Feb. 27, 1962 L. H. ROBINSON, JR 3,022,729

APPARATUS FOR DRILLING BOREHOLES WITH EXPLOSIVE CHARGES

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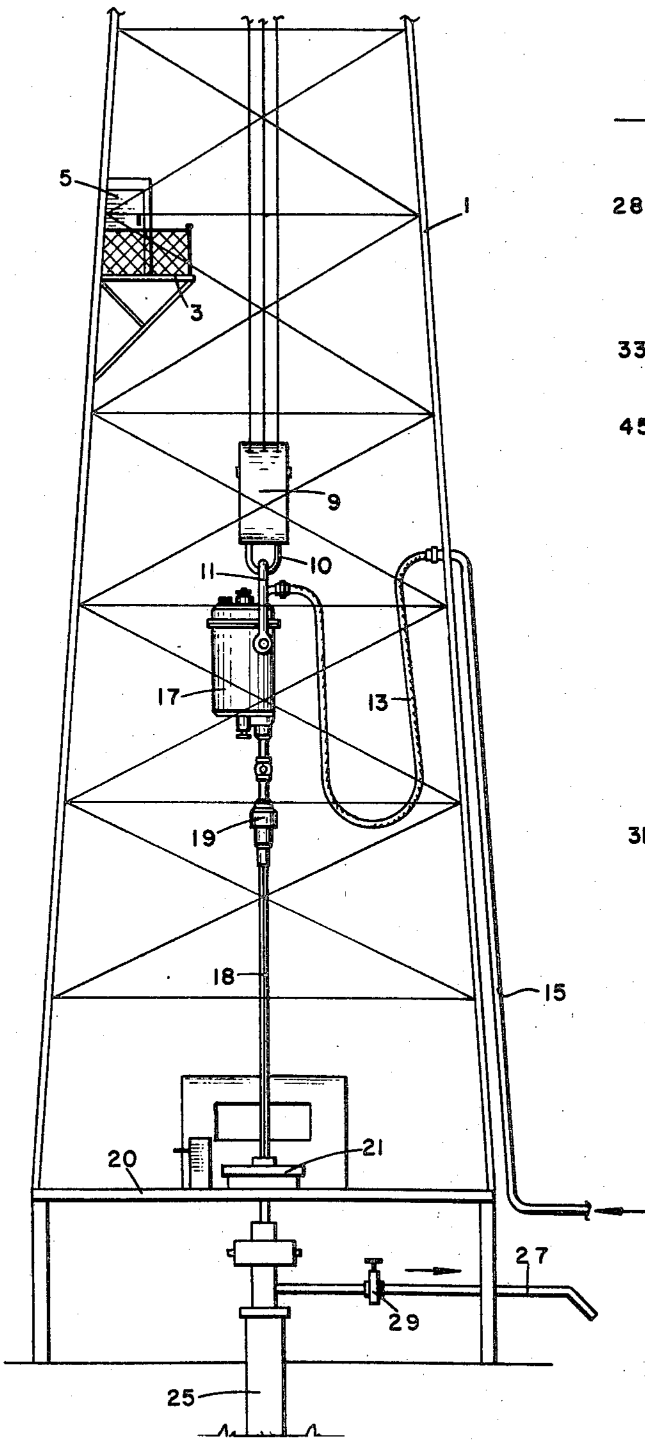
FIG. 1.



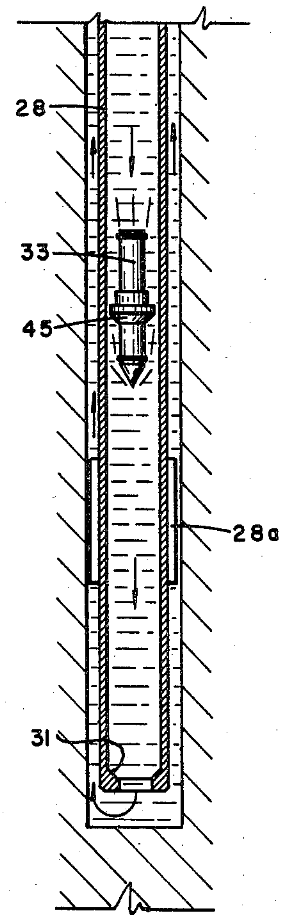


FIG. 2.

