Feb. 7, 1961 L. B. SCOTT 2,970,647

FIRING HEAD FOR FORMATION TREATING APPARATUS

Filed Feb. 5, 1957 2 Sheets-Sheet 1

FIG. 1.

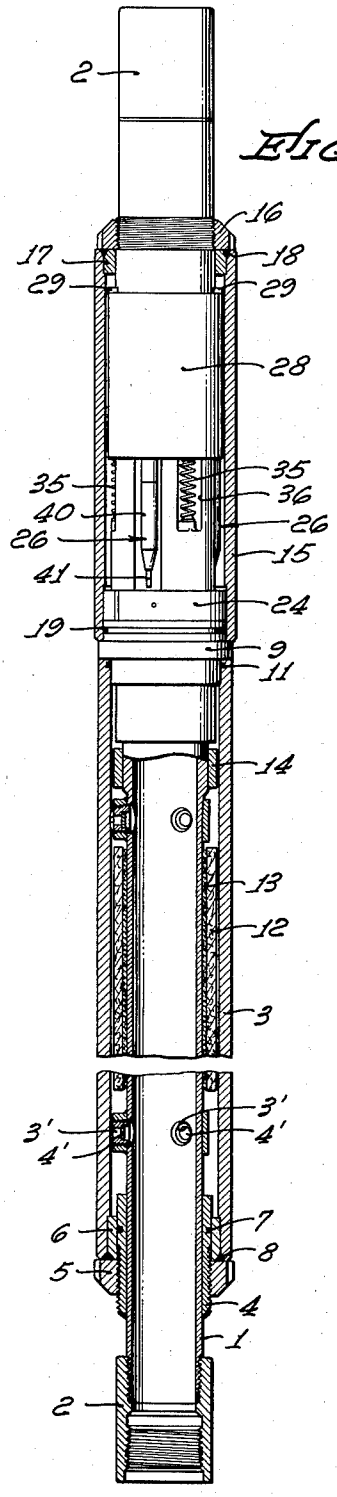
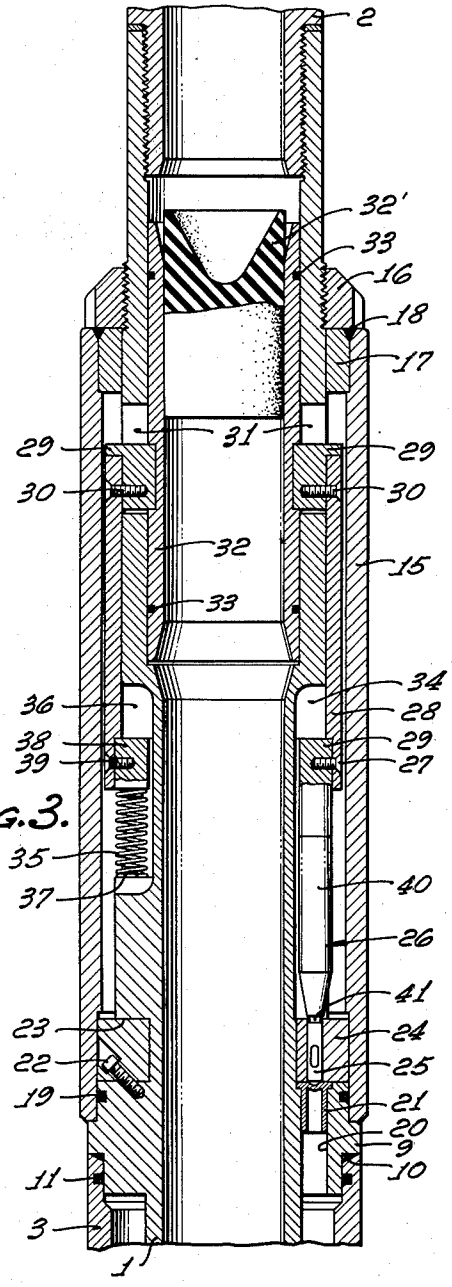


FIG. 3.



