Dec. 7, 1954 H. M. GREENE 2,696,259

APPARATUS FOR FIRING PROPELLENT CHARGES IN WELLS

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Fig. 1.

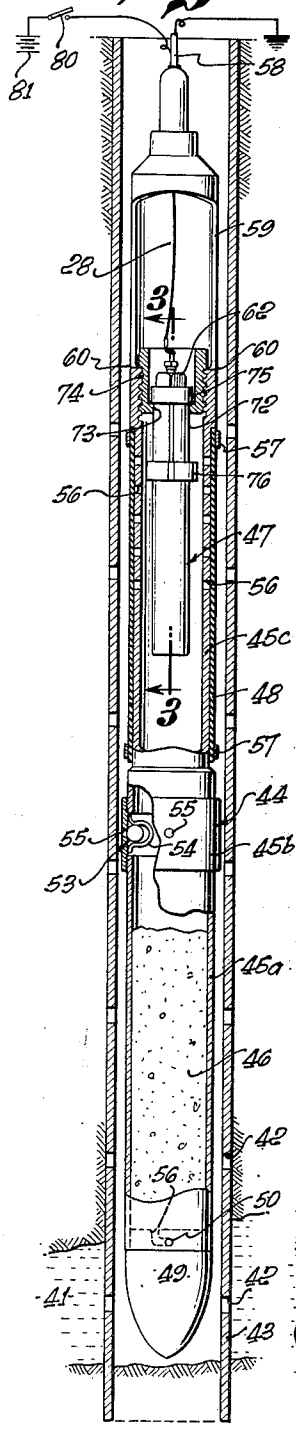


Fig. 2.

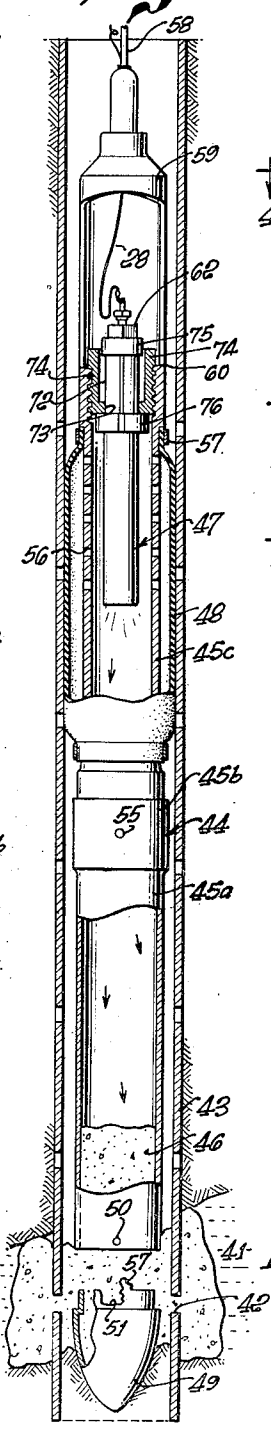
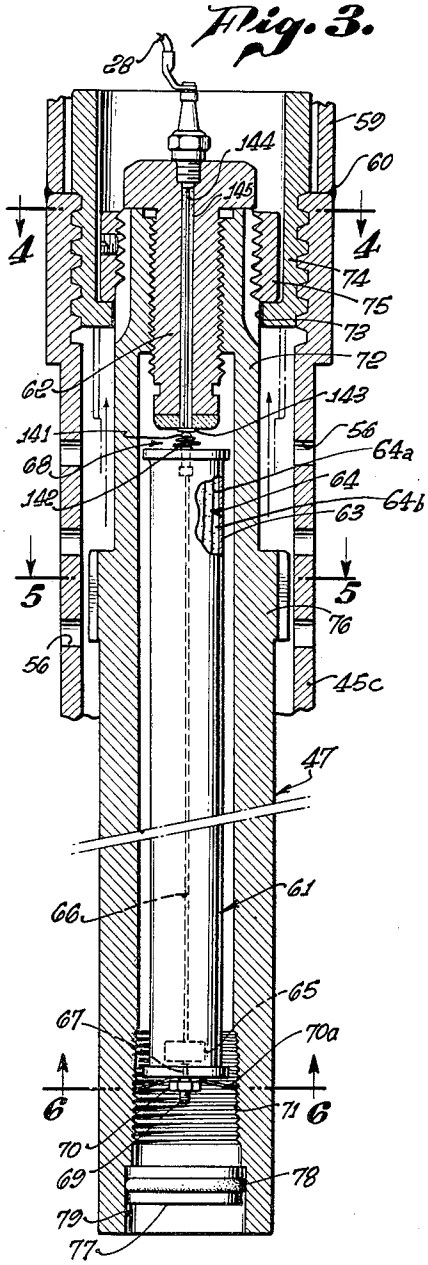


Fig. 3.



