May 1, 1962 J. D. CHESNUT 3,031,964

WELL PERFORATING METHOD AND MEANS THEREFOR

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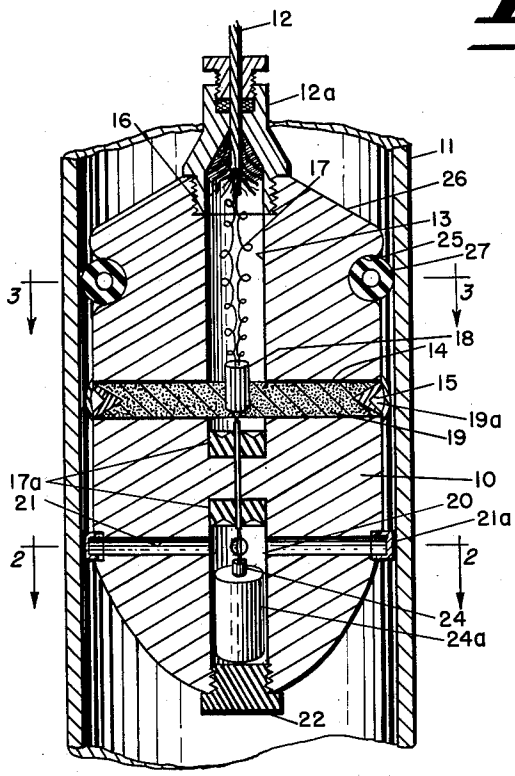


