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3,021,784
SHAPE CHARGE UNIT FOR WELL PERFORATORS
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6 Claims. (Cl. 102—20)

This invention relates generally to well perforators and more particularly to improvements in explosive shaped charges for use in perforating well casings and the surrounding earth formations in well boreholes.

In the employment of shaped charges for making perforations in well boreholes, a number of different apparatus and arrangements have been developed suitable for lowering one or more shaped charges through fluid-filled well casings or earth boreholes to locations wherein perforation is desired, and for the firing at such locations simultaneously or selectively of the shaped charges. As an example of one type of such apparatus, a so-called shaped charge perforator gun has heretofore been developed which makes provision for the mounting of one or more, and preferably a plurality of shaped charges adjacent one another inside a suitable, liquid-tight, thick-walled cylindrical, steel housing which is adapted to be lowered on a conductor cable into the fluid-containing well borehole and casing to be perforated. In such apparatus, the plurality of shaped charges are usually positioned at suitable, longitudinally spaced-apart intervals throughout the length of the cylindrical housing, with the jet-forming or perforating axes of the shaped charges directed laterally thereof in alignment with suitable ports formed in the housing walls. The ports are initially closed prior to firing of the shaped charges by suitable, relatively thin, frangible, replaceable, fluid-tight port seals. Upon firing of the shaped charges, usually by means of electrical current passed through the conductor in the before-mentioned conductor cable to suitable detonating means within the housing, the port seals are perforated, destroyed, or otherwise removed from the ports by the shaped charge perforating jets which are of sufficient penetrating power to continue on through the fluid in the borehole, through the casing and into the surrounding formations. The cylindrical housing serves initially before firing to exclude borehole liquid from contact with the shaped charges therein and also, upon firing, to confine therein all of the blast of the shaped charges other than that directed into the perforating jets which are projected through the perforated port openings. Typical examples of the before-described so-called shaped charge perforating gun apparatus in which the device of the present invention may be used are shown in U.S. Patent No. 2,707,917, issued May 10, 1955, to Will H. Lindsay, Jr., et al. and in the copending application of Will H. Lindsay, Jr., Serial No. 276,156 filed March 12, 1952, now abandoned in favor of the copending continuation application of Will H. Lindsay, Jr., Serial No. 703,670, filed December 18, 1957 now U.S. Patent No. 2,926,603, issued March 1, 1960.

In oil well perforating operations as hereinbefore mentioned, it is desirable to attain the maximum depth of penetration of perforations laterally through the well casing and into surrounding formations, together with the use of a minimum explosive charge and with a minimum resultant amount of damage to the cylindrical housing in which the shaped charges are contained. It is also in some cases desirable to attain a maximum size of perforation through the casing and into the surrounding formations, but in some cases and under some conditions it is also desirable to be able to control the perforation hole sizes obtained between certain specified limits.

Heretofore, the attainment of improved performance of the shaped charges in regard to increase of depth of perforation penetration and increased hole size has usually been at the expense of the use of greater and greater amounts of explosive, with attendant increased damage to the shaped-charge containing housings.

It is, therefore, an object of this invention to provide a shaped charge perforating unit of superior performance characteristics.

It is another object of this invention to provide a shaped charge perforating unit having increased penetrating power for a given amount of explosive charge.

It is a further object of this invention to provide a shaped charge unit of superior design whereby the perforating jet is of more effective shape and power.

It is a still further object of this invention to provide a shaped charge construction which will produce larger perforations for a given amount of explosive and in which adjustments may be readily made to vary the perforation hole sizes.

It is a still further object to permit adjustment of the shaped charge in the field to vary the size of the produced perforation.

A still further object of this invention is to provide a shaped charge construction which will permit of its use with a minimum of damage to the containing housing.

The objects of this invention are attained in general by employing an improved casing for the shaped charge explosive body, the primary constructional feature of which resides in the employment of a plurality of relatively thick, substantially separate, coaxial, metal ring members which closely and firmly encircle a part or all of the portion of the shaped charge which surrounds the jet-forming cavity therein. The reason for obtaining the improved shaped charge performance characteristics in this manner is not entirely understood, but it is thought possibly to result from employing such rings of sufficient weight and tensile strength as to provide an effective "back-up" and confinement for the shaped charge, while at the same time permitting rupture of the rings in a progressive, orderly manner from the rearmost one thereof forward therethrough through the plurality of such rings as the detonation wave is propagated forwardly from the detonator through the explosive charge body, in such a manner as to provide at all times a consistent and symmetrical confinement and direction of the gaseous explosive products into the formation of a more perfectly shaped and more powerful perforating jet. Erratic fracture of the entire case at any one instant as otherwise probably occurs is thus prevented by such separate ring construction of the case. Such progressive rupture of the casing rings also results in a substantial reduction of damage to the containing housing. In this
connection it has also been discovered that a variation in the number of rings employed will result in a variation in the resultant perforated hole size.

These and other objects, advantages and features of novelty of the invention will be evident hereinafter.

In the accompanying drawing wherein a preferred embodiment and the best mode contemplated by the inventor for carrying out his invention is illustrated:

FIGURE 1 is a longitudinal sectional view illustrating a typical arrangement of the shaped charge structure of this invention utilizing a shaped charge casing having a plurality of separate ring members.

