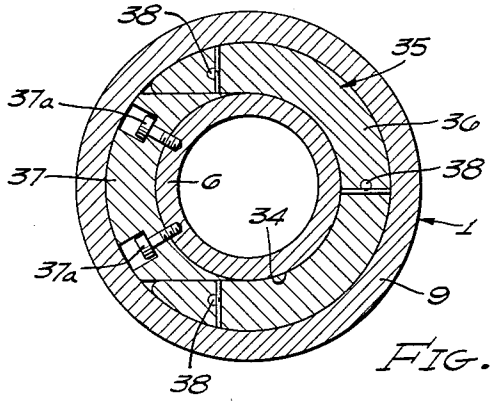


FIG. 8.

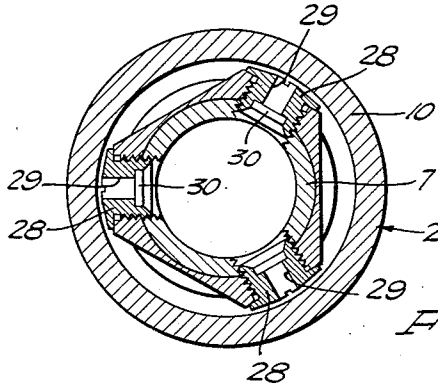


FIG. 9.

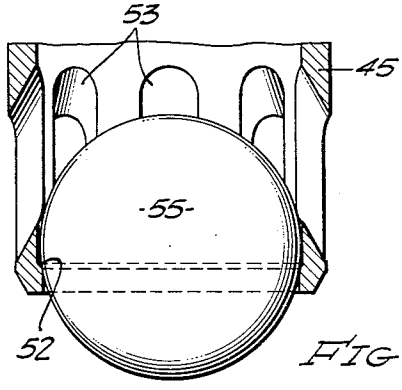


FIG. 10.

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APPARATUS FOR TREATING WELLS

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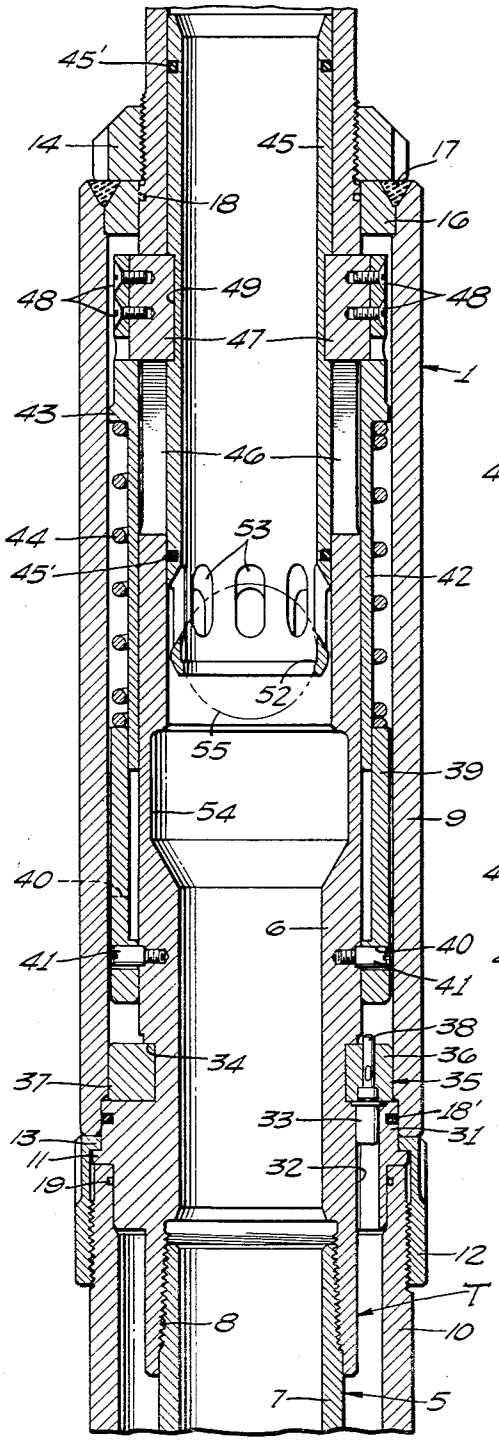


FIG. 2.