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Fig. 4.

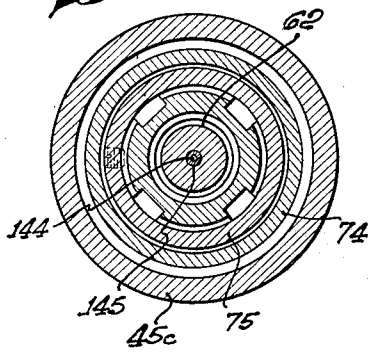


Fig. 5.

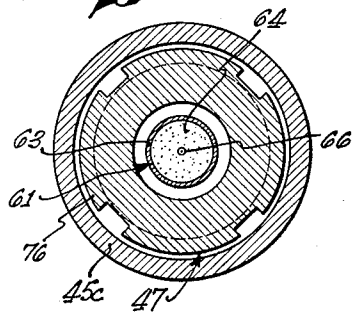


Fig. 6.

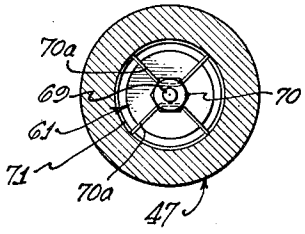


Fig. 8.

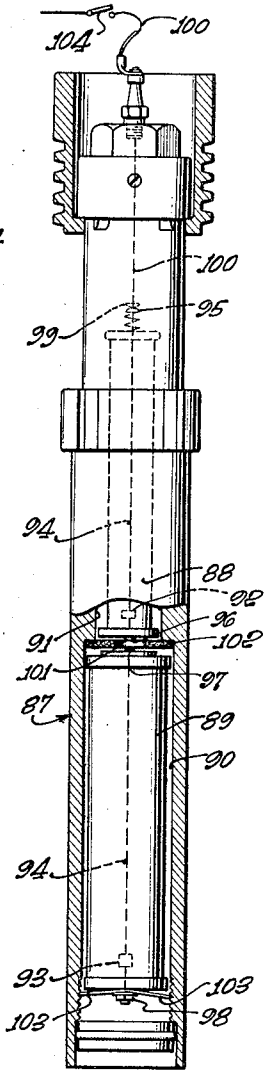
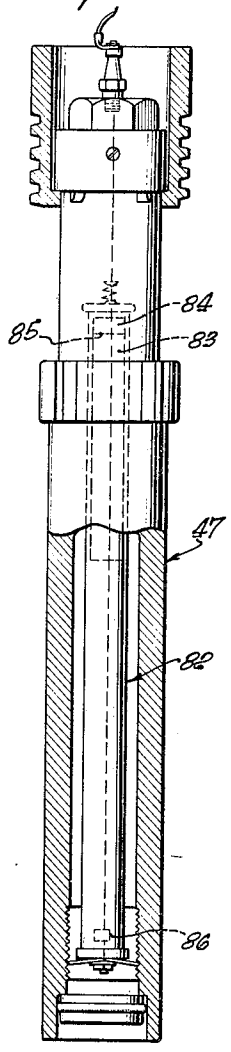


Fig. 7.



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United States Patent Office

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APPARATUS FOR FIRING PROPELLENT CHARGES IN WELLS

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6 Claims. (Cl. 166—63)

This invention relates to improved apparatus for treating wells by firing gas generating propellent charges, i. e. explosive or combustible charges, in a zone deep within the well. In certain respects, the invention is particularly concerned with the firing of propellents for the purpose of forcing well treating materials, such as cement, acid, detergent, or plastic, against the bore wall or into the formation.

Some features of the invention are improvements in the type of apparatus shown in my copending application Serial Number 161,986, filed May 15, 1950 on "Oil Well Cementing Packer." In that application, I have disclosed apparatus including a body adapted to be lowered into a well, a propellent charge carried by the body and adapted to generate high pressure gases in the well, and a packer carried by the body and acting to close off the bore against upward dissipation of the force of the gases. The packer may be expansible into sealing engagement with the bore wall by the force of the gases themselves. The gas force may be directed downwardly, and preferably against a mass of well treating material in a manner to force the material from the body and against the bore wall. To thus direct the gases downwardly, the apparatus of my above mentioned application includes a downwardly directed gun barrel within which the propellent charge is contained and fired.

