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GUN PERFORATOR AND METHOD OF MANUFACTURE

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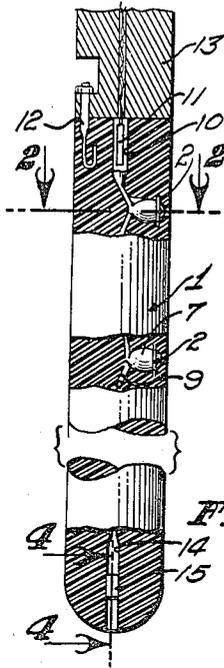


FIG. 1

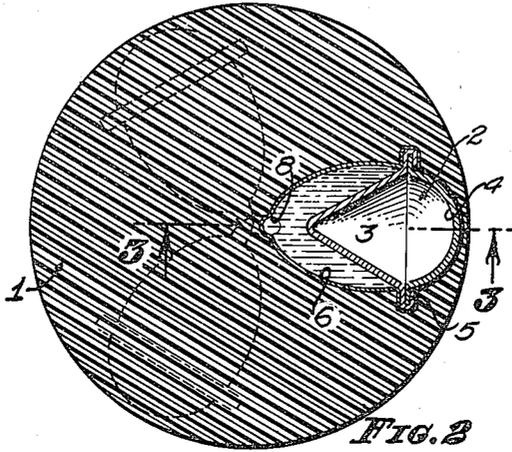


FIG. 2

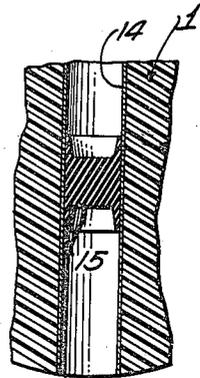


FIG. 4

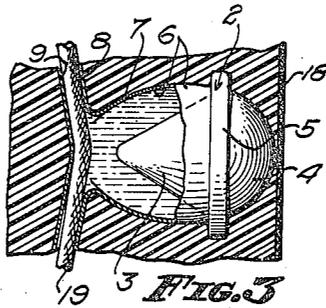


FIG. 3

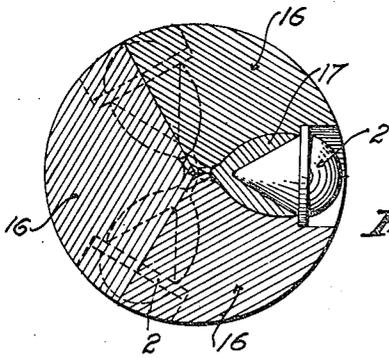


FIG. 5

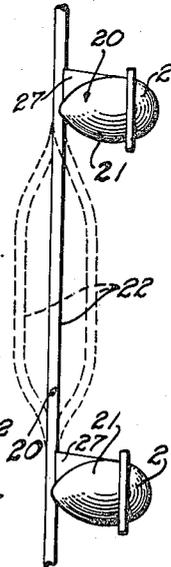


FIG. 6

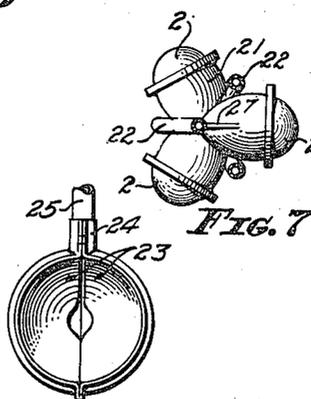


FIG. 7

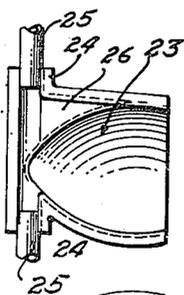


FIG. 8

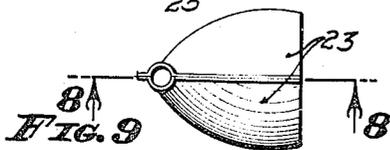


FIG. 9

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1

2,833,215

GUN PERFORATOR AND METHOD OF MANUFACTURE

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Application August 13, 1951, Serial No. 242,489

10 Claims. (Cl. 102—20)

My invention relates to gun perforators and method of manufacture, more particularly to gun perforators of the expendable type which utilize hollow or shaped charges to penetrate well casing. The present invention is a continuation in part of my copending application Serial No. 3,674, filed January 22, 1948, now abandoned.