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Filed Feb. 5, 1957 2 Sheets-Sheet 2

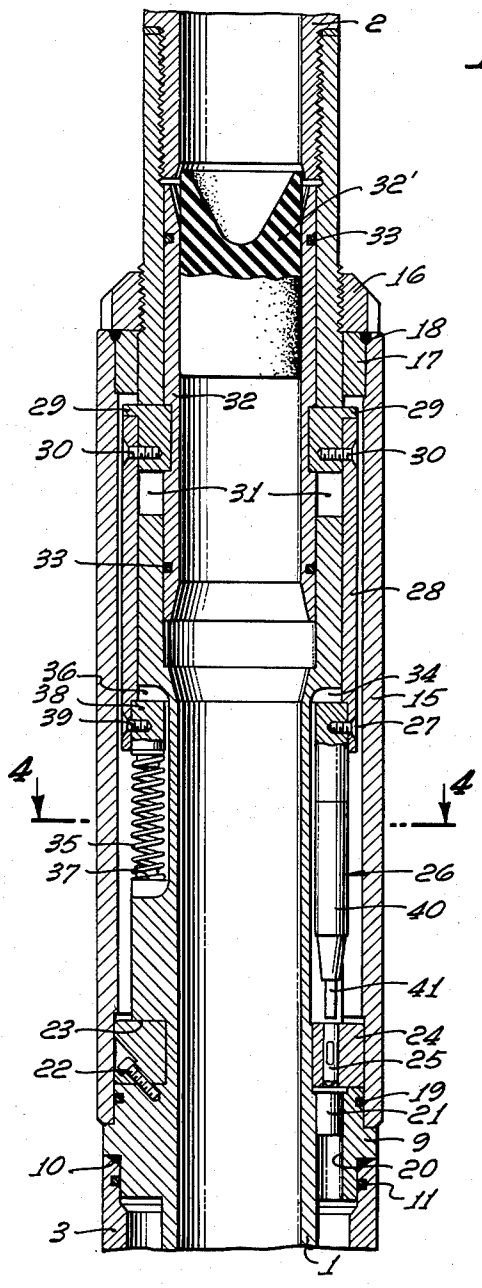
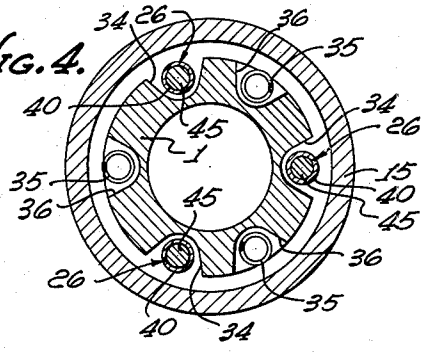


FIG. 2.

FIG. 4.



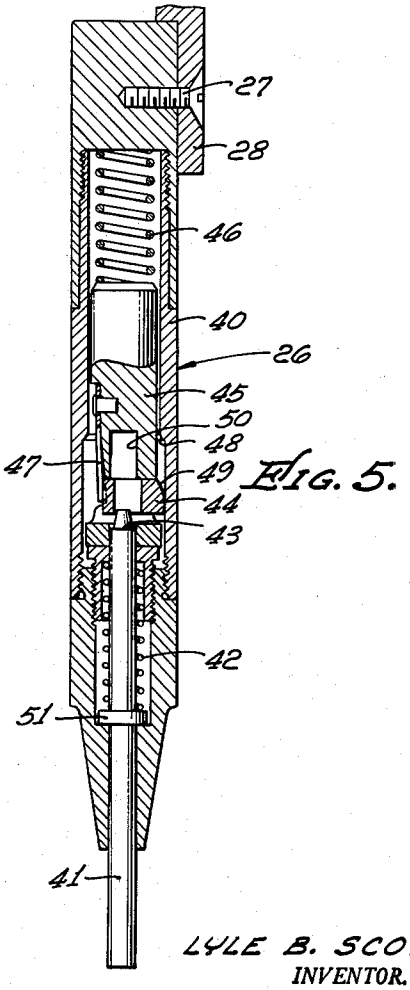


FIG. 5.