One highly important feature of the present invention resides in the special selection of the propellent charge in a manner assuring the continuance of the gas generation over an extended period of time, preferably between about 1½ and 30 seconds, so that the force exerted by the gases is of sufficient duration to assure attainment of the desired well treating purpose. The propellent is also desirably so selected as to produce considerably greater volumes of gases than are produced by many common propellents, the propellent preferably having a capacity for producing between about 100 and 400 cubic feet of gas at atmospheric pressure from each dram of propellent.

Under certain circumstances, I may employ two or more different propellent charges, which may have different burning characteristics if desired. These charges may be ignited in sequence, to extend the burning or gas generation period beyond that of either of the charges individually. The two or more charges may also have different burning characteristics to attain a desired particular result. For example, a first of the charges may be relatively slow burning, and be typically used to force a body of cement from the device and against the well bore wall, with a second charge being relatively fast burning, to then set the cement by subjecting it to extremely high temperature and pressure conditions.

The propellent gases may flow to the expandible packer through apertures in a tubular body of the tool about which the packer is carried. In order to minimize the possibility of rupturing the packer by the force of the gases, I may so form the body and gas gun as to require a rather circuitous flow of the gases toward the packer. Specifically, I may so form and position the gun that its lower discharge end extends substantially as low as, and preferably lower than, the lowermost aperture in the body leading to the packer.

When cement or other treating material is to be forced by the gases into the well, that material may be carried within a lower portion of the tubular body of the device, and be forced outwardly through a bottom opening in the body upon firing of the propellent. This bottom

opening may be initially closed by a cap or closure whose connection to the body is releasable or shearable by the force of the gases. In order to assure release of that connection, I find it helpful to specially mount the gas gun in a manner to introduce an abrupt shock into the gas produced forces. Specifically, I mount the gas gun for limited upward recoiling movement upon firing of the propellent, with the result that when such upward recoiling movement is halted, an abrupt shock wave is introduced into the force of the gases, acting to release or shear the cap connection.

The above and other features and objects of the present invention will be better understood from the following detailed description of the typical embodiments illustrated in the accompanying drawings, in which:

Fig. 1 shows a preferred form of cementing tool embodying the invention and positioned within a well bore prior to a cementing operation;

Fig. 2 is a view corresponding to Fig. 1 but showing the tool during the cementing operation;

Fig. 3 is an enlarged vertical section through the gas gun of the device, and taken on line 3—3 of Fig. 1;

Figs. 4, 5 and 6 are horizontal sections taken on lines 4—4, 5—5 and 6—6 respectively of Fig. 3;

Fig. 7 is a partly sectional view of the gas gun, showing a variational form of propellent charge positioned within the gun; and

Fig. 8 is a view corresponding to Fig. 7 of a variational form of gas gun utilizing two propellent charges.

Referring first to Figs. 1 to 6, the apparatus there shown is adapted to be used in any of the numerous situations where it may be desirable to deposit a mass of material, such as a detergent, treating acid, or resinous plastic material, in a given zone within a well bore, and in certain respects is especially effective for cementing a well. I have typically illustrated the situation where it is desired to cement off a water area 41 communicating with a well through perforations 42 in casing 43.

The preferred form of cementing tool 44 comprises essentially a tubular vertically extending body formed in three threadedly interconnected sections 45*a*, 45*b*, and 45*c* and containing a body of cement 46, a "gas gun" 47 carried by the upper end of the tool body and acting to direct the gases generated by a contained propellent charge downwardly through the body and against the cement, and a tubular packer sleeve 48 adapted to be radially expanded against the well bore casing to form a seal preventing upward dissipation of the actuating gases. Where a detergent, acid, plastic or other material is to be handled by the tool, that other material is of course substituted for the cement 46. Also, in certain instances, no cement or other well treating material is provided at that location, so that the gases produced by gun 47 may themselves be communicated directly into the earth formation, to clear the formation by subjection to gases under pressure.

The lower tubular portion 45*a* of the tool body serves to contain the body of cement or other material 46 to be deposited within the well. The lower end of this cement container is closed by a downwardly tapering nose member 49, which is attached to the body in a manner assuring retention of the cement during lowering of the tool while permitting the nose member to be blown downwardly from the body upon ignition of the propellent or gas generating charge. For this purpose, cement container 45*a* may carry a pair of inwardly projecting pins 50 receivable within bayonet slots 51 at the top of the nose member. When the gas producing charge is ignited and exerts a downward force on the body of cement, the material of the nose member shears or tears at 52 to the condition of Fig. 2, permitting downward expulsion of the nose member and downward and outward displacement of the body of cement.