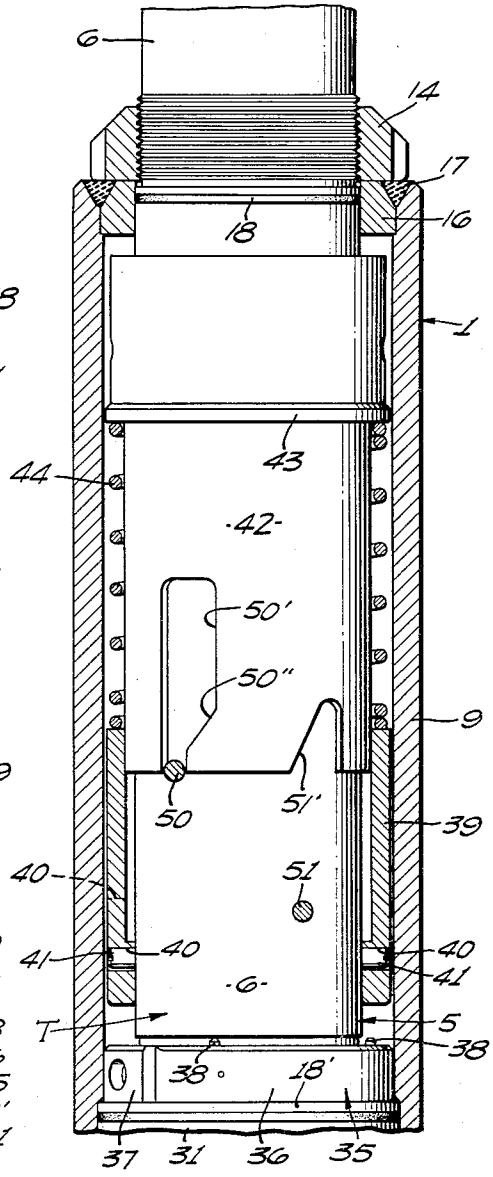


FIG. 3.

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APPARATUS FOR TREATING WELLS

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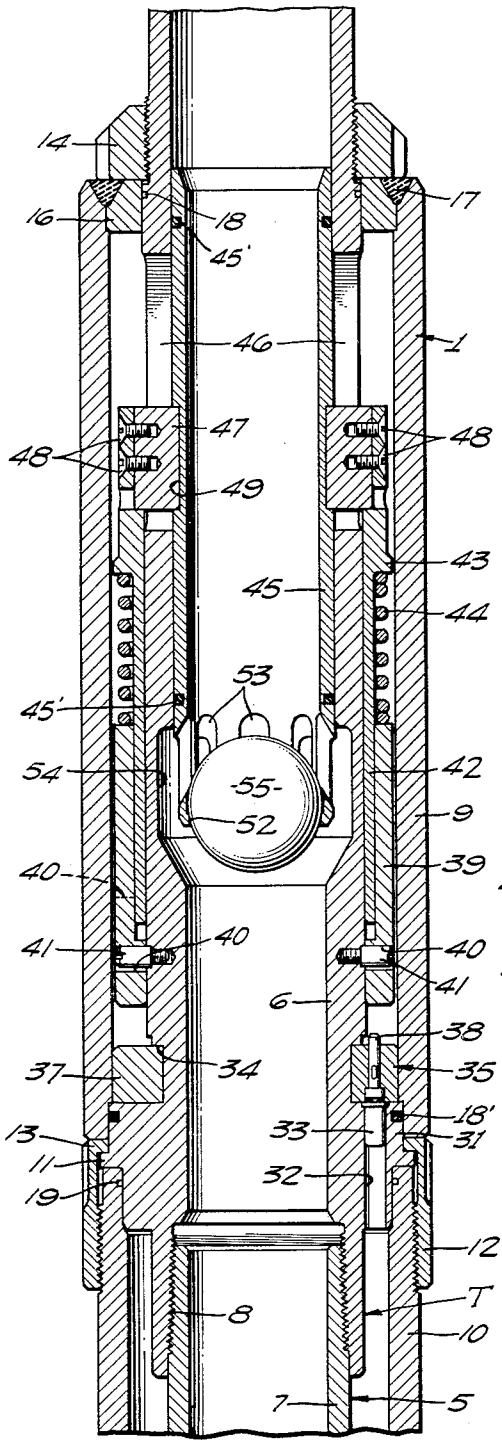


FIG. 4.

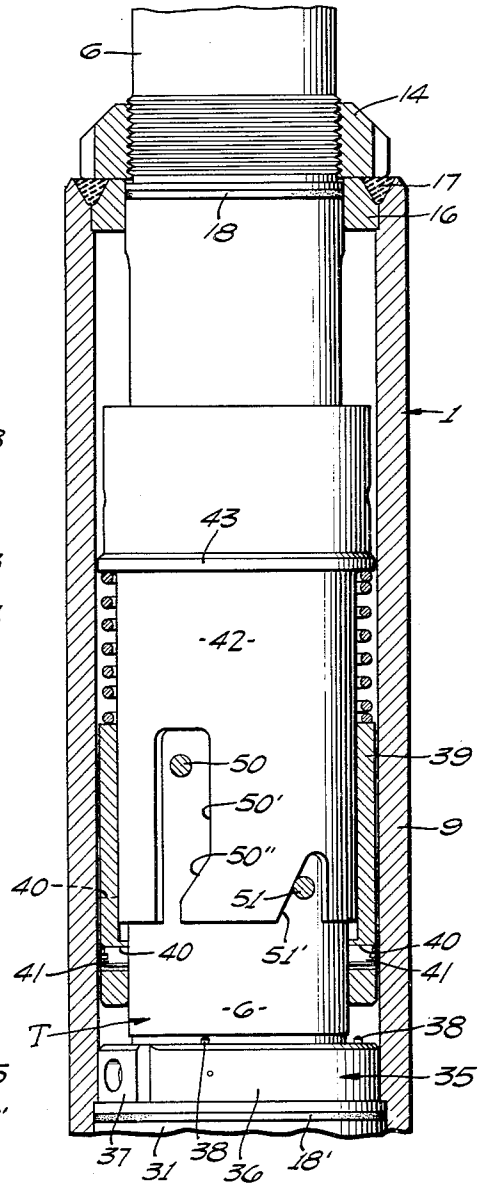


FIG. 5.