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FIG. 3.

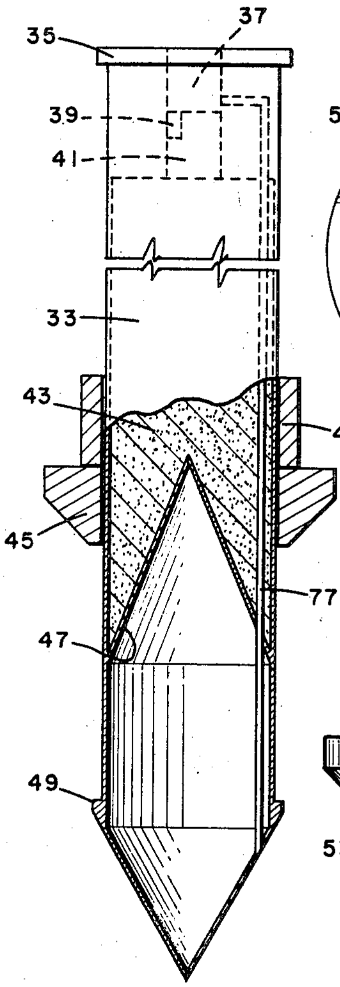


FIG. 4.

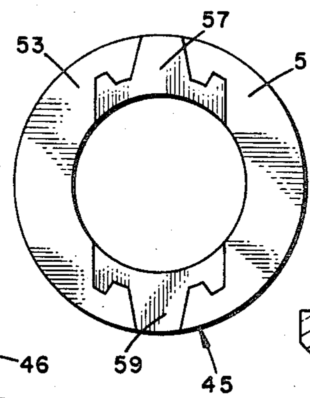
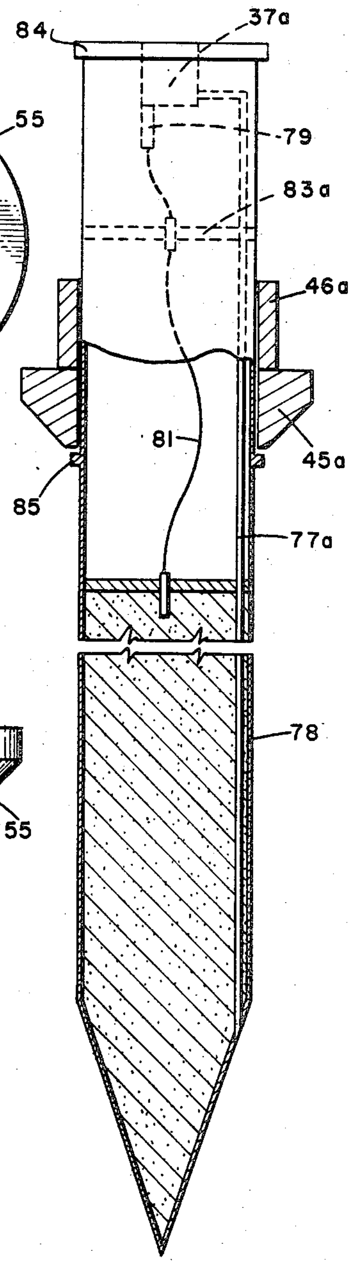


FIG. 7



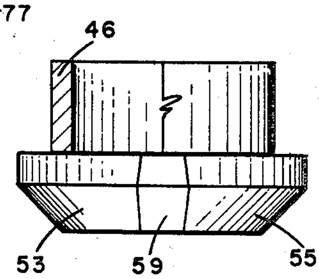
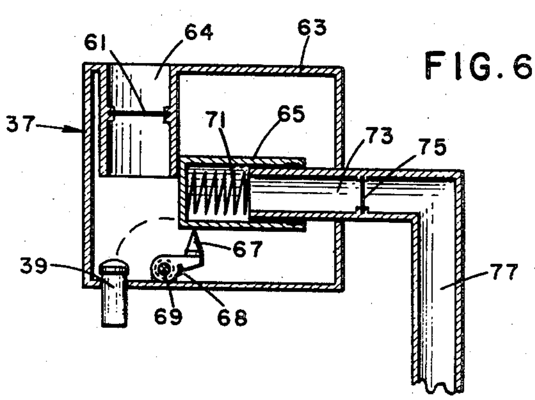


FIG. 5.