The portion 45*b* of the tool body above cement container 45*a* carries a number of outwardly seating check valves 53 serving to prevent outward escape of the cement displacing gases through the wall of the body while permitting an inward flow of well fluid into the body when the pressure within the body is reduced below that at its outside. These check valves may be of conventional ball check valve construction, including spherical valve ele-

ments free for limited movement within cages **54** toward and away from seats **55**.

The upper tubular portion **45***a* of the body is perforated at **56** to permit outward flow of the generated gases against packer sleeve **48**. This packer sleeve is formed of rubber or similar resilient material and is peripherally clamped by bands **57** at its opposite ends to the end portions of perforated body section **45***a*. The packer sleeve is thus radially expansible to the condition of Fig. 2 by the gases, and is then resiliently returnable to the condition of Fig. 1 when the pressure within the tool returns to normal. The device is suspended within a well by a wire line **58** connected to a bail **59**, whose ends attach at **60** to upper body section **14***c*.

The gas gun or firing chamber **47** comprises a cylindrical preferably metallic vertically extending body containing a propellent cartrige **61** (see Fig. 3), and closed at its upper end by a threadedly mounted plug **62**, so that the gases produced by the propellent cartridge are directed downwardly against the body of cement. Cartridge **61** may comprise a vertically elongated cylindrical cartridge case **63**, typically formed of stiff paper or cardboard, and filled with a propellent or gas burning charge **64**, which is ignitable at its lower end by an electrically ignited fuse **65**. Firing current is supplied to fuse **65**, through two wires **66** and **67**, the former of which extends upwardly to a point of connection with contact **68** at the top of case **63**, and the latter of which connects with a bottom screw **69**. Nut **70** is tightened onto screw **69**, and clamps in position a pair of resilient electrically conductive wires **70***a*, whose free ends project laterally in different directions from the cartridge (see Fig. 6). These wires are engageable with a series of annular grooves **71** in the inner surface of gun **47**, to retain the cartridge in the gun and electrically ground the lower fuse wire **67** to the conductive gun **47**, and thereby to conductive body **45***a*, *b*, *c* and supporting wire line **58**. The top contact **141** of cartridge **31** is carried and urged upwardly by a spring **142**, and engages a contact **143** on plug **27**, which contact is in turn connected by wire **144** and insulated binding post **145**, to lead **28** extending down from the surface of the earth. In order to assure that no well fluid or other unwanted moisture will reach charge **31**, the lower end of chamber or gun **47** is closed and sealed by a plug **77** carrying a rubber seal ring **78**, which slidably engages bottom bore **79** in the gun barrel.

Gas gun **47** is preferably mounted for limited upward recoiling movement upon firing, and for this purpose may have a portion **72** near its upper end which is vertically slidable within a shoulder portion **73** in a bushing **74**, the bushing being threadedly connected into upper body section **45***a*. A nut **75** on the upper end of the gas gun is engageable with shoulder **73** of the bushing to limit downward movement of the gun, while an integral flange **76** on the gun barrel limits its upward recoiling movement at the Fig. 2 position.

In order to prevent rupture of packer **48** by the gases generated within gun **47** on firing, I preferably so form the apparatus as to require a somewhat circuitous flow of the gases from the gun to the packer. For this purpose, the gun may be of a length to extend a substantial distance downwardly within the body, and apertures **56** for passing the gases to the packer may then all be located above the level of the bottom open end of the gun. Preferably, these apertures are above that end of the gun even in its elevated position of Fig. 2, so that the gases emanating from the gun must reverse their course and flow upwardly and then laterally to reach the packer.

Propellent charge **64** preferably comprises an explosive or combustible charge characterized by a capacity to produce a relatively prolonged pressure and temperature surge rather than a sharp instantaneous explosion, to thus effectively force the cement from the container and into the well zone without danger of rupturing the tool body itself. For best results, the propellent charge should be selected to burn over an extended period of between about 1½ and 30 seconds, under the particular hydrostatic pressure encountered at the zone being cemented or treated. Also, the propellent should be of a type to produce very large quantities of gases upon ignition, desirably between about 100 and 400 cubic feet of gases (at atmospheric pressure) per dram of propellent. The burning speed of the propellent or powder may be between about .2 of an inch to 5 inches per second.