Fig. 1

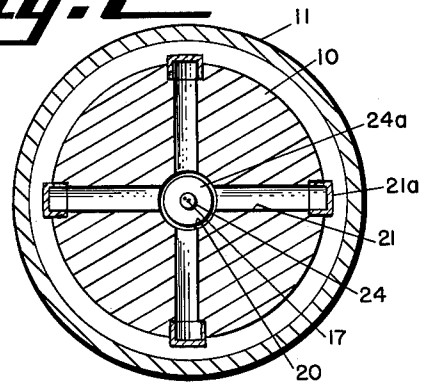


Fig. 2

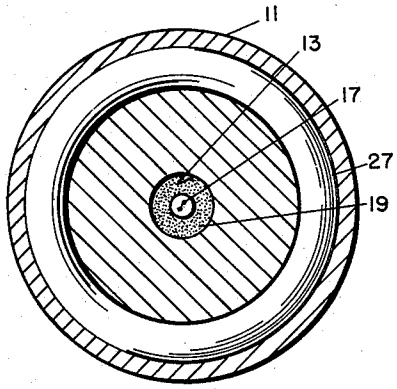


Fig. 3

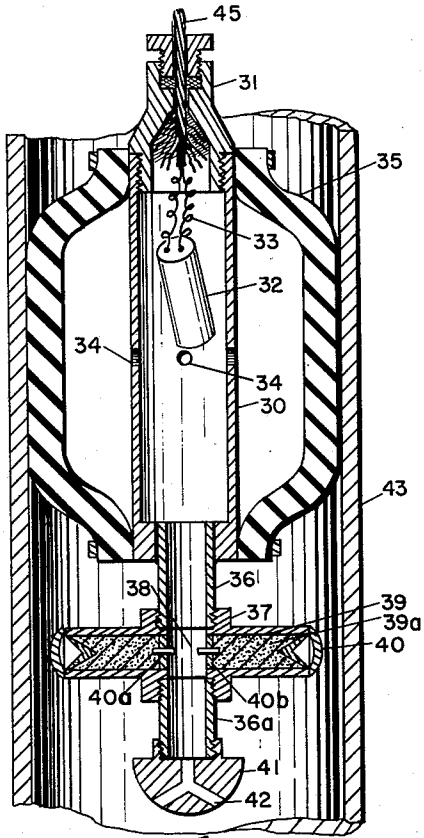


Fig. 4

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Fig. 5

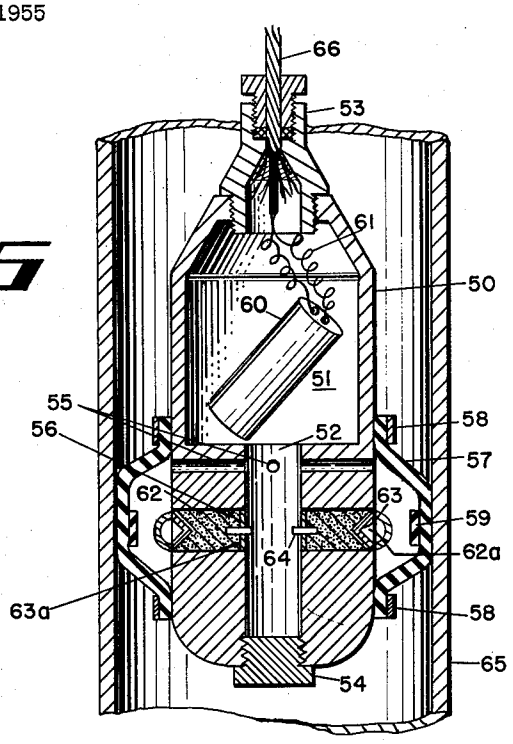
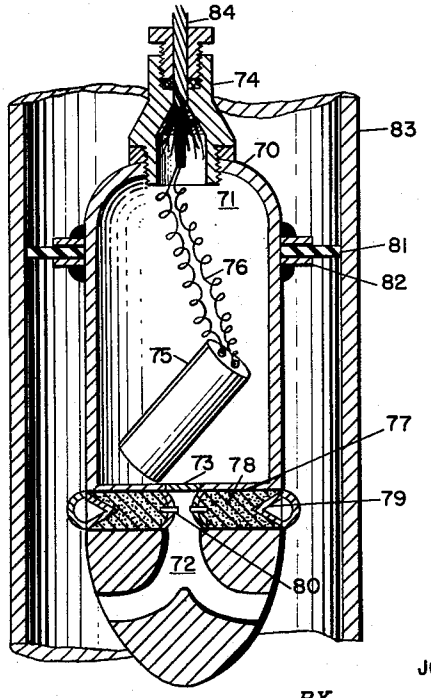


Fig. 6



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Fig. 7

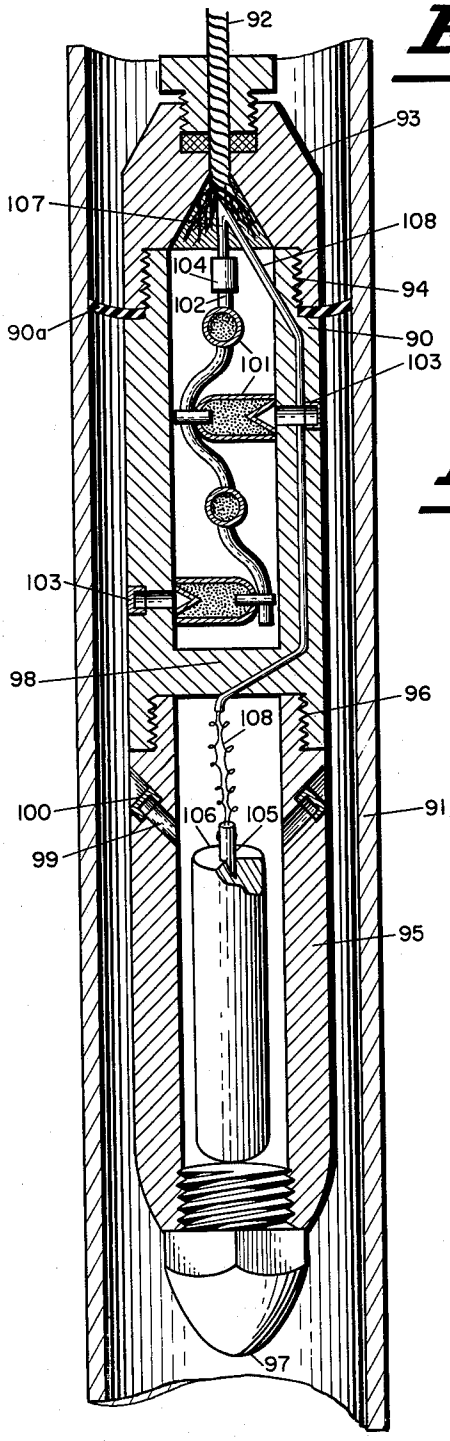
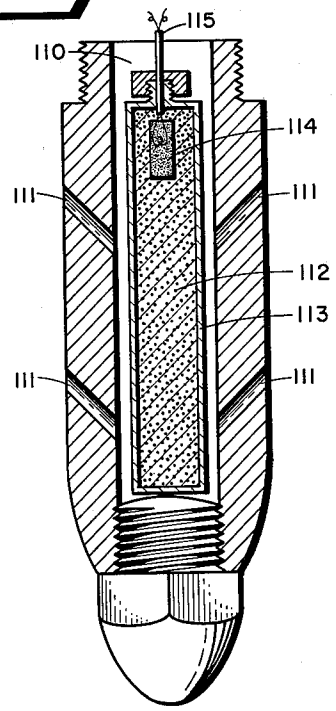