Included in the objects of my invention are:

First, to provide a gun perforator which utilizes hollow or shaped charges, which is completely destroyed or disintegrated when fired, and which may be formed largely of material which is substantially completely disintegratable or soluble in well liquids so as to minimize the residue or rubble which must be bailed from the well, particularly after producing a large number of perforations.

Second, to provide an expendable gun perforator wherein the internal and external pressures are equalized so that the body of the gun perforator may be relatively fragile and yet withstand the high pressures existing in a deep well.

Third, to provide an expendable gun perforator and method of manufacture which utilizes inexpensive and readily available material and permits production either in large or moderate quantity at a particularly low cost, so as to fully justify single use of each gun perforator.

Fourth, to provide an expendable gun perforator which is capable of utilizing a liquid explosive and so arranged that the explosive may be added just prior to lowering the gun perforator into the well bore, or at least after manufacture is completed, so that all manufacturing operations, as well as storage are free from the presence of an explosive, as well as avoiding the transportation of the gun perforator in a "loaded" condition.

Fifth, to provide an expendable gun perforator which may be made of material having a density not greatly different from well liquids so that the weight of the gun perforator need not be an appreciable factor, thus permitting the use of lightweight inexpensive surface equipment, even though a gun perforator may be made up to contain a large number of perforating units.

Sixth, to provide a gun perforator which may utilize explosives having relatively high detonating pressures, above the strength of the gun perforator body when in air; then, by employing a firing means sufficient to rupture the gun body, premature firing in air merely ruptures the gun body without detonating the explosive; however, when the gun body is suspended in a liquid surrounded by well casing, the resulting inertia of the system is sufficient to hold the gun body intact until detonation takes place; thus providing a gun perforator which may be so constructed as to be incapable of operation unless submerged in a liquid.

With the foregoing and other objects in view as may appear hereinafter, reference is directed to the accompanying drawings, in which:

Figure 1 is a fragmentary, partial sectional, partial elevational view of one form of my expendable gun perforator.

2

Figure 2 is an enlarged transverse sectional view thereof taken through 2—2 of Fig. 1.

Figure 3 is a fragmentary sectional view through 3—3 of Fig. 2.

Figure 4 is a fragmentary sectional view through 4—4 of Fig. 1.

Figure 5 is a transverse sectional view similar to Fig. 2 but showing a mold employed in the manufacture of the gun perforator.

Figure 6 is a fragmentary elevational view of a core structure employed in a modified method of manufacture.

Figure 7 is a transverse sectional view analogous to Fig. 2 showing the manner in which core structures may be disposed for later casing within a gun body.

Figure 8 is a fragmentary elevational view of a modified form of shell structure employed in the manufacture of a modified form of my gun body, the view being taken along the plane 3—3 of Fig. 9.

Figure 9 is a fragmentary bottom view of the shell structure.

Figure 10 is an end view of the shell structure.

My gun perforator involves a gun body 1 of cylindrical form. Molded in the gun body in a manner to be described hereinafter is a series of hollow or shaped charge cells 2, each comprising a conical inner shell 3 and a hemispherical, outer shell 4. The two shells may be provided with mating flanges 5 which are sealed together. The shaped charge cells are sufficiently strong to withstand the submergence pressure to which the gun perforator is subjected. To reduce the thickness of material required or to increase the depth at which the cells may be submerged, they may be initially pressurized; for example with carbon dioxide.

Behind each shaped charge cell 2, the gun body defines a detonation chamber 6 which may be provided with a lining 7. The cells 2 are sealed within the gun body as will be brought out in more detail hereinafter. The chambers 6 are serially connected by a longitudinally extending passage 8 which may be provided with a lining 9. The upper extremity of the passage is enlarged to form a detonator cavity 10 which receives a firing or detonator element 11.