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APPARATUS FOR TREATING WELLS

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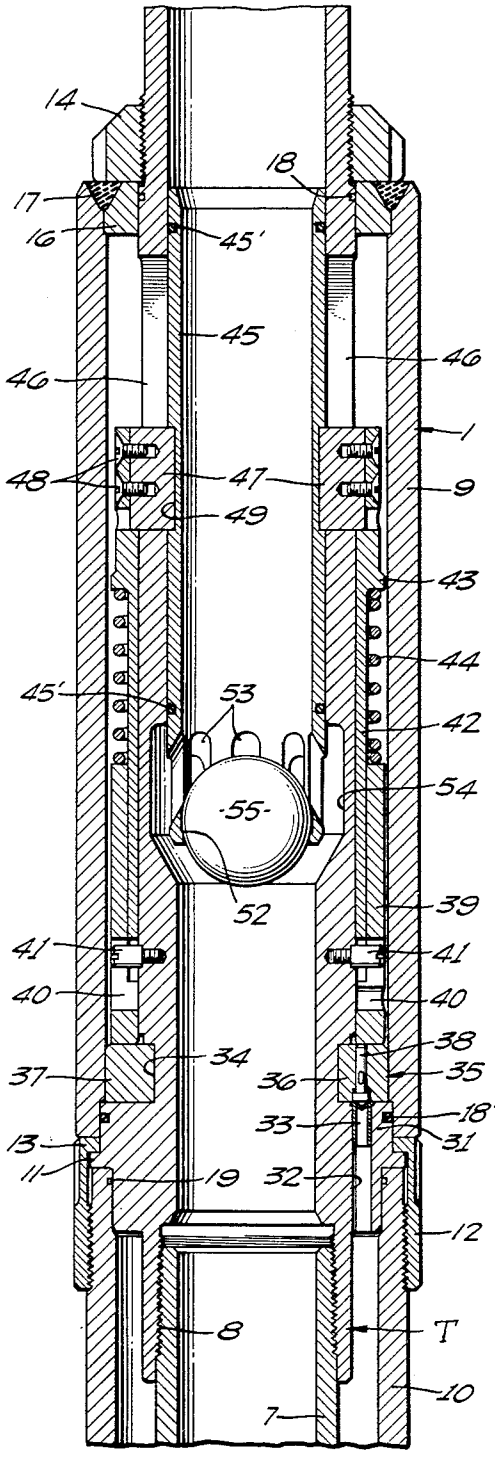


FIG. 6.

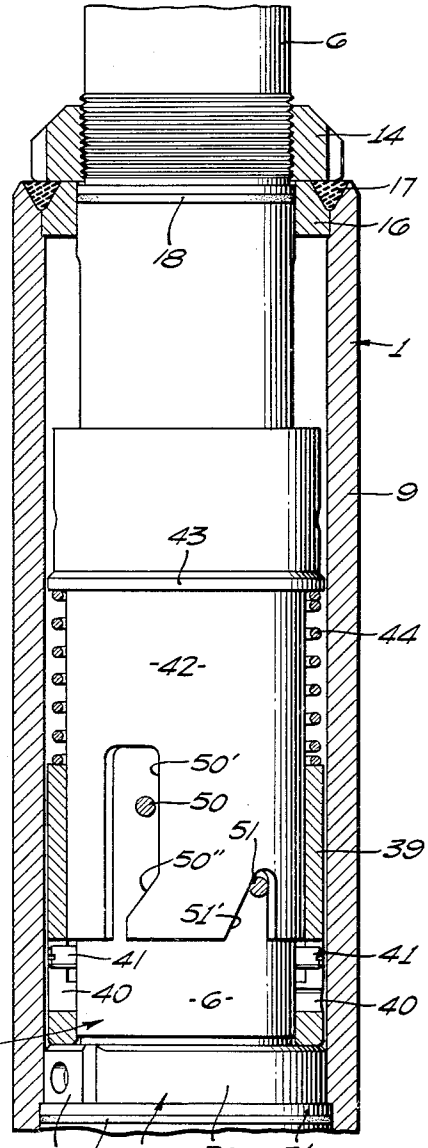


FIG. 7.

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3,001,584

APPARATUS FOR TREATING WELLS

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Filed Apr. 11, 1957, Ser. No. 652,286
13 Claims. (Cl. 166—63)

The present invention relates to an improved well treating apparatus.

In the field of treating oil and gas wells, it frequently becomes desirable to inject fluid down into the well for treating the earth formation traversed by the well as in formation fracturing, acidizing, cleaning and other fluid operations, as well as in cementing or the like. Relatively high fluid pressures and/or injection rates are often required in order for the treatment to be effective. Despite the availability of pump pressure at the well head, adequate downhole pressures are oftentimes difficult to attain because of friction losses, depending upon the viscosity of the treating fluid, whether the fluid is being pumped down tubing or down casing, into an open hole or into the formation through casing perforations, and other factors.

In fracturing earth formation to enhance the flow of oil into the well from relatively impermeable strata or to provide communication between the well and blocked oil bearing strata or sands to enable production thereof, fluid is pumped into the well under pressure for overcoming the stresses of adjacent tight or impermeable strata to form fissures or cracks radiating from the well, such cracks resulting in actual fracturing of rock or shale formations, or the like, having a yield point at which they will rupture responsive to internal tension. In the case of formations having existing tight fractures, the fracturing fluid merely overcomes the confining stress and opens the existing fractures, such as exist at boundries or the bed plane of different strata. Higher pressures are required to effect actual fracturing of the rock or other formation than are required for opening existing fractures, whereas lower viscosity fluids and higher injection rates are generally required in the latter case.