FIG. 6.



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APPARATUS FOR DRILLING BOREHOLES WITH EXPLOSIVE CHARGES

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Filed Nov. 27, 1959, Ser. No. 855,616
4 Claims. (Cl. 102—20)

This invention relates to the drilling of boreholes, and more particularly to drilling boreholes utilizing a succession of explosive charges including shaped jet charges.

In connection with drilling boreholes for the purpose of exploiting possible hydrocarbon deposits in the earth, it has been known to utilize explosive charges for the purpose of expediting drilling operations. It has also been known to use shaped jet charges in combination with nondirectional blasting charges. Examples of the prior art use of explosive charges for drilling operations may be found in U.S. Patent No. 2,897,756 to L. Borins et al. and U.S. Patent No. 2,587,243 to W. Sweetman.

Previous attempts to use explosive charges for earth drilling have been characterized by very slow penetration rates, great expense, and the necessity for using more or less cumbersome equipment. While the development of shaped jet charges has made the use of explosives for drilling more attractive because of the directional characteristics of the shaped charge, it has not proved to be a cure-all for the deficiencies of explosive drilling. A prime reason is that, while the shaped charge is capable of penetrating further into the earth than can a nondirectional explosive charge, it blasts a hole that is quite wide at its mouth but which narrows rapidly and terminates in an elongated cavity that is far too narrow to accommodate a well or drill pipe. The use of blasting charges in the manner taught by the aforecited Borins et al. patent has not particularly helped the situation because the blasting charges do not deepen or widen the hole drilled by the shaped charge to any great extent.

The present invention makes use of a well pipe having a landing seat or nipple at or near its lower end. The well pipe is connected to conventional mud circulating equipment at the surface so that drilling fluid is pumped down the well pipe and up the annulus around the well pipe. Use is made of elongated shaped jet charges and elongated non-directional gauging charges adapted to be pumped down the well pipe, and further adapted to seat on the landing nipple or seat so that a differential pressure is built up thereacross.

The jet charges and gauging charges are injected into the stream of drilling fluid going down the well pipe, according to a predetermined sequence. First, a shaped charge is pumped down the well pipe. After it seats on the landing seat, the explosive portion of the jet charge is spaced from the bottom of the borehole a predetermined distance, and a pressure of predetermined magnitude is built up across the shaped charge. Responsive to differential pressure, the charge is detonated so as to blast a hole in the earth at the bottom of the well bore. A gauging charge is then landed on the seat so as to extend into the hole produced by the preceding shaped jet charge. Preferably, the gauging charge is long enough to penetrate substantially the entire length of the hole blasted by the shaped charge. The gauging charge, which may be of a brisant or unbrisant explosive material or a combination thereof, is detonated while tamped with drilling fluid and preferably while under a hydrostatic pressure of at least 1000 p.s.i. Drilling fluid is circulated after each detonation of a shaped charge and a gauging charge so as to remove earth fragments and fragments of the explosive charge housing. Preferably, the explosive charges are injected into the drilling stream so as to be spaced apart substantially 100 to 4000 feet, and the drilling fluid is circulated so that particles therein are traveling at the rate of between 100 and 400 feet per minute so that the successive explosive charges are detonated between 1 and 10 minutes apart.