A typical propellent charge having the above characteristics may be formed in the following manner. About one-third of the charge may comprise a propellent **64***a* in sheet form composed of a nitro-cellulose base impregnated with fine black ballistic powder (see Fig. 3). Such a sheet propellent is sold by Hercules Powder Company of Wilmington, Delaware, under the product number 15X75. The other two-thirds of the charge may comprise pellets **64***b* of nitro-glycerine base smokeless powder containing some nitro-cellulose, and having the individual pellets or grains coated, and therefore mutually insulated, by Vaseline and paraffin to slow the burning speed. Such pellets are sold by Hercules Powder Company under the product number H. E. S. 5214.

The sheet propellent in the above charge may be rolled within cartridge case **63**, with pellets **64***b* being contained within the roll and between turns of the sheet. The burning speed of the charge may be controlled in any of various ways, as for instance by varying the pellet or grain size, the spacing of the grains by Vaseline or paraffin, or the overall length of the charge, to attain the desired extended gas generation period.

In preparing the tool for use, lower nose member **49** is first attached to the lower end of cement container **45***a* by means of bayonet connection **50—51**. Gas gun **47** is then removed from the upper end of the tool as permitted by the threaded mounting of bushing **74**, and cement is filled into the tool body through its open upper end. Sufficient cement will normally be poured into the body to substantially fill its lower imperforate section **45***a*. A gas producing propellent cartridge **61** is slipped into the firing chamber through its open lower end and moved to the condition of Fig. 3 in which the cartridge is releasably retained by reception of wire fingers **70***a* within one of the grooves **71** in the gun barrel. Plug **62** may then be applied to the lower end of the gun barrel to seal it against the entrance of any well fluid, after which the gun is mounted to the upper end of the body as shown.

The tool is lowered into the well to the zone to be cemented, in this case the water area **41**, and an electrical switch **80** is then closed at ground level to introduce current from a power source **81** to ignition fuse **65**. Ignition of propellent **64** produces a large quantity of high temperature gases under high pressure, which gases are directed downwardly by gun **47** against the body of cement **46**. The increase of pressure within the tool forces packer sleeve **48** outwardly to its Fig. 2 condition to seal off the casing against upward fluid flow and simultaneously force the cement downwardly and outwardly from the lower end of the tool body. As previously brought out, the connection between nose member **49** and the cement containing portion of the body is sheared by the force of the propellent to permit downward and outward flow of the cement. The initial force of the gases causes upward recoiling movement of the gas gun from its Fig. 1 to its Fig. 2 position, with this movement being limited abruptly upon engagement of gun shoulder **76** with bushing shoulder **73**. Such sudden stopping of the gun movement sets up an abrupt shock wave in the gases, which assures that the nose retaining pins **50** will be sheared.

The extreme pressure squeezes out substantially all of the moisture from the cement and, together with the heating of the cement by the generated gases, causes it to set instantly. As the pressure within the tool diminishes after an operation, packer sleeve **48** resiliently returns to its normal condition of Fig. 1, permitting removal of the tool from the well, and check valves **53** permit inward passage of well fluid into the tool to equalize the pressures at the opposite sides of the tool body.

Fig. 7 shows the gas gun **47** with a variational form of propellent cartridge **82** positioned within it. This cartridge **82** is essentially the same as cartridge **61** of Fig. 3, except as to the nature of its contained propellent. Specifically, the propellent of cartridge **82** includes two superimposed and preferably unlike propellent charges **83** and **84**, which burn sequentially upon ignition of the cartridge. The lower of these charges **83** preferably extends vertically from the bottom of the cartridge case to a location **85** near its upper end, with the top cartridge **84** comprising an upper layer of a different type propellent powder. The lower charge is ignited at its lower end by electrically energized fuse **86**, and has the same slow burning and large gas volume characteristics heretofore discussed in connection with charge

64 of Fig. 3. Charge 82 thus burns upwardly from its lower end, and finally ignites upper charge 84. Preferably, this upper charge is of a faster burning powder than lower charge 83, to produce a final very high temperature and high pressure mass of gases within the well during the last portions of the cementing operation. The lower charge may thus act to displace the cement from the tool body and into the well, with the upper charge 84 then subjecting the positioned cement to high pressure and temperature conditions acting to assure rapid setting of the cement regardless of the presence of fluid in the well. A suitable fast burning rifle powder may be employed for the upper charge 84, one such powder being Hercules Powder Company's FFF–G smokeless powder.