Fig. 8



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United States Patent Office 3,031,964 Patented May 1, 1962

3,031,964

WELL PERFORATING METHOD AND MEANS THEREFOR

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Filed Aug. 22, 1955, Ser. No. 529,622
6 Claims. (Cl. 102—21)

This invention relates to perforation of wells or well casings.

Wells and well casings are generally perforated by explosive means either by firing armor-jacketed bullets into or through them, or by directing jet blasts from shaped charges at them. If liquids are standing in the region through which the bullet or jet is to pass, the effectiveness of these perforating means is drastically reduced because of the great pressure usually acting on the liquid and the energy consumed in forcing the projectile or jet through it. It is an object of this invention to increase the penetration of such perforating means by displacing liquids from their path so that they need pass only through a gaseous medium. The invention is applicable also to the perforation of wells which do not contain casings, and also to that form of casing perforation known as casing severing.

In accordance with the present invention, I provide a method and means for filling the region of the well which is to be perforated with a volume of gas under sufficient pressure to displace any well liquid which may be present and retain the gas as an envelope surrounding the perforating tool so that the perforating operation can be performed in this gaseous medium instead of in a liquid medium.

A feature of the invention resides in the provision of a carrier adapted to be lowered into a well casing, the carrier being provided with perforating means of the explosive type and a gas producing material. A suitable barrier to yieldably close the casing at the carrier is employed. Suitable means initiates the gas production so that gas is formed under pressure and caused to enter the casing below the perforating means and below the barrier.

The perforating mechanism is located somewhat below the barrier and in the region of the casing to be filled with the gas. The release of the gas beneath the barrier will displace all well liquids upwardly out of the gas filled region so that the perforating means such as bullets or jets will operate in the gaseous medium.

A preferred feature is the use of a gas-producing charge of a material which carries the oxygen for its own combustion so that outside oxygen such as from the atmosphere is not required for producing the gas.

These and other features of the invention will be fully understood from the following detailed description and the accompanying drawings, of which:

FIG. 1 is an elevation, partly in cross-section, of an embodiment of a well perforator incorporating the present invention;

FIG. 2 is a cross-section taken at line 2—2 of FIG. 1;

FIG. 3 is a cross-section taken at line 3—3 of FIG. 1;

FIGS. 4–6 are elevations, partly in cross-section, of other types of perforators incorporating the invention; and

FIGS. 7 and 8 are elevations, partly in cross-section, of still other embodiments of the present invention.

Referring now to the drawings, FIG. 1 shows a jet-type perforator incorporating the gas enveloping means of the invention. A carrier **10** is made of a material dense enough to sink in the well. It is suspended in the well casing **11** by an insulated electric line **12**. A wire

line socket **12***a* on the carrier provides an attachment for the line. An access port having a central bore **13** is formed in the top of the carrier and extends downward therefrom. Two or more horizontal perforator ports **14** branch off from this bore **13**, and are plugged off at the carrier surface by frangible conical retainers **15**. The central bore **13** is closed by the socket **12***a* which is threaded therein as indicated at **16**.

The electric line **12** passes through plug **16** and the leads **17** connect to a low resistance detonator **18** within the central bore **13**. These leads make contact with a source of electricity (not shown) at the surface of the well. A perforating charge **19** for jet perforation of the casing is disposed in each of the perforator ports. The construction and use of shaped charges are well known in the art. They comprise a charge which is rigidly enclosed except at the location from which the jet is to issue. This location is plugged by a metal retainer such as the conical retainer **15**. These retainers form a cavity **19***a* in the charge, which usually is conical in shape, and which serves to cause the hot metal from the retainer and the hot gases from the perforating charge to issue in a jet from the enclosure holding the charge. As shown in FIG. 1, the jet will issue horizontally from the perforator ports **14**, the retainers **15** being the weakest structural part of the enclosure.