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The invention will be more completely understood, and the various objects and features of the invention will become apparent upon consideration of the following description thereof when taken in connection with the accompanying drawings, wherein:

FIG. 1 is a perspective diagram of a portion of equipment that may be used at the earth's surface in connection with the practice of the invention;

FIG. 2 is a view of a shaped jet charge being pumped down a well pipe, showing a preferred construction of the lower end of the well pipe;

FIG. 3 is a side view, partially in cross-section, of a preferred jet charge capsule to be used in connection with the invention;

FIG. 4 shows certain details of the firing collar shown in FIG. 3;

FIG. 5 is a side view of a portion of the firing collar of FIG. 3;

FIG. 6 is a cross-sectional view showing the differential pressure responsive firing mechanism shown in FIG. 3;

FIG. 7 is a side view, partially in cross-section, of a gauging charge to be used in connection with the present invention.

In FIG. 1 there is shown surface equipment for use in connection with the present invention. The usual drilling rig **1** is provided with an explosive charge loader's platform **3** at a distance above the drilling floor **20** determined by the length of well or drill pipe to be run into the hole to be drilled with the apparatus. An explosive charge housing **5** for storing explosive charges is located on the loader's platform **3**.

The usual traveling block **9** is suspended from a crown block (not shown) by cables in the usual manner. Located between the swivel **19** and hook **10** is an explosive charge magazine housing **17**. Connected to swivel **19** is a Kelly joint **18** which extends through the rotary table **21** into the surface casing **25**. The function of the magazine housing is to provide remotely controlled apparatus for injecting a plurality of explosive charges into the well according to a predetermined sequence. Drilling fluid is circulated through the magazine housing **17** into the swivel **19** and Kelly joint **18** from the usual standpipe **15** and hose connection **13**. A mud pump (not shown) supplies pressurized drilling fluid to the standpipe. Below the drilling floor **20** is located the usual mud return line **27** which may be controlled by a valve **29**. The mud control line is hydraulically coupled to the annular space around the drill pipe in the usual manner.

As shown most perspicuously in FIG. 2, the drill or well pipe **28** is provided with a landing seat **31** at or near its lower end. The purpose of this landing seat is to receive a collar **45** fitted around an explosive charge **33** which is pumped down the well. When the collar **45** lands on the seat **31**, flow of drilling fluid down through and out the lower end of the well pipe will be either stopped or substantially reduced so that a differential pressure will be built up across the explosive charge. As will be described in detail below, differential pressure is used for the purpose of firing the explosive charge.

The details of the explosive charge magazine housing **17** are described in copending application Serial No. 855,681 of L. H. Robinson and R. H. Friedman, filed concurrently herewith.

FIGS. 3, 4, 5, and 6 illustrate a preferred embodiment for the shaped jet charge, its container, and the firing collar illustrated in FIG. 2. As shown in FIG. 3, the brisant explosive charge material **43** is encapsulated in a housing or container **33** along with the usual booster charge **41** and detonator **39**. In addition, there is provided a firing mechanism **37** for the purpose of firing the detonator **39** responsive to a predetermined differential pressure across the opposed ends of the explosive charge container. The details of the firing mechanism will be described below with reference to FIG. 6. Inasmuch as the use of a shaped jet charge is contemplated, the usual conical liner **47** is provided. At the upper and lower ends of the container **33** there are provided stop members **35** and **49**. The purpose of the stop members is to hold a seating ring or firing collar **45** on the charge container. The firing collar is longitudinally slidable along housing **33** and has a tapered lower surface for the purpose of seating on the seat **31** at the bottom of the drill pipe so that a differential pressure can be produced across the charge. A frangible sleeve **46** is attached to the upper end of collar **45** by a suitable adhesive, the sleeve **46** serving to keep the collar **45** properly aligned on the housing **33**. The details of the firing collar are best illustrated in FIGS. 4 and 5. The firing collar is formed of members **53** and **55** and locking members **57** and **59**. The purpose of the locking members is to prevent the firing collar from coming apart before the charge is fired and to permit the firing collar to collapse inwardly when the container is destroyed by firing the charge. As shown in FIG. 5, the outer edges of the locking members have a V shape so that they will not drop away from the members **53** and **55** when in locking engagement therewith.