The upper extremity of the gun body is provided with mounting bolts 12 anchored therein and arranged to attach the gun body to a weight bar 13 or other means adapted for suspension from a cable, not shown. In the present instance the detonator 11 is indicated as of the electrically fired type and provided with leads which extend through the weight bar 13 and communicate in a conventional manner with a conductor within the suspension cable. However, it should be understood that other types of detonators and firing means may be used.

The lower extremity of the detonator passage is connected with an equalizer tube 14 open to the bottom of the gun body and adapted to receive a plunger 15 which seals the lower end of the detonator passages but will displace axially under gradual change in pressure to equalize approximately the external and internal pressures.

The detonation chambers 6 and passages 8 as well as the cavity 10 and tube 14 are adapted to be filled with an explosive. The explosive is preferably a liquid such as nitromethane sensitized with aniline. However, the explosive may be one capable of being poured into the gun body when in a liquid state, even though solid at normal temperatures. For example, TNT may be used. It should be observed that under the conditions of use of a gun perforator the bottom hole temperatures may be above the melting point of TNT.

In any case, the cavities of the gun body with the exception of the cavities within the conical cells are in-

3

tended to be completely filled with an explosive so that the gun body itself is not subjected to any appreciable pressure differential between the interior explosive liquid and the exterior well fluids.

This is important for it is desired to construct the gun body of inexpensive, friable and relatively weak material. In fact, a material may be used which when disintegrated by the explosive charge is soluble in the well liquids; for example tar, asphalt, paraffines or waxes having a melting point above the well temperatures encountered may be used. This is of substantial advantage for wherever feasible economically a large number of perforations are desired and the cumulative debris of a number of gun bodies requires expensive bailing. However, it is not mandatory that soluble materials be used, for the body may be made of plaster, cement or analogous, readily castable material.

Whatever the material selected, the method of manufacture of the gun perforator is essentially the same. A mold 16 is provided, which, for example may take the form shown in Fig. 5. As it is desired for the hollow charges to be faced in different directions, the mold is divided into segments, in this case, three. The mold defines the prototype of the cavities desired in the gun body. The mold is so constructed that the hollow charge cells may be secured therein at the radially outer ends of what will later be the detonation chamber cavities.

The mold cavities are filled with a low melting metal alloy or other easily castable material, so as to form a core 17. The resulting casting is then plated, if of non-conductive material, it is first coated with graphite. The plating later becomes the lining 7 and 9 as well as the lining of the detonator cavity and equalizer tube. As will be brought out more fully, hereinafter, the plating may be relatively thick (about one-sixteenth inch of copper) if the gun perforator is not to be used submerged and a nitromethane type of explosive is used. However, if TNT is to be used or the gun perforator is to be fired submerged, a thin plating merely strong enough to permit handling in the course of manufacture is sufficient.

The plated core, or the plating with the core melted therefrom together with the hollow charge cells is placed in a suitable cylindrical form and the material of the gun body cast therearound. The hollow charge cells are preferable in place during the plating of the core, as this insures a seal at the forward extremities of the detonation chambers. In place of plating, the core and the hollow charge cells may be spray coated with fusible metal or a synthetic paint or analogous material.

The gun body may be provided with a reinforcing fabric sleeve 18, although it is desirable to avoid as much as possible substances which might later cause clogging of the well bore. Also the surface of the gun body may be coated with a material to inhibit its solution in the well fluids.

While the explosive may propagate its own detonation wave through the passages of the gun body, propagation may be enhanced by use of a detonating cord 19, such as one containing PETN. Such cord is threaded through the passages as shown in Fig. 3.

It is highly desirable that the diameter of the gun perforator be as large as possible to place the shaped charges as close as possible to the well casing. Different size molds may be used to accomplish this, or the passage forming portions of the core 17 may be bent to vary the radial spacing. If different axial spacing between detonation chambers is desired, correspondingly different molds are required.