A lower central bore **20** is drilled upward through the carrier and intersects with four or more radially extending gas ports **21**, the ends of which are closed by seals **21***a*. The lower central bore is closed off by a plug **22** which is threaded into the bore at the bottom. The leads **17** extend through the low resistance detonator **18** and through the body **10** into the lower bore **20** where they are connected to a high resistance igniter **24** attached to a propellant charge **24***a*. The leads **17** are preferably sealed against the ingress of well fluids where they pass through the body **10** as by means of double-lipped rubber sealing plugs **17***a*. It will be appreciated that other types of ignition systems can be used. For example, a clock-actuated igniter can be placed in the bore **20**. A gas producing charge **24***a*, preferably a propellant mixture such as an intimate stoichiometric mixture of asphalt and potassium perchlorate is placed in the bore near the igniter. This propellant mixture is conveniently compressed into a cylindrical shape.

The carrier, which is preferably circular in cross-section, has an annular groove **25** above the perforator ports **14** and gas ports **21**. A retainer shoulder **26** projects from the carrier at the upper edge of this groove. A baffle ring **27**, which can be a hollow O ring if desired, is placed within the groove so as to bear against both the carrier and the well casing. This O ring is flexible and unitary. This creates a flexible barrier or boundary between the carrier and the casing, which will permit liquid to pass upwardly of the baffle ring as the carrier is lowered into position and enable the liquid to be displaced upwardly when gas is discharged from the carrier below said barrier.

It will be appreciated that a greater or lesser number of gas ports and perforator ports can be used if desired, and also that other kinds of propellant or gas-generating charges can be used. The selection and number of these elements will depend on the conditions under which the device is to be used.

FIG. 4 shows another type of perforating device according to the invention. A central tube **30** serves as a carrier and has a closure plug and wire line socket **31** threaded into its upper end. A gas-producing charge **32**, preferably of propellant material, is attached to this plug within the tube. This charge **32** can conveniently be compacted to a cylindrical shape. Electric lead wires

33 from inside the line 45 pass to the propellant for setting off the gas-producing charge. A flexible sleeve 35 of an impermeable material such as rubber is affixed to the opposite ends of the tube so as to surround the tube. Holes 34 in the walls of the central tube provide communication between the inside of the tube 30 and the inside of the sleeve 35, so that the sleeve is adapted to be inflated.

A pipe 36 connects with the bottom of the central tube 30. A receptacle 37 has a central passage 38 therethrough, and two or more perforator ports 39 which extend outward from the central passage 38. Shaped charges 39*a* are placed in these perforator ports, and are held therein by retainers 40 at their outer ends. Plugs 40*b* act as inner retainers to hold the charges in the ports. A heat sensitive igniter 40*a* is inserted into the end of each perforating charge and projects into the central passage 38. Another pipe 36*a* connects with the central passage 38 at one end, and with a gas distributor 41 at the other. The gas distributor has several gas ports 42 which connect with the pipe 36*a*.

The carrier can be suspended in a well casing 43 by a line 45 attached to wire line socket 31, the line being paid out from the surface of the well. The line 45 also carries electric leads 33.

FIG. 5 illustrates still another form of the invention in which the perforating means are completely protected from well liquids at all times. A carrier 50 with a substantially circular cross-section throughout its length has an upper chamber 51, and a lower bore 52 connecting with the chamber. The upper chamber is closed by a wire line socket 53, and the lower bore by a plug 54. A series of gas ports 55 and two or more perforator ports 56 are drilled through the carrier wall from the lower bore.

A flexible sleeve 57 made of impermeable material such as rubber surrounds the carrier and is bound to the carrier by straps 58 at each end of the sleeve. Rubber reinforcing patches 59 are fixed to the inside of the sleeve opposite perforator ports.

A gas-producing charge 60, preferably of a propellant mixture, is placed in the upper chamber, and is connected by electric lead wires 61 to a source of electricity (not shown). The charge 60 can conveniently be compressed to a cylindrical shape. Shaped perforating charges 62 having a cylindrical cross-section and a conical cavity 62*a* in their outer end are placed in the perforating ports with frangible retainers 63 at the carrier's outer surface, and plugs 63*a* at the bore 52. Heat sensitive detonators 64 are inserted through plugs 63*a* into the propellant charges so as to project into the lower bore 52.