Depending upon the rate of loss of fluid into the formation, the depth of the well, and the viscous properties of the treating or fracturing fluid, as well as upon the capacity of the surface pumps to provide high injection rates and/or pressures, sufficient pressures and/or injection rates may at times be practically unattainable. Means for providing a single-stroke, pump-like boost to the fluid pressure to implement available surface pump pressure are disclosed in the copending patent application of Lyle B. Scott and Mathew B. Riordan, Jr., filed October 16, 1956, Serial No. 616,333 for Well Treating Method and Apparatus.

According to the invention of that application, a container of low-propellant or rocket-type fuel is disposed in the well adjacent to, or just above, the producing or potentially productive zone to be fractured or otherwise treated. Without interrupting the flow of fluid from the surface pumps, the propellant is ignited or detonated so as to produce a large volume of gas pressure which is, so to speak, super-imposed upon the pump pressure to provide a powerful boost or assist to the effective pressure of the treating fluid, which in a fracturing operation may be required to lift the overburden at the zone of fracture. Such overburden of ordinary sedimentary formation applies a vertical stress of approximately 1.0 p.s.i. per foot of depth, although this may vary due to the overlying weight of some strata being borne by a briding action caused by earth movements. Therefore, in relatively deep wells, substantial pressures must be developed in order to effect fracturing.

The detonation or ignition of the propellant or rocket

fuel charge aforementioned is adapted to supply, in addition to the pump pressure which may be inadequate for effective fracturing, a pulse-like pressure boost of thousands of pounds, thus enabling initial opening of the formation by the creation of new, or opening of old, fractures. Following such initial opening, continued pump pressure is adequate to open the formation further, so that fractures radiating from the well may be of substantial extent, depending upon the differences in stress between adjacent formations through which the fractures extend and the borehole wall being fractured. Such fractures may extend radially of the well upwards of 1,000 feet or more.

A primary object of the present invention is to provide an improved apparatus of the type disclosed in the aforementioned copending patent application, the apparatus hereof having a novel firing head for detonating the propellant or rocket fuel responsive to engagement of the firing head by a plug, ball, or other element adapted to be inserted into the treating fluid at the well head and to move therewith or therethrough into contact with the firing head.

Another object is to provide a firing head in accordance with the preceding objective, including means for detonating firing means for the propellant or rocket fuel, responsive to engagement of the firing head by the plug, ball, or the like, while leaving the apparatus free of obstruction to continued flow of treating fluid therethrough.

A further object of the invention is to provide an apparatus for producing "vertical" fractures in the earth formation traversed by a well bore, it being intended that the term "vertical" as employed herein contemplates fractures which are not necessarily truly vertical, but which may be disposed at a substantial angle relative to a vertical plane.

In wells where the tensile strength of the surrounding formation is high and vertical compressive strengths are low, pressure fluid will leak off into bedding planes or high permeability sections and will help to start so-called horizontal fractures. When native fractures exist, a stress wedge is provided by the pressure fluid which will open the native fractures at a pressure which may be less than the least stress in the surrounding formation. If such native fractures and high permeability areas are sealed off, thus causing uniform pressure distribution around the hole, initial fracture will occur in a plane where rock or formation strength is lowest. Such fractures will usually be vertical, or at least nearly so, but may, depending upon varying formation strength characteristics, vary to the point of being nearly horizontal.

Still another object is to provide fluid injection apparatus including a container adapted to be disposed in a tubing string and run down a well to a position adjacent to the earth formation to be treated, the container having a flow passage communicating with said tubing, said container also having a chamber containing a material capable of generating gas upon ignition, and a firing head for igniting the gas-generating material, and actuator means for the firing head adapted to be injected into the tubing to travel in the fluid in the well into engagement with the firing head for operating the same, said firing head including an axially moveable sleeve having a fluid flow passage therein, a seat at the bottom of said sleeve on which the actuator means is adapted to seat as a valve, and by-pass openings in the sleeve, said by-pass openings being closed when the sleeve is in a normal position, whereby when the actuator means seats in the sleeve as a valve, the sleeve will be moved downwardly to a position where said by-pass openings are opened for the passage of fluid therethrough, and means operative responsive to such downward movement of the

sleeve to fire the firing means and effect gas generation by said gas-generating material. Other objects and advantages of the invention will be hereinafter defined or will become apparent to those skilled in the art, and the novel features thereof will be defined in the appended claims.