While in Fig. 1 a single passage is shown connecting all the detonation chambers serially, the detonation chambers may be divided into the sets, the members of each set occupying a common plane and being connected to a common passage. In this regard, reference is directed to Fig. 6 wherein a core 20 is shown as compris-

4

ing a set of chamber cores 21 and a common passage core 22. The passage core may be bent substantially so that the three sets of hollow charges may nestle closely as shown in Fig. 7 or be radially spaced outwardly any distance desired. The passages formed by the passage cores 22 are preferably connected at their upper ends to a common detonator cavity and at their bottom ends to a common equalizer tube.

While it is desirable to employ a core and then coat the mold to form a gun body cavity lining, it is feasible to form the linings by means of thin sheet metal stampings and connecting tubes soldered or otherwise fabricated as shown in Figs. 8, 9 and 10. In this case, complementary sheet metal shells 23 define the detonation cavities. These shells clamp the hollow charge cells and are provided with nipples 24 which receive connecting tubes 25. With this arrangement, virtually any diameter of gun perforator or shot spacing may be obtained.

It is, of course, desirable that in filling the gun perforator cavities, no air bubbles be entrapped. Thus it is desirable to provide a thin slit or small bleeder passage from the top sides of the detonation chambers to the passageways. Such means is indicated by 26 in Fig. 8 and a web 27 to cast such bleeder passage is shown in Figs. 6 and 7.

If the gun perforator is formed of an asphalt or analogous composition, it need not weigh appreciably more than the well liquid it displaces. Thus the submerged weight of the gun perforator may be virtually zero, and a weight bar employed to facilitate descent through the well liquid. Actually, the entire weight may be maintained so low that single strand measuring lines commonly used in oil wells may be used, and mechanical detonation employed. This is of primary importance, for the number of shots which may be provided in each gun body may be few or great without appreciably influencing the travel of the gun perforator in the well bore or require heavy and expensive surface equipment.

It is highly desirable that the gun perforator be safe to handle and, preferably, incapable of being fired unless within a well bore. If an explosive such as sensitized nitromethane is used, the gun perforator may be made so that it will not function unless submerged in liquid. This is made possible by the fact nitromethane may be so sensitized as to require a predetermined degree of confinement in order to detonate. Thus if the gun body be cast of asphalt, cement or similar material of low strength and the cavity linings be relatively thin, firing of the detonator can be caused to only rupture the gun body, not develop pressures therein high enough to detonate the explosive. However, if the gun perforator be submerged in a liquid, particularly when surrounded by a rigid well casing, the inertia of the system is such that the surrounding liquid functions as a solid during the extremely short period required for detonation, consequently, the detonation pressures rise to the required value and the gun perforator functions. Also, the increased temperature and pressure existing at the bottom of the well are factors conducive to detonation of the explosive at the bottom of a well without attendant hazard at the well mouth.

The equalizer tube and plug may be omitted if the lining of the detonation chambers and connecting passages is yieldable and a gun body material capable of plastic flow is employed. In such case the submergence pressure may be transmitted directly to the explosive through the body and lining.

Having described certain embodiments of my invention, I do not desire to be limited thereto, but intend to claim all novelty inherent in the appended claims.

I claim:

1. A gun perforator, comprising: a cast gun body of easily rupturable material defining a plurality of laterally directed detonation cavities and connecting passages; a lining for said cavities and passages; and hollow shaped charge cells cast as inserts in said gun body at the radially

5

outer ends of said detonation cavities; a continuous, uninterrupted body of a liquid explosive completely filling said cavities and said connecting passages; and means at the upper end of said gun body for causing that portion of said liquid explosive within said passages to propagate a detonation wave through said passages past said detonation cavities and to cause branching detonation of the portions of said liquid explosive within said detonation cavities.