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FIRING HEAD FOR FORMATION TREATING APPARATUS

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Filed Feb. 5, 1957, Ser. No. 638,375
15 Claims. (Cl. 166—63)

The present invention relates to apparatus for treating earth formation traversed by a borehole, and more particularly, to a novel and proved firing pin for use in such apparatus.

In the co-pending patent application of Lyle B. Scott and Mathew B. Riordan, filed October 16, 1956, Serial #616,333, for Well Treating Method and Apparatus, there is disclosed a method and apparatus for use in hydraulic treating or fracturing of earth formation; i.e., applying hydraulic pressure to a localized area of the formation.

In the art of drilling and completing wells, particularly oil and gas wells, a number of conditions render desirable the pumping of fluids into the well under pressure. The application of fluid pressure in the well may be desirable for the purpose of hydraulic fracturing, that is, forming fissures or cracks in the formation by raising the overburden of earth. Fluids may also be pumped into a well for cleaning, acidizing, cementing, sand consolidation, and other well-known purposes.

Before the objectives of such fluid treating operations can be attained, high pressures and/or injection rates must oftentimes be provided, thus necessitating a powerful surface pumping set-up. Hydraulic fracturing of the earth formation where the permeability of oil-bearing strata, and hence the ability to produce oil, is improved, in practice may require injection rates and pressures which are difficult of attainment.

The fracturing fluid must be pumped down the well through a tubing or casing and into the open hole either from the bottom of the tubing or casing or through perforations therethrough. This results in friction losses with consequent reductions in injection rates and pressures, depending upon the characteristics of the fluid and depth of the well and the loss of fluid into the formation. In some circumstances, these factors will preclude the application of sufficient pressures downhole as may be necessary to lift the overburden, and no fracturing, or inadequate fracturing, may result. Similar difficulties are encountered in the other fluid treating operations referred to above.

One ideal solution to the problem of applying sufficient downhole fluid pressures and/or injection rates in various well treating operations is the subject of the co-pending patent application above identified. In accordance with the invention therein disclosed, means are provided for assisting the surface pumps in supplying sufficient injection rates and pressures as to render the fluid treatment effective, or at least substantially more effective.

To accomplish this, a container of rocket fuel or low propellant is interposed in the tubing or casing string so as to run into the well and disposed in the vicinity of, or just above, the formation to be fractured or otherwise treated. The propellant or rocket fuel may be of any well-known type which is capable of generating a large volume of gas upon detonation or ignition.

Accordingly, the container is provided with a firing head which is adapted to initiate detonation or ignition of the propellant, without interrupting the injection of fluid into the well. Following such detonation, the invention hereof acts as a huge single-stroke pump generating a tremendous surge of hydraulic horsepower to

displace fluid and boost existing surface-pumped fracturing force.

The burning rate of the propellant or rocket fuel and the quantity of such fuel employed, of course, will determine the value of the increased pressure, so that high boosting pressures may be obtained over varying periods of time. As stated above, this pressure implements and does not replace pump pressure and does not compete or interfere with normal fracturing procedures. It literally assists fluid flow by greatly accelerating and emphasizing the fracturing power right at the zone to be fractured. Little energy is lost to friction; yet markedly higher injection rates at markedly higher pressures are realized with minimum fluid loss.

It is particularly desirable that the flow of treating fluid not be interrupted in fracturing operations where sand or some other propping agent is employed for disposition in the fissures or cracks to prevent their collapse when the pumps are halted. When pumping of fluid stops prior to actual fracturing, such propping agents will settle to the bottom of the well, thus requiring bailing of the well with attendant economic disadvantages.

A primary object of the present invention is to provide a firing head for use in well treating apparatus of the type generally referred to above, wherein the firing head enables continuous flow of treating fluid therethrough before, during, and after the detonation of the rocket fuel or propellant.