The carrier is suspended in a well casing 65 by a line 66 which is paid out from the surface. The line is attached to the wire line socket 53 on the carrier.

FIG. 6 illustrates another form of the invention in which a carrier 70 has an upper chamber 71 and a lower passage 72 which are separated by a frangible disc 73. The upper chamber is closed by a threaded wire line socket 74. A gas producing charge 75 is placed in the upper chamber and is connected by electric lead wires 76 enclosed inside a line 84 to a source of electricity (not shown). This charge 75 is conveniently compressed to a cylindrical shape.

Two perforating ports 77 are drilled to interconnect with the lower passage or gas port 72, and perforating means such as shaped charges 78 with retainers 79 are inserted therein. Heating-sensitive detonators 80 are inserted into the shaped charges so as to project into the lower passage 72.

A flexible baffle 81 is held between two spaced annular shoulders 82 welded or otherwise secured to the carrier, and projects from the carrier so as to bear against both the carrier and the well casing 83. The carrier is suspended in the well casing by a line 84 attached to the wire line socket 74 on the carrier, the line being paid out from the surface.

The operation of these embodiments will now be described. In all the forms shown, the carrier is first lowered into the well casing so that the perforating means are opposite the places to be perforated. When the carrier of FIG. 1 is inserted in the well casing, the sealing ring 27 makes a resilient contact with both the casing and the carrier. The outer diameter of the uncompressed ring should therefore be somewhat greater than the inner diameter of the well casing. Then the ring will be compressed when the carrier is lowered into the well, and will form a baffle or boundary which retards upward flow of gaseous fluid past it, while permitting liquid to be displaced upwardly past the ring.

When the carrier is in the desired position the propellant charge is ignited by closing the circuit through the lead lines 17. Some of the body of gas generated by the ignition of the propellant material escapes into the casing through gas ports 21 and, being less dense than the well liquids, rises until it encounters the baffle ring 27. As the gas flows into the well, the liquids in the well are displaced. After sufficient gas has been introduced under the sealing ring, the liquids will have been replaced by gas to a level below the baffle ring 27 and below the perforator ports 14. These ports are thus entirely surrounded by a gaseous medium.

The perforating means then be fired, in this case by sending an electric current through leads 17 to ignite the squib 18 which detonates the shaped charge. The jet blasts then discharge through the perforator ports, and the surrounding gaseous medium to perforate the casing.

When the device shown in FIG. 4 is lowered into the well, a tight fit is not made with the casing at once, since the flexible sleeve 35 is uninflated. Therefore when the carrier is positioned properly, an electric current will be sent through lead wire 33 to ignite the gas-producing charge 32. Gas thereupon flows through holes 34 to the inside of the flexible sleeve 35. This inflates the sleeve, creating an expansible chamber inside it, and making the necessary tight fit with the well casing. This creates the fluid retarding barrier or boundary which extends between the carrier and the well casing.

Another portion of the generated gas flows through pipes 36 and 36*a*, and gas ports 42, to enter the well. This gas rises around the carrier beneath the barrier created by the inflated sleeve, and displaces the well liquids below the perforator ports 39.

The igniters 40*a* are set off by the hot gases which flow around them and through the passage 38. The blast from the shaped charge then perforates the well casing, passing only through the gaseous medium provided by the envelope of gas around the carrier.

The device shown in FIG. 5 operates in substantially the same manner as that of FIG. 4, except that the flexible sleeve surrounds both the gas ports 55 and the perforator ports 56. By this means, well liquids are kept completely away from the perforating charges. When the gas-producing charge is set off, gases inflate the flexible sleeve 57 to produce an expansible chamber therein, and expand that chamber so that the sleeve fits tightly against the casing. This action displaces liquids out of the region occupied by the inflated sleeve. Hot gases also flow through lower bore 52 and contact the heat-sensitive detonators 80, thereby setting off the perforating charges. The perforating charges then fire through the gas envelope and the sleeve itself. The sleeve must be replaced after each use.

The device shown in FIG. 6 is similar in operation to that of FIG. 1, in that the gas producing charge is set off so as to flow directly into the well and displace liquids away from the exposed perforating ports. After an electric current ignites the gas-producing charge 75, and sufficient pressure is generated, the frangible disc 73 breaks and releases the gas from the chamber 71. The gas

then flows through lower passage **72** and displaced the well liquids beneath the barrier **81**. The heat sensitive detonators **80** then ignite the perforator charges, which discharge through the gas envelope to puncture the casing.