In the accompanying drawings:

FIG. 1 is a longitudinal sectional view of a tool embodying the invention;

FIG. 2 is an enlarged fragmentary sectional view, as taken longitudinally through the firing head of FIG. 1, with the firing head in a normal non-operating condition, and showing in broken lines an actuator ball valve therefor;

FIG. 3 is an enlarged fragmentary sectional view, as taken longitudinally of the firing head, with certain of the parts shown in elevation and in their respective non-operating positions;

FIG. 4 is a view similar to FIG. 2, but showing the parts in the positions they assume upon downward movement of the operating sleeve responsive to seating of the ball valve in the sleeve, just prior to the firing of the firing means;

FIG. 5 is an enlarged fragmentary view in longitudinal section, showing certain of the parts in elevation and in the relative positions shown in FIG. 4;

FIG. 6 is a view similar to FIGS. 2 and 4, but showing the parts in a firing position;

FIG. 7 is an enlarged fragmentary view in longitudinal section showing certain of the parts in elevation and in the relative positions shown in FIG. 6;

FIG. 8 is a transverse sectional view on an enlarged scale, as taken on the line 8—8 of FIG. 1;

FIG. 9 is a transverse sectional view on an enlarged scale, as taken on the line 9—9 of FIG. 1; and

FIG. 10 is an enlarged fragmentary view in vertical section as taken axially through the ball seat, with an actuator ball shown in full lines seated thereon.

Like reference characters in the several views of the drawings and in the following description designate corresponding parts.

The apparatus shown in the accompanying drawings, referring particularly to FIGS. 1 and 2, generally comprises a firing head section 1 and a lower propellant-containing chamber or receptacle 2. The illustrative embodiment is adapted to be interposed in a tubing string, and accordingly, the firing head is adapted for connection in such a tubing string (not shown) as by means of a tool joint 3, the propellant container or compartment 2 being adapted for connection in the tubing string as by means of a coupling or tool joint 4.

Otherwise, the assembly includes an elongated orifice tube generally designated T having an upper firing head section 6 and a lower propellant-container section 7, these tube sections 6 and 7 being threadedly interconnected with one another as at 8 and being concentrically disposed within coaxially extended firing head and propellant container cases 9 and 10 respectively. Adjacent to its lower end, the firing head tube section 6 is provided with a radially projecting adapter flange 11 against which the upper extremity of the propellant container case 10 abuts, with the case 10 held in tight abutting contact with the flange 11 by an interiorly threaded sleeve 12, threadedly engaged with the case 10 and having a radially inwardly projecting flange 13 engaged with the flange 11. The firing head case 9 abuts with the flange 13 at the lower extremity of the case and is retained in position by means of a threaded nut 14 engaged with the threaded outer periphery of the tube section 6 and the upper end of the firing head case 9. A spacer ring 16 is preferably disposed between the case 9 and the upper extremity of the tube section 6 and welded to the firing head case 9 as at 17.

Suitable sealing means such as a sealing ring 18 interposed between the spacer ring 16 and the firing head tube section 6, a sealing ring 18' interposed between the lower extremity of the firing head casing 1 and the lower portion of tube section 6, a sealing ring 19 interposed between the upper extremity of the propellant compartment case 10 and the tube section 6, and a sealing ring 20 disposed at the base of the propellant chamber 10 are provided for sealing the firing head and the propellant compartment against the entry of well fluids. The sealing ring 20 (see FIG. 1) is interposed between an adapter sleeve 21, which is suitably mounted upon the exterior of the orifice tube section 7, and a spacer ring 22 interposed between the sleeve 21 and the case 10 and preferably welded or otherwise suitably secured to the latter as at 23. A lock nut 24 threadedly engaged with the sleeve 21 aids in retaining the case 10 in place.

The propellant container 2 has disposed therein a quantity of gas-generating material, and without departing from the invention, such gas-generating material may be any of a number of diverse types, either liquid or solid. But for illustrative purposes, strips of a solid propellant material generally designated 25 are shown interposed in the annular space between the case 10 and the orifice tube section 7, with a firing strip 26 interposed between the propellant strips 25 and the orifice tube section 7, and with an ignitor strip or ring 27 encircling the orifice tube section 7 between the propellant strips 25 and suitable firing mechanism which will be hereinafter more particularly described.

The propellant itself may, when a solid propellant such as herein disclosed is employed, consist of a slow burning propellant such as rubberized ammonium nitrate or the like. Such a solid propellant may be obtained, for example, from Grand Central Rocket Company, Montone, California, under their designations "CBS–128K" or "CBS–128H." Alaternatively, it may consist of ordinary railroad fusee material, such as saw dust impregnated with sodium or ammonium nitrate, or it may consist of one of a variety of rocket fuels. Suitable propellants are described by T. L. Davis in Chemistry of Powder and Explosives, 1943, John Wiley & Son, Publishers. As is well known, these solid propellants may vary in their composition so as to burn at varying rates, but when employed in the present invention, a burning time of on the order of about ten seconds is preferable. Such burning of the propellant material will result in the generation of a high volume of gas within the sealed annular space between the case 10 and the orifice tube section 7.

A suitable number of gas relief plugs 28 are threadedly mounted in the orifice tube section 7, these relief plugs each having an orifice 29 therethrough sealed by means of a frangible disc 30 which, when subjected to high internal gas pressures, will rupture and allow the escape of gas from the gas chamber between the case 10 and the orifice tube 7 into the passage through the latter. The result of the generation of such gas and escape thereof through the orifice tube will be more particularly described hereinafter.

Within the case 9 is suitable means for effecting firing or detonation of the propellant material, and more particularly, the ignitor strip 27. To this end, a suitable number of axially extended openings are formed through a radial orifice tube enlargement 31 on the firing head tube section 6, from which the adapter flange 11 projects, these openings being designated 32 and each having disposed therein a blank cartridge 33. The firing head tube section 6 is provided with a peripheral groove or channel 34 in which is disposed an annular breech block 35, the breech block 35 being constituted of a U-shaped section 36 partially embracing the firing head tube section 6 in the groove 34 and a retaining section 37 which is secured to the firing head tube section 6 as by means of a suitable number of screw fasteners 37*a* (see FIGS. 5 and 8).