Another object is to provide a firing head of the type which is controllable from the surface so as to be operative when the pumps have reached their capacity and the pressure or injection rates supplied therefrom are inadequate to produce the desired results. Accordingly, the firing head hereof is adapted to be rendered operative upon engagement by a plug or other device injectable, without interruption of flow, into the fluid stream at the earth surface so as to flow with the fluid into contact with the firing head.

Another object is to provide a firing head of the just-described type, including an axially shiftable sleeve engageable by said plug so as to be shifted axially in a flow passage through the firing head, said sleeve being interconnected with impact-producing means for actuating a firing pin or for applying a percussive blow to a blank cartridge for firing the latter. The flash from the cartridge serves to ignite or detonate the propellant or rocket fuel charge and thus to promote gas generation, the plug travelling through the flow passage with the treating fluid subsequent to completion of such detonation and responsive to continued pumping action at the surface.

Still another object is to provide a comparatively simple firing head and propellant container, including an orifice tube adapted to be interposed in a tubing or casing string with an outer sleeve or shell encircling the orifice tube to provide therebetween a chamber in which the propellant or rocket fuel is disposed, the chamber also having therein supporting means for a plurality of circumferentially spaced blank cartridges with an annular breech block disposed above the cartridge supporting means, and having firing pins therein engageable with the caps of the cartridges. Supported for axial movement in the chamber above the breech block is a cylindrical support having a plurality of impact-producing devices secured at its lower end in circumferentially spaced relation in axial alignment with the firing pins. At the upper end of the cylindrical support is a number of radially, inwardly extending, supporting lugs, which project through axially extended slots in the orifice tube, for engagement with an operating sleeve, this sleeve being axially shiftably supported within the orifice tube. Thus, a rubber or other type plug, or the like, may be

injected into the fluid stream flowing through the tubing or casing and through the orifice tube, and such plug, or the like, will flow into contact with the operating sleeve to shift the same axially with attendant axial movement of the impact-producing means into operating contact with the firing pins; whereupon the blank cartridges will be fired, the propellant or rocket fuel detonated, and the resultant gases will flow through gas-releasing ports in the orifice tube and apply the pressure produced by such gas to the fluid passing through the orifice tube, thus substantially increasing the hydraulic fracturing horsepower, depending upon the burning rate, quantity, and gas-producing characteristics of the fuel.

Still another object of the invention is to provide a firing head for use in well treating systems as generally described above, including blank cartridges for detonating the propellant or rocket fuel, and including means for applying a percussive blow to the cap of the blank cartridge to fire the same, such means comprising a conventional and well-known type of punch known as a "Starrett" which includes means for creating a sharp impact or percussion responsive to predetermined axial movement thereof, such punches being continuously operatable and needing no cocking in order to be effective. Thus, the firing head hereof is always cocked and ready for use.

Other objects and advantages will be hereinafter described 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 as taken through a pressure-assisting tool embodying the invention with certain of the parts shown in elevation;

Fig. 2 is an enlarged fragmentary view in section as taken longitudinally through the novel firing head hereof, with the parts in a non-firing position;

Fig. 3 is a view similar to Fig. 2, but showing the parts in a firing position;

Fig. 4 is a transverse sectional view as taken on the line 4—4 of Fig. 2; and

Fig. 5 is an enlarged detail view in section as taken axially through a "Starrett" punch device of the type employed in the firing head hereof.

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

Referring to Fig. 1 particularly, the tool therein shown, which embodies the present invention, generally comprises a longitudinally extended orifice tube 1 having tool joints or couplings 2, 2 at its opposite ends. Encircling the orifice tube 1 in concentric spaced relation thereto is a propellant container shell 3 which extends from a point adjacent the bottom of the tube 1 as viewed in Fig. 1, to a point substantially above the middle of the tube 1.