It will be noted that in the devices illustrated in FIGS. 1 through 6 the gas generated by the burning propellant is discharged from the carrier body in a generally horizontal direction. This is to avoid the creation of an upward thrust which would tend to force the carrier body up the well casing away from the point at which the casing is to be perforated.

FIG. 7 illustrates an embodiment of the present invention wherein the gas generated by the burning propellant is discharged from the carrier body in a generally upward direction in order to create a downward thrust which not only holds the carrier body in fixed position on the lower end of the supporting line but also serves to increase the pull on the suspension line, thereby indicating the beginning and end of the gas generating cycle.

In FIG. 7 the carrier body is indicated at **90** with a flexible barrier **90***a* suspended within a well casing **91** from an electric line **9** secured in a socket **93** in the manner heretofore described. The carrier body **90** is tubular and is threadedly attached at its upper end to the line socket **93** as indicated at **94**. The lower end of the carrier body **90** is threadedly attached to a tubular propellant chamber **95** as indicated at **96**. A removable threaded plug **97** closes the lower end of the propellant chamber **95**. A barrier wall **98** separates the propellant chamber **95** from the interior of the carrier body **90** to prevent the passage of hot gas from the propellant chamber into the interior of the carrier body. The propellant chamber **95** is provided, near its upper end, with a series of upwardly directed discharge ports **99** which are normally closed by means of frangible seals **100**.

The carrier body **90** contains air at atmospheric pressure which serves to cushion the shock caused by detonation of the shaped charges **101** contained therein. These shaped charges, and the associated detonating cord **102**, are of conventional design and form no part of the present invention, being illustrative only. The jets from the shaped charges pass through frangible seals **103** positioned in the wall of the carrier.

The leads from the electric line **92** are connected to a detonator **104** for the explosive cord **102** and also to an igniter **105** in a propellant charge **106** within the propellant chamber **95**. The leads **107** to the shaped charge detonator may be of lower resistance than the leads **108** to the propellant igniter **105**, or a time delay relay (not shown) can be interposed in the electric circuit between the shaped charge detonator and the propellant igniter, so that the propellant **106** can be ignited before the shaped charges **101** are detonated. This delay allows the gas generated by the propellant **106** to fully envelop the carrier body **90** before the shaped charges **101** are fired. A baffle ring or barrier is employed to retard the upward movement of the gases past the ports **103**.

The gases issuing from the upwardly directed ports **99** will cause a downward thrust which will be imparted to and resisted by the electric line **92**. The changes in thrust or weight on the line **92** are usually indicated by a weight indicator (not shown) at the top of the well associated with the line **92**. A sudden increase in weight will indicate that the gas generator is in operation. After a predetermined elapsed time, sufficient to allow the carrier body **90** to become enveloped in gas, the shaped charges **101** are fired. The jets issuing from the shaped charges will pass through a gaseous medium rather than through a liquid medium and will thus suffer less retardation before reaching their target which is the wall of the well casing **91**.

FIG. 8 illustrates an embodiment of the present invention wherein the gas envelope is generated by the application of heat to a well fluid, rather than by the chemical reaction of the ingredients comprising a propellant charge of the type described in connection with FIGS. 1–7. Materials of the "thermit" type (aluminum powder and iron oxide) are well known as generators of heat with little or no gas being formed.

Since well perforators of the explosive type are almost always used below the surface of the fluids which are in the well, a portion of such fluids (which are usually water, mud or oil) can be vaporized by the application of sufficient heat.

Apparatus for vaporizing a portion of the well fluid, as shown in FIG. 8, is substantially similar to that shown in FIG. 7 except that the propellant chamber **110** is provided wtih several open ports **111** which permit the well fluid to enter the interior of the chamber and surround the heat-generating charge **112**. The latter is preferably enclosed in a fluid tight container **113**, such as a steel shell or the like, which also encloses the igniter **114** on the end of the lead wires **115**.

In operation, when the electric circuit through the lead wires **115** is closed, the igniter **114** will ignite the material **112** inside the shell **113**. Heat of combustion of the material **112** will destroy the shell **113** and will vaporize a portion of the well fluid within the chamber **110**. The vapors will issue through the ports **111** and form a gaseous envelope around the perforating tool, as previously described in connection with FIGS. 6–7.