Shiftably mounted in the breech block 35 and disposed for engagement with the blank cartridges 33, is a like number of firing pins 38 which, upon receiving a sharp

percussive blow, will fire the blank cartridges, thus in turn igniting or firing the propellant material. The means for providing such a percussive blow to the firing pins 38 includes an annular hammer 39 disposed between the firing head tube section 6 and the firing head case 9. At opposite sides thereof, the hammer 39 is preferably provided with a pair of generally L-shaped slots 40, with a like number of pins 41 threadedly fixed to the firing head tube section 6 and projecting into the slots 40, so that when the pins 41 are disposed in the off-set base portions of the L-shaped slots 40, the hammer 39 will be retained against axial shifting movements, whereas upon slight rotative movement of the annular hammer 39, the elongated portions of the slots 40 will enable axial movement of the hammer 39 into engagement with the firing pins 38.

An axially extended operator member 42 is slidably mounted upon the outer periphery of the firing head tube section 6, this actuator member 42 having a radially outwardly projecting flange or shoulder 43 thereon, disposed in opposed spaced relation to the upper extremity of the annular hammer 39. A coiled spring 44 is disposed between the shoulder 43 and the latter end of the hammer 39 so as to normally bias the hammer towards the firing pins 38. Means are provided for shifting the actuator member 42 axially, such means including an actuator sleeve 45 slidably mounted within the firing head tube section 6. A number of axially extended slots 46 are formed in the firing head tube section 6, and a number of lugs 47 project through the slots 46 and are connected to the upper extremity of the actuator member 42 as by means of a suitable number of screw fasteners 48, these lugs 47 being seated in an annular groove 49 in the outer periphery of the actuator sleeve 45 so that the actuator member 42 and the sleeve 45 are moveable axially as a unit. Preferably, sealing rings 45', 45' are interposed between the actuator sleeve 45 and the firing head tube section 6 to prevent the passage of fluid into operating mechanism.

Referring particularly to FIGS. 3 and 7, the hammer 39 is provided with a pair of radially, inwardly projecting, pins 50 and 51, these pins being spaced from one another both in an axial direction and in a circumferential direction with relation to the hammer 39. The pin 51 is adapted to cooperate with an inclined cam surface 51' on the actuator member 42 so that upon engagement by the pin 51 responsive to axial movement of the actuator member 42, the hammer 39 will cam rotatively in a direction to unseat the pins 41 from the bases of the L-shaped slots 40, thus freeing the hammer 39 for axial movement responsive to the pressure applied thereto by the spring 44. The actuator member 42 is provided with a longitudinally extended slot 50' having a cam surface 50'' engageable with the pin 50, so that axial movement of the hammer 39 in the opposite direction will effect camming of the hammer 39 rotatively in a direction whereby the pins 41 are moved into the bases of the slots 40.

The structure thus far described is merely illustrative of a construction which is particularly adapted for use in connection with actuator means embodying the invention, and is described in particular detail in the copending application of Mathew B. Riordan, Jr., and Lyle B. Scott, filed October 16, 1956, Serial No. 616,333 for Well Treating Method and Apparatus. Illustratively, it is to be understood that the impact producing hammer means may, if desired, be of the type disclosed in my copending application, Serial No. 638,375, filed February 5, 1957, for Firing Head for Formation Treating Apparatus.

However, as has been hereinbefore pointed out, the apparatus hereof is particularly well-suited for the performance of vertical fracturing operations, wherein the fractures are more or less vertical; that is, fracturing the earth formation by overcoming the lateral or horizontal stresses in the surrounding earth formation as distinguished from the longitudinal or vertical compressive stresses.

Accordingly, the actuator sleeve 45 is provided with an annular seat member 52 at its base, and extending upwardly in the sleeve 45 from closely adjacent the seat 52 is a plurality of circumferentially spaced by-pass orifices or openings 53. Preferably these orifices 53 are of such a size and configuration that their overall area is at least equal to or greater than the opening through the seat 52. Formed in the inner periphery of the firing head tube section 6 is an annular by-pass chamber 54 so that when the openings 53 of the sleeve 45 register with the by-pass chamber 54, fluid passing downwardly through the sleeve 45 will flow through the orifices 53 and the by-pass chamber 54 and thence on through the tube sections 6 and 7. The outer periphery of the annular seat member 52 is preferably of a slightly smaller diameter than the inside diameter of the firing head tube section 6, so that a limited fluid flow is permitted past the member 52 to prevent sand clogging in certain fracturing operations where sand or some other propping agent is employed in the fluid.

However, when the operator sleeve 45 is in the position shown in FIG. 2 where it is normally maintained by the pressure of the spring 44, the orifices or openings 53 in the sleeve 45 will be closed off by the inner periphery of the firing head tube section 6 so that fluid passing downwardly through the sleeve 45 will flow through the seat 52 until such time as a check valve or the like engages with said seat 52 to deter such flow. Such a check valve is herein shown as being constituted by a ball 55 having a diameter slightly greater than the seat 52, but of such a size as to freely pass downwardly through the sleeve 45 into engagement with the seat 52. The ball 55 may be injected into the well through a suitable lubricator mechanism at the well head (not shown), which is shown and described in the copending Scott and Riordan application above referred to.