The details of the firing mechanism are shown in FIG. 6. The firing mechanism includes a housing **63** having an inlet tube **64** open to borehole pressure, and an outlet tube **73** opening into a low pressure tube **77**. The low pressure tube **77** extends the length of the shaped charge container to the bottom of the container so that it is exposed to the pressure outside of the drill pipe when the firing collar **45** is seated on seat **31**. The outlet tube **73** extends into the interior of the housing **63**. A flexible, resilient diaphragm **61** of rubber-like material such as neoprene seals the inlet tube **64**. A similar diaphragm **75** seals the outlet tube **73**. The interior of the housing **63** thus is fluid-tight and is filled with water, glycerin, or other suitable, substantially incompressible liquid. A release collar **65** is in sliding fit over the tube **73**. A spring **71** normally biases the release collar **65** away from the tube **73** so that it engages the tube **64** of the inlet port. A firing pin **67** is pivoted about a pivot member **69** and is spring-biased by means of spring **68** to rotate counterclockwise as shown in FIG. 6. The firing pin will be released when release collar **71** is moved to the right so as to strike detonator **39** at one end of its arc of movement. The release collar is moved to the right when a sufficiently large differential pressure exists between the inlet tube **64** and the low pressure tube **77**. The differential pressure will cause diaphragm **61** to bulge downwardly into the housing **63** so as to force the release collar to the right and release the firing pin **67** so that it will strike the detonator **39**.

The diaphragms **61** and **75** are not absolutely necessary, but serve to keep clean fluid around the working parts of the firing mechanism. This is desirable to insure that the firing mechanism will function properly.

FIG. 7 illustrates a gauging charge particularly adapted for use with the present invention. The gauging charge comprises a housing **78** similar to the housing used with the shaped charge. A firing collar **45*a*** is provided that is similar to firing collar **45**. A frangible sleeve **46*a*** is also attached to the collar **45*a***. The firing mechanism **37*a*** may be substantially the same as firing mechanism **37**. A low pressure tube **77*a*** extends from the firing mechanism **37*a*** to the lower end of the charge container in the same manner as described above with respect to low pressure tube **77**. A substantial section of the lower portion of the container is filled with a brisant or unbrisant explosive material or a mixture of brisant and unbrisant explosives. There is no conical liner provided with the device so that the explosive effects of the gauging charge are substantially nondirectional. A stop **85** is provided above the topmost level of the explosive so that firing collar **45*a*** will land on seat **31** in such a manner that the topmost level of the explosive charge will be spaced from the bottom of the well pipe. The housing **78** is also provided with an upper stop **84**. This construction is for the purpose of preventing damage to the well pipe when the explosive charge is detonated. The container may be formed of a frangible material so as to be destroyed easily. The blasting cap **79**, when struck by firing pin **67**, will be detonated and will ignite a length of primacord **81**. To facilitate destruction of the container, the primacord may be wound in a spiral around the inner surface of the container. Also, an auxiliary disintegrating charge **83*a*** of tetryl or like material may be used to complete the destruction of the container. The container may be formed of a plastic material. A particularly suitable explosive for use in connection with the gauging charge is PETN or composition B (RDX and TNT). Other suitable explosives may be found on page 4 of the text "The Science of High Explosives" by M. A. Cook (Reinhold Publishing Company, 1958). The length of the lower end of the container **78** containing the explosive preferably is long enough to extend substantially the length of the hole blasted by the shaped charge.

The operation of the apparatus described in FIGS. 1 through 7 is as follows. Before the apparatus described above is used, a borehole may be drilled in the earth through the relatively soft earth formations near the earth's surfaces by means of conventional rotary drilling equipment. Alternatively, the apparatus described above may be utilized from the time that the well is spudded. However, it usually will be found to be more economical to use a rotary drilling procedure for the initial stages of drilling the borehole until relatively hard earth formations are encountered.