Propellant materials such as are used as fuels in rocket propulsion are to be preferred as gas-producing materials. These propellant mixtures are selected and compounded for maximum heat and gas emission per unit of weight. They are also self-combustible in that they contain all substances necessary for the reaction, and do not depend on the atmosphere for the oxygen used in the reaction, nor do they require any other substances from other sources. They are therefore excellent substances for creating the gas envelope. It will be appreciated, however, that substances which are not primarily suited for propellants can also be used, the only requirement being simply the ability to generate a body of gas.

In addition to its usefulness as a perforator, this device can also be used as a pipe cutter by providing a large enough number of jet blasts to make a continuous perforation around the casing or pipe. It will also be appreciated that perforating means other than jet blasts may be used as for example, bullet-type guns.

This invention provides a gas envelope for displacing well liquids from the region through which a perforating means must pass, and retaining an envelope of gas around the perforating means so that these means need pass only through gases. This increases the efficiency and penetration of the perforating means.

My invention is not to be limited by the embodiments shown in the drawings and described in the description, which are given by way of example rather than of limitation, but only in accordance with the scope of the appended claims.

I claim:

1. The method of perforating a well comprising placing within the well a carrier having a yielding barrier member adapted to pass fluid from a region of higher pressure to a region of lower pressure when in operative position and adapted to extend between the carrier and the wall of said well, and discharging a body of gas into the well below said barrier member whereby liquids are displaced past said barrier to form a gas-filled region immediately below said barrier member, and then firing perforating means through said gas-filled region.

2. A well casing perforator comprising a carrier adapted to fit within the casing, a flexible sleeve attached to and surrounding the carrier, forming an expansible chamber between the sleeve and the carrier, propellant operated well casing perforating means disposed in the carrier below the sleeve and directed toward the casing, and means disposed in the carrier for releasing a body of gas into said sleeve to provide a resilient barrier between

the carrier and the casing when in operative position comprising a charge of self-combustible propellant material, the ignition of which produces the body of gas, means for discharging a portion of said body of gas into the casing below the barrier whereby liquids are displaced from the vicinity of the perforating means, and means providing a gas flow passage from said discharge means to said gas releasing means and said perforating means.

3. The method of perforating a well containing fluid, by the use of a carrier provided with a yieldable barrier means adapted to extend between the carrier and the wall of the well containing perforating means comprising; positioning in said carrier materials which can react to generate heat within the carrier, submerging said carrier to a predetermined depth in the well, permitting a portion of the well fluid to enter the carrier and surround said heat generating materials, initiating generation of heat by reaction of said materials to vaporize said well fluid by the heat generated, discharging said vapor outwardly of the carrier into the well opposite said perforating means, and subsequently, while said carrier is enveloped in a body of vapor, initiating said perforating means.

4. A propellant operated well casing perforator comprising, a carrier adapted to fit within a casing, a yieldable barrier arranged peripherally around said carrier and adapted to extend between the carrier and the casing, said barrier being adapted to pass fluid from a region of higher pressure to a region of lower pressure when in operative position, casing perforating means disposed in the carrier below the barrier and adapted to be directed toward the casing, and means arranged within said carrier for releasing a body of gas from said carrier below said barrier, whereby liquids within the casing in the vicinity of said perforating means are displaced.

5. Apparatus according to claim 4 in which the generated gas is discharged outwardly and upwardly to provide a downward thrust on the carrier and cable on which said carrier is suspended and thus give an above ground indication of the operation of the device.

6. A propellant operated well casing perforator comprising, a carrier adapted to fit within a casing, gas body generating means disposed within said carrier a yieldable barrier arranged peripherally around said carrier and adapted to extend between the carrier and the casing, said barrier when in operative position being adapted to pass fluid from a region of higher pressure to a region of lower pressure, propellant actuated casing perforating means disposed in the carrier below the barrier and adapted to be directed toward the casing, said perforating means being operative in response to ignition of the propellant contained therein, and means arranged within said carrier for releasing gas to said propellant actuated casing perforating means and from said carrier below said barrier, whereby liquids within the casing in the vicinity of said perforating means are displaced in said casing and said perforating means are activated in response to generation of said body of gas by said gas body generating means.

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