For supporting the shell 3 at its lower extremity, the orifice tube 1 has an exteriorly threaded collar 4 welded or otherwise suitably secured thereto with a supporting nut 5 threadedly mounted upon the collar 4. The lower extremity of the shell 3 has an internal spacer ring 6 slidably engaged with the outer periphery of the collar 4 with a suitable seal, such an as O ring 7 interposed therebetween. The shell 3 is adapted to seat upon the nut 5 and a sealing gasket or ring 8 is preferably disposed in an inverted V-shaped groove defined between the tip of the shell 3 and the contiguous portion of the spacer ring 6.

At its upper extremity, the shell 3 is disposed in abutting engagement with a radially-projecting circumferential flange 9 which is preferably integrally formed with the orifice tube 1. The flange 9 preferably includes an inset shoulder against which the upper end edge of the shell 3 abuts with a sealing ring or element 10 interposed therebetween (see Figs. 2 and 3). In addition, a further sealing element or O ring 11 is interposed between the inner periphery of the upper extremity of the shell 3 and a cylindrical surface of the flange 9. Thus it will be seen that the shell 3 may be forced into engagement with the flange 9 upon rotation of the threaded nut 5, and the sealing elements at opposite ends of the shell 3 will seal the annular space between the shell 3 and the orifice tube 1.

Disposed in the annular space just mentioned, which constitutes a gas chamber, is a gas-generating propellant, preferably of the slow-burning type requiring on the order of ten seconds more or less to burn completely, this propellant being designated 12 and being secured in strip form to the orifice tube 1. The propellant may be one of diverse slow-burning propellants; such as, for example, rubberized ammonium nitrate or the like. A suitable solid propellant may be obtained, for example, from Grand Central Rocket Company, Minton, California, under their designations "CBS–128K" or "CBS–128H." In addition, it may be composed of railroad fusee material, such as sawdust impregnated with sodium or ammonium nitrate, or it may comprise one of a variety of rocket fuels. Suitable propellants are described in Chemistry of Powder and Explosives, 1943, by T. L. Davis, John Wiley & Son, publishers.

The particular type of propellant and the manner of applying the same or disposing the same in the gas chamber forms no part of the instant invention and, therefore, need not be further described herein, except to note that in order to insure detonation of the same, a firing strip or igniter strip 13 is interposed between the fuel and the orifice tube 1, and an igniter ring 14 is disposed about the orifice tube 1 in closely adjacent relation to the firing head now to be described.

It will be noted in view of the foregoing that the chamber defined between the shell 3 and the orifice tube 1 is a closed chamber, sealed by the sealing elements previously described. Means are provided, however, for permitting egress of gas generated by the propellant or rocket fuel. Preferably such means include a plurality of relief ports through plugs 3′ mounted in the orifice tube wall. The relief ports are initially sealed with frangible discs 4′ which will permit the passage of gas through the ports upon such gas attaining a predetermined pressure.

Seating upon the upper portion of the flange 9 and extending axially in concentric spaced relation about the orifice tube 1 is a firing head housing 15 which is engaged at its upper extremity with a lock nut 16, this lock nut being threaded upon the outer periphery of the orifice tube 1 for forcing the housing 15 downwardly into engagement with the flange 9. A spacer ring 17 is disposed between the outer periphery of the orifice tube 1 and the housing 15, and a sealing ring 18 is preferably seated in a groove defined between the ring 17 and the housing 15 for sealing engagement with the undersurface of the nut 16. Thus, the upper end of the housing 15 is desirably sealed by the interpositioning of an O ring or other seal 19 between the flange 9 and the lower extremity of the housing 15.

The flange 9 has a suitable number of axially extended openings 20 therethrough adapted to receive the case of a blank cartridge 21, with the rim of the cartridge preventing passage of the cartridge therethrough. Disposed above the flange 9 and secured as by means of screws 22 in a channel 23 in the outer periphery of the orifice tube 1 is a sectional breech block 24 which is preferably composed of a pair of semi-circular sections which are respectively fastened in position about the orifice tube. The breech block 24 has a suitable number of vertically disposed firing pins 25 reciprocally mounted thereon and contacting the head of the blank cartridges 21, so that an impact upon the firing pins 25 will fire such cartridges.