When a hole has been drilled to a desired depth in the conventional manner, the rotary drill pipe may be pulled out of the hole and a thinner walled pipe **28** such as shown in FIG. 2 may be substituted therefor. An advantage associated with utilizing thinner walled pipe is that larger explosive charges can be run down the pipe. The lower stand of the pipe may be provided with reamer blades **28*a*** for the purpose of reaming the hole should such become necessary. Likewise, the lowermost edge of the pipe may be studded with diamonds to rotary-drill for short time intervals should relatively soft earth formations be encountered.

Initially, a shaped charge **33** from magazine housing **17** is injected into the drilling fluid stream. At intervals of approximately 1 to 10 minutes, the driller may inject the other charges from the magazine housing **17** into the fluid stream. When a shaped charge is seated at the bottom of the well pipe, manifestly the differential pressure across the shaped charge will detonate the charge as described above. An elongated tapered hole will be produced. Drilling fluid circulation will continue so that detritus including earth fragments, fragments of the shaped charge container, and fragments of the firing collar **45** will be circulated up the annulus around the well pipe.

One or more gauging charges are landed in succession at the bottom of the pipe after each shaped charge. It will be found that one gauging charge is sufficient to enlarge the entire hole to a desired diameter. As mentioned above, the gauging charges should extend substantially to the bottom of the hole formed by the jet charge. Collar **45*a***, inasmuch as it is slidable along at least a portion of the gauging charge container, will readily seat on the seat **31** so that a differential pressure will build up to detonate the gauging charge. Manifestly, the gauging charge will be tamped; a hydrostatic pressure of at least

1000 p.s.i. will be exerted thereon. When a gauging charge is detonated, it will be found that an almost perfect cylindrical hole will be blasted into the earth formations by the gauging charge. The hole will be amazingly uniform in diameter and will be of a sufficiently large diameter so that the well pipe 28 may be lowered to the depth of the hole blasted by the shaped charge 33. It will be found that, by virtue of the fact that the gauging charge is tamped and under hydrostatic pressure, the volume of earth that is spalled by the gauging charge will be between 50 and 100 percent greater than when the explosive charge is not tamped and is not under hydrostatic pressure. A hydrostatic pressure of at least 1000 pounds has been found to be satisfactory. Much higher hydrostatic pressures may be utilized with the effectiveness of the gauging charge increasing as the hydrostatic pressure is increased. Detritus produced by the gauging charge may be circulated out of the hole formed as described above, as the well pipe is lowered.

The invention is not to be restricted to the specific structural details, arrangement of parts, or circuit connections herein set forth, as various modifications thereof may be effected without departing from the spirit and scope of this invention.

What is claimed is:

1. An explosive charge capsule for injection into a well pipe having a seating surface at the lower end thereof, comprising: an elongated housing having a compartment for an explosive charge material; an annular seating ring slidably affixed to the elongated housing and longitudinally slidable along the housing, adapted to seat on the seating surface of the well pipe to substantially seal the well pipe against fluid flow downwardly therethrough; a firing apparatus enclosure in said capsule; an inlet line hydraulically coupling the exterior of the upper portion of the capsule to the interior of the enclosure; an outlet line extending into said enclosure hydraulically coupling the interior of said enclosure to the exterior of the lower portion of said capsule; a sleeve in said enclosure slidably fitting over the end of said outlet line, and having a closed end; a coil spring within said sleeve biasing the closed end of said sleeve away from the end of said outlet line within said enclosure, yieldable under differential pressure between said outlet line and said inlet line so that the closed end of said sleeve slides toward said end of said outlet line; first and second resilient diaphragms respectively sealing the interior of said inlet line and the interior of said outlet line so that said enclosure is fluid-tight; a substantially incompressible fluid within said enclosure; a detonating charge extending into said enclosure and into said compartment for detonating explosive material within said compartment; a firing pin pivotally supported within said enclosure positioned to strike said detonating charge at one end of its arc of movement, said firing pin being positioned relative to said sleeve so that said sleeve prevents rotation of said firing pin toward said one end of its arc of movement from the other end of its arc of movement until a predetermined differential pressure between said inlet line and said outlet line moves said sleeve a predetermined distance toward said end of said outlet line; and spring means biasing said firing pin for pivotal movement to engage said sleeve and strike said firing pin.