2. A gun perforator, comprising: a lining structure including a plurality of laterally directed detonation chamber cells and tubes integrally connected to said chamber cells to join said chamber cells in series thereby to form a single continuous cavity; a hollow submergence pressure resistant shell sealed in the outer end of each detonation chamber and including an end member extending into said detonation chamber and defining the focusing surface of a shaped charge; a continuous, uninterrupted body of liquid explosive completely filling said chamber cells and connecting tubes and a gun body of easily rupturable material cast around said lining and hollow shells.

3. A gun perforator, comprising: a lining structure defining a plurality of laterally directed detonation chambers and connecting passages and adapted to receive an explosive; a hollow submergence pressure resistant shell sealed in the outer end of each detonation chamber and including an end member extending into said detonation chamber and defining the focusing surface of a shaped charge; a gun body of easily rupturable material cast around said lining and hollow shells; a continuous, uninterrupted body of liquid explosive completely filling the spaces within said lining; and means for subjecting said explosive to the submergence pressures present when said gun body is submerged in a liquid.

4. A gun perforator adapted to be submerged to great depths in a liquid filled well bore, comprising: a cast gun body of yieldable, easily rupturable material defining a plurality of laterally directed detonation cavities and connecting passages said gun body being collapsible when subjected to submergence pressures; hollow pressure resistant sealed shaped charge cells cast as inserts secured in the radially outer ends of said detonation cavities; and a continuous uninterrupted body of liquid explosive completely filling the cavities of said gun body, and subjected to submergence pressures applied through the walls of said gun body to support said gun body against collapse.

5. A gun perforator, comprising: a gun body formed of material soluble in well fluids, and defining a plurality of laterally directed detonating chambers and connecting passages forming a single continuous cavity; hollow submergence pressure resistant shaped charge cells sealed in the outer ends of said chambers; a continuous, uninterrupted body of liquid explosive completely filling said detonation chambers and connecting passages comprising said continuous cavity; said gun body adapted, on detonation of said explosive to be fragmented whereby the resulting pieces may dissolve in the well liquids.

6. A gun perforator, comprising: a gun body formed of material soluble in well fluids, and defining a plurality of laterally directed detonating chambers and connecting passages forming a single continuous cavity; a continuous

6

non-soluble lining for said cavity; submergence pressure resistant hollow shaped charge cells sealed in the outer ends of said chambers; a continuous, uninterrupted body of liquid explosive completely filling said detonation chambers and passage comprising said lined cavity; said gun body adapted, on detonation of said explosive to be fragmented whereby the resulting pieces may dissolve in the well liquids.

7. A gun perforator, comprising: a plurality of hollow sealed shells, each including a shaped charge defining portion and a cap thereover, said shells adapted to withstand the submergence pressures exerted by liquids within a well bore; and a frangible gun body cast completely around said shells with said caps imbedded within and located adjacent the surface thereof, said gun body defining detonation chambers behind said shells and connecting passages joining said chambers and adapted to form therein a single continuous cavity; and a continuous, uninterrupted body of a liquid explosive completely filling said cavity formed by said chambers and passages.

8. A gun perforator as set forth in claim 7 wherein: said gun is formed largely of material soluble in well liquids, whereby, on detonation of said explosive the resulting particles of the gun body readily dissolve.

9. A gun perforator as set forth in claim 7 wherein: an explosive is employed which requires, in order to detonate, a pressure surge above the bursting strength of the gun body whereby said gun body must be submerged in well liquids and utilize the inertia thereof in order to withstand a pressure surge of sufficient magnitude to cause detonation of said explosive, thereby rendering said explosive ineffective unless said gun body is liquid submerged.

10. A gun perforator as set forth in claim 7 wherein: an explosive is employed which requires, in order to detonate, a pressure surge above the bursting strength of the gun body whereby said gun body must be submerged in well liquids and utilize the inertia thereof in order to withstand a pressure surge of sufficient magnitude to cause detonation of said explosive, thereby rendering said explosive ineffective unless said gun body is liquid submerged, said gun body being formed largely of material soluble in well liquids whereby on detonation of said explosive therein the resulting gun body fragments are eventually dissolved.

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