As the ball passes down through the tubing into engagement with the seat 52, the further free flow of fluid through the sleeve 45 will be prevented or minimized. Therefore, continued operation of the surface pumps, as is customary, will force the sleeve 45 downwardly until the fluid is free to pass through the orifices 53 and into the by-pass chamber 54, thus resulting in firing of the blank cartridges 33. If desired, the ball 55 may be composed of a soft material such as aluminum or a deformable plastic material such as nylon so that in the event of blockage of the by-pass orifice 53, a build up of pressure behind the ball 55 within the sleeve 45 will extrude the ball through the seat 52.

In the use of the apparatus described above, fluid will be injected into the well through a tubing string in which the apparatus is interposed. In a vertical fracturing operation, such fluid will preferably be of a so-called low fluid loss type; that is, of a type consisting of a gelled hydrocarbon such as kerosene or gasoline having a relatively high viscosity, but having the characteristic of not materially retarding the injection rate by virtue of the increase in viscosity due to gelling. In addition, the fluid preferably will include a suitable well-known fluid loss preventing material which will form a filter cake upon the wall of the bore hole in those areas where fluid tends to flow out into the formation. Such fluid will be pumped down into the hole until such time as the pumps may be halted and pressure retained in the well. Indeed, it may require building up in increments to an internal pressure in the well just below the incipient breakdown pressure of the formation to be fractured; that is, the well will be pressurized up to a point and the pumps shut down to determine whether the pressure will hold. And such operation may be repeated until the well will hold the desired pressure.

With the surface pumps halted, the ball valve 55 may then be injected into the well without relieving the pressure and allowed to settle down in the tubing until it

rests upon the seat 52, thus precluding free flow of fluid through the firing head, whereupon recommencement of the pumps will exert a pressure upon the ball, thereby moving the actuator sleeve 45 downwardly. Such movement of the actuator sleeve will effect a corresponding downward movement of the member 42 with the result that the cam surface 51' thereon engaging with the pin 51 will effect rotation of the hammer 39 until the pins 41 are released from the off-set bases of the slots 40 and the spring 44 forces the hammer 39 into contact with the firing pins 38. Thus, the cartridges 33 will be fired, the propellant or rocket fuel ignited or detonated, and a high volume of gas will be generated in the annular space between the orifice tube section 7 and the propellant container case 10. The frangible discs 30 will accordingly be blown out by the gas pressure and the gas will escape into the orifice tube section 7 and exert a sudden impulse of high pressure on the fluid therebeneath with the result that the earth formation will be fractured. Since the low fluid loss characteristics of the fracturing fluid and the fluid loss preventing material therein will prevent the flow-off of fluid into the formation through native fractures or through porous areas of high permeability, no pressure wedges will be forced off into the formation such as would ordinarily tend to produce a horizontal fracture. Instead a pressure is produced which surpasses the tensile strength of the borehole, overcoming the tangential opposing forces and fracturing the earth formation at the point where the tensile strength is the lowest, this type of fracture generally being referred to as a vertical fracture, though it may indeed be disposed other than vertically.

It is to be understood that while the structure hereof is adapted for use in a vertical fracturing operation as above described, such use is merely exemplary, since the structure is also adapted for use in ordinary fracturing operations, where the pumps at the surface are not interrupted, and the ball valve 55 may be injected into the stream of fluid as it is being pumped downhole. Indeed the apparatus may also be employed in a variety of fluid injection well treatments as hereinabove pointed out.

While the specific details of the apparatus hereof have been specifically shown and described, changes and alterations may be resorted to without departing from the spirit of the invention as defined in the appended claims.

I claim:

1. Fluid injection apparatus for a well, comprising a tube, means defining with said tube a container for a material capable of generating gas upon ignition, said container having an opening to permit the discharge of gas into the well, firing means for said gas-generating material carried by said tube and including an actuator sleeve disposed in said tube for axial movements, a seat on said sleeve, and a valve engageable with said seat to prevent the flow of fluid through said sleeve for causing said sleeve to be moved axially by said fluid, said sleeve having means for by-passing fluid around said valve upon limited axial movement of the sleeve to actuate said firing means.

2. Fluid injection apparatus for a well, comprising a tube, means defining with said tube a container for a material capable of generating gas upon ignition, said container having an opening to permit the discharge of gas into the well, firing means for said gas-generating material carried by said tube and including an actuator sleeve disposed in said tube for axial movements, a seat on said sleeve, and a valve engageable with said seat to prevent the flow of fluid through said sleeve for causing said sleeve to be moved axially by said fluid, said sleeve having by-pass ports therein for by-passing fluid around said valve upon limited axial movement of the sleeve to actuate said firing means.

3. In apparatus for use in fluid injection apparatus for treating wells, including a container of material capable of generating a large volume of gas upon ignition and adapted to be disposed in the well, said container having an opening to permit the discharge of gas into the well, shiftable means for effecting firing of the gas-generating material, and means for shifting the shiftable means, that improvement wherein said shifting means includes a member having a fluid flow passage therethrough, and including means for effecting movement of said member with the treating fluid, said member having means for by-passing said fluid upon predetermined movement of said member.