Fig. 8 shows a variational form of gas gun 87, which is specially designed to contain two separate propellent cartridges 88 and 89. Both of these cartridges may be cylindrical, with the lower cartridge 89 being of a somewhat larger diameter than the upper one. The lower cartridge is received within an enlarged diameter bottom bore 90 in the gas gun barrel 87, with the upper cartridge being received within an upper reduced diameter bore 91. The two cartridges contain individual electrically ignited fuses 92 and 93 near their lower ends, with the two fuses being connected by wires 94 to upper and lower contacts 95, 96, 97 and 98 on the cartridges. The upper contact 95 of top cartridge 88 is spring urged upwardly against contact 99 connecting with lead wire 100. The lower contact 96 of the upper cartridge, and the upper contact 97 of the lower cartridge, are electrically connected through the central conductive portion 101 of a disc having an annular electrically insulative portion 102 engaged against a shoulder formed in the gas gun wall at the juncture of bores 90 and 91. Bottom contact 98 of the lower cartridge is electrically connected by spring fingers 103 to the grounded gun barrel. From the above, it will be apparent that the closing of switch 104 at the surface of the earth simultaneously ignites fuses 92 and 93 within the two cartridges. However, the upper of these fuses 92 preferably is of the delay type, so that the propellent charge within cartridge 89 burns for a predetermined period before ignition of the propellent charge within cartridge 88. Such delay ignition of one of the charges may be employed to extend the period of gas generation, or to control the timed ignition of two unlike propellent charges. For example, the propellent within lower cartridge 89 may be relatively slow burning and adapted to produce very large quantities of gases, while the propellent within upper cartridge 88 may be faster burning, so that when it is ignited after burning of most of the lower charge, the upper charge performs the cement setting function of powder 84 in Fig. 7. In the Fig. 8 form of the invention, the combined burning time of the two charges is preferably between about 1½ and 30 seconds (under the hydrostatic pressure at the well zone being cemented), as is the burning of the charge or charges in the other forms of the invention. The propellents used in the two Fig. 8 cartridges also are desirably of the large gas volume type, preferably being capable of producing between about 100 and 400 cubic feet of gases at atmospheric pressure from each dram of propellent.

I claim:

1. A well tool comprising a body lowerable into a well, a mass of material contained in a chamber in the body, a gun barrel, an electrically ignited cartridge of gas generating propellant insertible axially into an end of said gun and adapted to generate and force from said end of the barrel a volume of gases acting to force said material from the body and against the well bore wall, and detent means carried by said cartridge and resiliently urged against the wall of said barrel to retain the cartridge therein, said barrel having a transverse shoulder formed in its inner wall and engageable by said detent means to retain the cartridge in the barrel, said detent means comprising electrically conductive means connected to said charge and acting as a contact for transmitting igniting current to the charge from said barrel.

2. A well tool as recited in claim 1, in which said detent means comprises a plurality of resilient spring fingers projecting outwardly from said cartridge, said barrel having a plurality of said shoulders formed by providing a series of annular notches in the barrel wall.

3. A well tool comprising a tubular vertically extending body adapted to be lowered into a well, a gun barrel within said body for containing a gas generating propellent charge and having an upper closed end and a discharge opening at its lower end through which gases generated by said charge are discharged, a packer disposed about said tubular body in communication with said gas generating charge and radially expansible by the force of said gases outwardly against the bore wall and acting when thus expanded to seal the bore against upward dissipation of the force of said gases, the wall of said body containing aperture means through which said gases may flow outwardly against the packer, and said lower opening of the gun barrel being located substantially as low as the lower extremity of said aperture means.

4. A well tool as recited in claim 3, including a mass of material contained within the body beneath said gun and adapted to be forced from the body and against the well bore wall by said gases.

5. A well tool comprising a body adapted to be lowered into a well, a downwardly directed gun barrel mounted in the body adapted to contain a gas generating propellent charge and having a lower discharge opening through which gases generated by said charge are discharged, a packer carried by said body in communication with said charge and expansible by said gases against the well bore wall in a sealing relation preventing upward dissipation of the force of said gases, means mounting said gun barrel for upward recoiling movement relative to the body upon firing of said charge, and shoulders on the body and barrel limiting said upward recoiling movement.

6. A well tool as recited in claim 5, including a mass of material contained within the body beneath said gun and adapted to be forced from a lower end of said body and against the well bore wall by said gases, a closure initially closing said lower end of the body, and a connection retaining said closure against opening movement and constructed for release by the force of said gases upon the limitation of said recoiling movement by engagement of said shoulders.

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