In order to impose an impact upon the firing pins 25, a plurality of "Starrett" punches 26 are supported in cir-

cumferentially spaced relation above the respective firing pins 25, as by means of screws 27, at the lower extremity of an axially extended and axially movable operating collar 28. At its upper end, the collar 28 is provided with a pair of diametrically opposed, radially inwardly projecting, lugs 29, which are fastened to the collar as by means of screws 30. The lugs 29 extend through elongated, axially extended, slots 31 in opposing relation through the orifice tube 1 and into interlocking engagement with the outer periphery of an axially movable operating sleeve 32, which is slidably disposed within the orifice tube 1, with an O ring 33, or the like, interposed between the contacting surfaces of the sleeve 32 and the orifice tube 1, at the upper and lower ends of the sleeve 32, so as to prevent the passage of fluid therebetween and into the firing head housing 15.

Referring particularly to Figs. 2 and 3, it will be observed that the orifice tube 1 is provided with longitudinally extended, circumferentially spaced, grooves or depressions 34 for accommodating the "Starrett" punches 26. Interspersed with the "Starrett" punches 26 in alternate relation is a like number of compression springs 35, these springs being disposed in longitudinally extended depressions 36 in the orifice tube 1, and seating at their lower ends on a seat 37 formed at the base of each depression 36. An upper spring retaining seat element 38 is also provided for each spring 36, such seat elements being supported at the lower extremity of the operating collar 28 and secured thereto as by a screw 39 or the like.

Accordingly, the springs 36 will normally maintain the operating collar 28 at the limit of its upward movement, with the lugs 29 engaged with the orifice tube 1 at the upper extremity of the slots 31. With the collar 28 in this position, the "Starrett" punches 26 will not be in engagement with the firing pins 25. However, upon downward axial movement of the operating sleeve 32 with attendant downward movement of the operating collar 28 and the "Starrett" punches 26 to the position shown in Fig. 3, the "Starrett" punches 26 will produce a cartridge-firing impact upon the firing pins 24.

Such an action of the punches 26 will best be understood upon reference to Fig. 5, wherein a punch is shown in detail. This punch 26 includes a hollow barrel 40 in the lower end of which is reciprocally mounted a pin 41, this pin being axially shiftable, projecting into the barrel, and having a spring 42 therearound for urging the pin 41 downwardly to the position shown in Fig. 5. At its upper end, the pin 41 is provided with a shoulder 43 projecting radially, whereby, as the pin is caused to move axially upwardly, the shoulder 43 will engage an annular spring-biased cam latch 44 at the margin of an axial opening therethrough. Disposed above the cam latch 44 is a hemmer 45 and a compression spring 46 which is disposed between the hammer 45 and the upper end wall of the barrel 40. Riveted or otherwise suitably secured to one side of the hammer 45 is a downwardly projecting leaf spring 47 which biases the cam latch 44 laterally into engagement with the side wall of the barrel 40.

Upon movement of the pin 41 into the barrel 40, the shoulder 43, engaging with the cam latch 44, will push the hammer 45 upwardly in the barrel 40 against the pressure of the spring 46. However, the barrel 40 is provided with an internal shoulder 48 disposed in the path of movement of the cam latch 44 which is provided with an arched cam surface 49 engageable with the shoulder 48, whereby the cam latch 44 will be cammed laterally against the pressure of the spring 47, whereupon the cam latch 44 will be displaced from the pin shoulder 43 allowing the hammer 45 to be forced downwardly as the upper extremity of the pin 41 passes through the opening in the cam latch 44, with the result that the hammer will strike a sharp blow on the upper extremity of the pin 41. In order to afford a fairly substantial stroke for the hammer 45, it is preferably provided with an axially extended socket 50 into which the upper end of the pin 41 will project prior to the hammer's striking the pin at the base of the socket 50. When the pin 41 is free to reassume the position shown in Fig. 5, the spring 42 will urge the pin outwardly of the barrel 40 until a stop flange 51 on the pin engages at the base of the barrel 40. At the same time, the spring 46 will urge the hammer 45 and the cam latch 44 downwardly as the leaf spring 47 returns the cam plate 44 to its original position.