4. In apparatus for use in fluid injection apparatus for treating wells, including a container of material capable of generating a large volume of gas upon ignition and adapted to be disposed in the well, said container having an opening to permit the discharge of gas into the well, shiftable means for effecting firing of the gas-generating material, and means for shifting the shiftable means, that improvement wherein said shifting means includes a member having a fluid flow passage therethrough, said member having a valve seat therein, and a valve engageable with the seat responsive to the flow of fluid through the member to close said flow passage, whereby said member will move with the fluid, said member also having means for by-passing the fluid around said valve responsive to movement of the member beyond a predetermined distance.

5. Fluid injection apparatus comprising a tube having a fluid passage therethrough, a container of gas-generating material on said tube, means carried by said tube for initiating gas generation of said material, said container having an opening to permit the discharge of gas into the well, and operating means for said initiating means, said operating means including a member shiftably disposed in said fluid passage and having a fluid opening therethrough, means responsive to the flow of fluid in one direction through said opening for blocking said opening to effect shifting of said member with the fluid, said member having by-pass means for allowing fluid to pass said blocking means upon movement of the member to a position to effect operation of said initiating means.

6. Fluid injection apparatus as defined in claim 5, wherein said blocking means includes a valve freely moveable in the opening in the operating member, said member having a seat with which said valve is engageable.

7. Fluid injection apparatus as defined in claim 5, wherein said blocking means includes a valve freely moveable in the opening in the operating member, said member having a seat with which said valve is engageable, said valve being only slightly larger than said seat and being composed of a material enabling extruding of the valve through the seat upon being subjected to excessive pressure by said fluid.

8. Fluid injection apparatus comprising a tube having a fluid passage therethrough, a container of gas-generating material on said tube, means carried by said tube for initiating gas generation of said material, said container having an opening to permit the discharge of gas into the well, and operating means for said initiating means, said operating means including a member shiftably disposed in said fluid passage and having a fluid opening therethrough, means responsive to the flow of fluid in one direction through said opening for blocking said opening to effect shifting of said member with the fluid, said member having a by-pass port and said tube having a by-pass recess for communication with said port for allowing fluid to pass said blocking means upon movement of said member to a position to effect operation of said initiating means.

9. Fluid-pressure-operated actuator means of the class described comprising a tube having a fluid flow passage therethrough, an actuator sleeve slidably disposed in said passage, said sleeve also having a fluid passage therethrough, said tube having a slot extending therethrough and longitudinally thereof, an actuator member disposed externally of said sleeve, means interconnecting said actu-

ator sleeve and actuator member and extending through said slot, a seat on said sleeve in said sleeve passage, a valve member freely moveable in said sleeve passage along with fluid flowing through said passage for engaging said seat to block such flow of fluid and effect movement of the sleeve in one direction, means normally maintaining said sleeve shifted in the other direction, and said sleeve having by-pass means for permitting the free flow of fluid past said valve member upon limited movement of the sleeve in the fluid pressure responsive direction.

10. A fluid-pressure-operated actuator device as defined in claim 9, wherein said valve member is a ball.

11. A fluid pressure operated actuator device as defined in claim 9, wherein said sleeve has a reduced diameter about said seat providing a clearance between said sleeve and said tube, said clearance communicating with said by-pass means for allowing limited flow of fluid past said valve when the sleeve is in its normal position aforesaid.

12. Fluid-pressure-operated actuator means of the class described comprising a tube having a fluid flow passage therethrough, an actuator sleeve slidably disposed in said passage, said sleeve also having a fluid passage therethrough, said tube having a slot extending therethrough and longitudinally thereof, an actuator member disposed externally of said sleeve, means interconnecting said actuator sleeve and actuator member and extending through said slot, a seat on said sleeve in said sleeve passage, a valve member freely moveable in said sleeve passage along with fluid flowing through said passage for engaging said seat to block such flow of fluid and effect movement of the sleeve in one direction, means normally maintaining said sleeve shifted in the other direction, said sleeve having a by-pass port at one side of said seat, and said tube having a by-pass opening communicable with said port upon limited movement of the sleeve in the fluid pressure responsive direction.

13. Fluid-pressure-operated actuator means of the class described comprising a tube having a fluid flow passage therethrough, an actuator sleeve slidably disposed in said passage, said sleeve also having a fluid passage therethrough, said tube having a slot extending therethrough and longitudinally thereof, an actuator member disposed externally of said sleeve, means interconnecting said actuator sleeve and actuator member and extending through said slot, a seat on said sleeve in said sleeve passage, a valve member freely moveable in said sleeve passage along with fluid flowing through said passage for engaging said seat to block such flow of fluid and effect movement of the sleeve in one direction, means normally maintaining said sleeve shifted in the other direction, said sleeve having a plurality of longitudinally extended by-pass ports at one side of the seat, said ports having a total area substantially comparable to the cross-sectional area of the tube passage, and said tube having an annular depression in its inner periphery defining a by-pass chamber communicable with said ports upon limited fluid pressure responsive movement of said sleeve.

References Cited in the file of this patent

UNITED STATES PATENTS

2,488,819	Larkin	Nov. 22, 1949
2,651,368	Baker et al.	Sept. 8, 1953
2,696,259	Greene	Dec. 7, 1954