2. An explosive charge capsule for injection into a well pipe having a seating surface at the lower end thereof, comprising: an elongated housing having a compartment for an explosive charge material; an annular seating ring slidably affixed to the elongated housing and longitudinally slidable along the housing, adapted to seat on the seating surface of the well pipe to substantially seal the well pipe against fluid flow downwardly therethrough; a firing apparatus enclosure in said capsule; an inlet line hydraulically coupling the exterior of the upper portion of the capsule to the interior of the enclosure; an outlet line extending into said enclosure hydraulically coupling the interior of said enclosure to the exterior of the lower portion of said capsule; a sleeve in said enclosure slidably fitting over the end of said outlet line, and having a closed end; a coil spring within said sleeve biasing the closed end of said sleeve away from the end of said outlet line within said enclosure, yieldable under differential pressure between said outlet line and said inlet line so that the closed end of said sleeve slides toward said end of said outlet line; a detonating charge extending into said enclosure and into said compartment for detonating explosive material within said compartment; a firing pin pivotally supported within said enclosure positioned to strike said detonating charge at one end of its arc of movement, said firing pin being positioned relative to said sleeve so that said sleeve prevents rotation of said firing pin toward said one end of its arc of movement from the other end of its arc of movement until a predetermined differential pressure between said inlet line and said outlet line moves said sleeve a predetermined distance toward said end of said outlet line; and spring means biasing said firing pin for pivotal movement to engage said sleeve and strike said firing pin.

3. An explosive charge capsule for injection into a well pipe having a seating surface at the lower end thereof, comprising: an elongated housing having a compartment for an explosive charge material; an annular seating ring slidably affixed to the elongated housing and longitudinally slidable along the housing, adapted to seat on the seating surface of the well pipe to substantially seal the well pipe against fluid flow downwardly therethrough; a firing apparatus enclosure in said capsule; an inlet line hydraulically coupling the exterior of the upper portion of the capsule to the interior of the enclosure; an outlet line extending into said enclosure hydraulically coupling the interior of said enclosure to the exterior of the lower portion of said capsule; a sleeve in said enclosure slidably fitting over the end of said outlet line, and having a closed end; a coil spring within said sleeve biasing the closed end of said sleeve away from the end of said outlet line within said enclosure, yieldable under differential pressure between said outlet line and said inlet line so that the closed end of said sleeve slides toward said end of said outlet line; a detonating charge extending into said enclosure and into said compartment for detonating explosive material within said compartment; and a spring-biased firing pin biased so as to strike said explosive charge at one extremity of its path of movement, and positioned relative to said sleeve so that said sleeve holds said firing pin away from said detonating charge until a predetermined differential pressure exists between said inlet line and said outlet line whereby said firing pin will be released to strike said detonating charge.

4. An explosive charge capsule for injection into a well pipe having a seating surface at the lower end thereof, comprising: an elongated housing having a compartment for an explosive charge material; an annular seating ring operatively associated with said elongated housing adapted to seat on the seating surface of the well pipe to substantially seal the well pipe against fluid flow downwardly therethrough; a firing apparatus enclosure in said capsule; an inlet port hydraulically coupling the exterior of the upper portion of the capsule to the interior of the enclosure; an outlet port extending into said enclosure hydraulically coupling the interior of said enclosure to the exterior of the lower portion of said capsule; a sleeve in said enclosure slidably fitting over the end of said outlet port, and having a closed end; a coil spring within said sleeve biasing the closed end of said sleeve away from the end of said outlet port within said enclosure, yieldable under differential pressure between said outlet port and said inlet port so that the closed end of said sleeve slides toward said end of said outlet port; a detonating charge extending into said enclosure and into said compartment for detonating explosive material within said

compartment; and a spring-biased firing pin biased so as to strike said explosive charge at one extremity of its path of movement, and positioned relative to said sleeve so that said sleeve holds said firing pin away from said detonating charge until a predetermined differential pressure exists between said inlet port and said outlet port whereby said firing pin will be released to strike said detonating charge.

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