In practice, fluid under pressure will be pumped down into the well through a tubing or casing and through the orifice tube 1. With the surface pumps providing injection rates and/or pressure at a peak or somewhat below, the rubber or other plug 32' will be inserted into the fluid stream through the lubricator at the well head and will travel down with the fluid until it frictionally engages in the operating sleeve 32.

The plug 32' is preferably of a greater diameter than the axial flow passage through the operating sleeve 32 so that the plug will tend to carry the sleeve 32 therewith. Such movement of the sleeve 32 will effect corresponding downward movement of the operating collar 28. Continued downward movement of the shiftable firing mechanism as aforesaid, will result in the application of a sharp percussive blow to the firing pin 25 by the respective punches 26. This will, of course, fire the cartridges 21.

When the cartridges 21 are fired, the igniter 14 will be ignited or detonated and the ignition will be carried to the propellant strips 12, their continued ignition being assured by the underlying igniter strips 13. Such ignition of the propellant or rocket fuel 12 will produce over a period of time, a high volume of gas which will blow the relief plugs out of the relief ports, thus allowing the gases to escape into the orifice tube 1 and exert a single-stroke pumping force upon the fluid column, substantially increasing the hydraulic horsepower available for treating the well.

During this period of time the surface pumps are continuously operated, and upon exhaustion of the gases from the burning of the propellant, continued fluid pressure will force the rubber plug through the orifice tube, thus allowing continued application of pump pressure to the formation.

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

I claim:

1. In well treating apparatus comprising a container of gas-generating material adapted to be disposed in a well adjacent to earth formation to be treated, means for initiating the release of gas generated by said material into the well, including means responsive to a percussive blow, and mechanism for striking such a percussive blow, that improvement wherein the striking means includes an axially moveable support, a punch assembly extending from said support towards said blow responsive means, said punch assembly including a pin engaged with said blow responsive means, an elongated barrel connected to said support and embracing said pin, said barrel being axially shiftable relative to said pin, and means within the barrel for exerting a hammer blow on said pin upon movement of said support beyond a predetermined limit towards said blow responsive means.

2. In fluid injection apparatus for a well, a tubing string adapted to be disposed in the well, a container located in said string beneath the earth surface, said container having a flow passage communicating with said tubing, said container also having a closed chamber, an ignitable material capable of generating gas upon ignition in said closed chamber, firing means for igniting said material including a firing head having a fluid passage communicating with said tubing, fluid pumping means at the earth surface above said well for pumping fluid into the well through said tubing and through said firing head

and container, actuator means insertable into the tubing into the path of flow of the fluid, and axially moveable operating means on the firing head engageable by said actuator means, that improvement wherein said firing head includes an axially moveable support interconnected with said operating means for movement therewith, and punch means carried by said support and engageable with said firing means for imposing a sharp percussive blow thereon, said punch means including a pin and means for striking said pin upon movement of said punch means beyond a predetermined extent, said firing means being operative responsive to said percussive blow to ignite said gas generating material.

3. Fluid injection apparatus as defined in claim 2, including resilient means acting upon said support to urge the latter oppositely to the firing direction of movement thereof.

4. A firing head of the class described, comprising a housing, firing means in said housing operative responsive to a percussive blow, and operating means for producing such a percussive blow including a punch assembly, said punch assembly including a pin engageable with said firing means, an elongated barrel carrying and embracing said pin and movable axially relative thereto, and means within the barrel for exerting a hammer blow on said pin upon movement of said barrel beyond a predetermined limit towards said firing means.

5. A firing head as defined in claim 4, wherein said operating means includes a reciprocatable support on which said punch assembly is rigidly mounted, said housing having an opening therein, and said support includes a portion projecting through said opening and adapted to be engaged by actuator means for shifting said support.

6. A firing head as defined in claim 4, wherein said operating means includes a reciprocatable support having means adapted to be engaged by actuator means for shifting the same in a punch-operating direction, and resilient means for biasing said support in the other direction.

7. A firing head of the class described, comprising a housing, said housing having inner and outer walls defining a space therebetween, firing means in said housing operative responsive to a percussive blow, means for producing such a percussive blow including a punch mechanism disposed in the space aforesaid and having a pin engaged with said firing means, means for striking said pin upon movement of said punch mechanism in said space beyond a predetermined limit and means for shifting said punch mechanism.

8. A firing head of the class described, comprising a housing, said housing having inner and outer walls defining a space therebetween, firing means in said housing operative responsive to a percussive blow, said firing means including a plurality of circumferentially spaced blank cartridges, means for supporting said cartridges, means for producing such a percussive blow including a punch mechanism having a pin engaged with each cartridge, means for striking said pin upon movement of said punch mechanism in said space beyond a predetermined limit and means for shifting each punch mechanism.

9. A firing head as defined in claim 8, wherein the means for operating each punch mechanism includes a support axially moveable in the housing space, said support having means projecting therefrom through a wall of said housing and adapted to be engaged by actuator means for shifting the same, each of said punch mechanisms being rigidly mounted upon said support for movement therewith.

10. A firing head as defined in claim 8, wherein the means for operating each punch mechanism includes a support axially movable in the housing space, and including means for shifting said support in one direction, and resilient means operative upon said support to bias the same in the other direction.

11. A firing head as defined in claim 8 wherein one of said housing walls is provided with a plurality of circumferentially spaced, axially extended depressions, with each punch mechanism disposed in one of said depressions, and including springs disposed in other of the depressions and engaged with said operating means for opposing operation of said punches.

12. A firing head of the class described, comprising a hollow elongated support, firing means carried by said support including a plurality of spaced firing elements, and means for subjecting said firing elements to a percussive blow, said latter means including a plurality of shiftable punch assemblies having pins engaged with the respective firing elements, means for shifting said punch assemblies simultaneously in the direction of said firing elements, and said punch assemblies having means for striking said pin upon movement of said punch assemblies beyond a predetermined limit.

13. A firing head of the class described, comprising a hollow elongated support, firing means carried by said support including a plurality of spaced firing elements, and means for subjecting said firing elements to a percussive blow, said latter means including a plurality of punch assemblies engaged with the respective firing elements, means for operating said punch assemblies simultaneously, said operating means including a member shiftably mounted on said support for movements towards and away from said firing means, said punch assemblies being rigidly mounted on said operating member for movement therewith, and each punch assembly including a pin engaged with said firing means, an elongated barrel embracing said pin and shiftable relative to said pin, and means within the barrel for exerting a hammer blow on said pin upon movement of said barrel beyond a predetermined limit towards said firing means.

14. A firing head of the class described, comprising a hollow elongated support, firing means carried by said support including a plurality of spaced firing elements, and means for subjecting said firing elements to a percussive blow, said latter means including a plurality of punch assemblies engaged with the respective firing elements, means for operating said punch assemblies simultaneously, said operating means including a member shiftably mounted on said support for movements towards and away from said firing means, said punch assemblies being rigidly mounted on said operating member for movement therewith, and said support and said operating means having means biasing the same relatively in one direction, including a spring operatively interposed between said support and said operating member.

15. A firing head of the class described, comprising a hollow elongated support, firing means carried by said support including a plurality of spaced firing elements, and means for subjecting said firing elements to a percussive blow, said latter means including a plurality of punch assemblies engaged with the respective firing elements, means for operating said punch assemblies simultaneously, said operating means including a member shiftably mounted on said support for movements towards and away from said firing means, said punch assemblies being rigidly mounted on said operating member for movements therewith, said support having a plurality of spaced grooves therein, said firing elements being respectively disposed in substantial alignment with said grooves, and said punch assemblies being respectively bodily disposed in said grooves.

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