FIGURE 2 is a fragmentary sectional view of an alternative embodiment in which the shaped charge casing is provided with a plurality of encircling annular grooves formed in the outer periphery thereof.

FIGURE 3 is a fragmentary sectional view of an embodiment alternative to that of FIGURE 2 and in which the annular grooves are formed in the inner surface of the shaped charge casing.

FIGURE 4 is a longitudinal sectional view showing a modified embodiment of the invention and illustrating the manner in which the number of reinforcing rings may be varied to control the dimensions of the perforation produced by the shaped charge.

FIGURE 5 is a view, partly in elevation and partly in longitudinal section, of a complete assembled perforator apparatus illustrating a typical arrangement of the shaped charge devices of this invention.

FIGURE 6 is a cross-sectional view, on an enlarged scale, taken on line 6—6 of FIGURE 5.

Referring first primarily to FIGURE 1, the shaped charge apparatus of the invention therein illustrated, incorporates a basic explosive body and cone assembly. This explosive body and cone, which may be pelletized or cast together as is conventional practice, is seated in a separate rearward portion of the case, which may be considered basic for a given shaped charge body, and need not vary in form as the remaining case parts are assembled or varied.

The before-mentioned basic rearward portion 1 of the case may be formed preferably of a material of substantial tensile strength, such as steel, although diecast zinc, aluminum, Bakelite, or equivalent materials may be used. It consists of a cylindrical rear portion 2 having a frusto-conical portion 4 flared outwardly and forwardly from the basic case 1 thus of generally conical form about its longitudinal axis, but is bored transversely through the cylindrical rear portion 2 as shown at 5 to receive therethrough an explosive fuse 6, and the case 1 is also internally bored at 7 along its longitudinal axis to form a cylindrically shaped recess to receive a booster charge 9. Booster charge 9 may be pressed into the bored portion 7 of case 1, but is preferably contained in a metal, cup-shaped container comprising a thin-walled, cylindrical portion 20 and a relatively thick, annular, rear end closure member 9b which surrounds a thin, central diaphragm aperture portion 9c. Forward of the booster charge 9 the basic case 1 is formed with a generally frusto-conical interior portion 10 defining a conical seat for the reception of the correspondingly shaped rear end portion of the main explosive shaped charge body 11. The explosive charge body 11 is formed with a coaxial, forwardly directed concavity or recess 12 of generally conical form and which may have the apical portion rounded as at 13. The concavity section 10 is closed by a closely adherent liner 14 of copper or similar material.

The shaped charge concavity 12 and liner 14 flare outwardly from the rounded portion 13 near the booster 7, to intersect the inner wall of the case 20 near or within a charge aligner receiving ring 15. Charge aligner receiving ring 15 is formed with an annular recess 16 to provide for the reception therein of the inner end of a suitable charge retainer and aligner member which may be of the type illustrated at 35 in the hereinbefore mentioned copending patent application of Lindsay, Jr., which retainer and aligner member provides for the proper alignment and stand-off distance required for the perforating jet when the charge is seated in a gun for firing.

The outer surface of the explosive charge 11 may be, under some circumstances, protected by a thin metallic coating or shell as shown at 17 in the embodiment of FIGURE 4. The shell or coating 17 preferably extends completely around the frusto-conical portion 4a of the shaped charge 11 and cylindrical rear portion 2a in order to provide a conveniently handled, substantially sealed unitary structure.

The remainder of the casing between the charge aligner receiving ring 15 and the frusto-conical portion 4 of the basic case as shown in FIGURE 1 is made up of a plurality of relatively thick, coaxial annular, ring members, generally indicated at 20, and which closely, and preferably tightly, encircle the exterior surface of the explosive body which surrounds the shaped charge cavity 12. Ring members 20 may be held together and retained securely upon the exterior of the shaped charge body by a suitable means, such as, for example, by cementing.

A modification of the construction shown in FIGURE 1 may be seen in fragmentary form in FIGURE 2. Here the shaped charge casing, generally indicated at 25, includes in one piece the retainer recess portion of the annular ring portions 27, and a rear portion 29 corresponding to the basic case portion shown at 2 in FIGURE 1. The aligner receiving ring 26 and the annular ring portions 27 are, however, formed integrally instead of separately as in the embodiment of FIGURE 1. The individually functioning annular portions are then defined by cutting a plurality of annular slots into the external periphery of the casing 25. These slots may extend for only a portion of the casing wall thickness, although preferably they extend almost entirely therethrough, as shown at 35. In some cases sufficient stress concentration may be provided by grooves of medium depth.

A related alternative embodiment is shown in FIGURE 3, in which slots 31a—31f, inclusive, are cut into the internal surface of a similar case 32 before the shaped charge body 11 is inserted.

In the embodiments of FIGURES 2 and 3, it will be seen that the essential characteristic of the embodiment of FIGURE 1 is that a reservoir of pressure-stabilizing annular members is presented to the traveling shock wave, essentially separate so far as their ability to resist rupturing stresses, yet mechanically joined for ease in construction and convenience in handling during assembly.

FIGURE 4 illustrates the manner in which the number of rings applied about the charge may be varied in the field or elsewhere by the operator, to control the diameter of the hole produced. In tests on one embodiment, it has been found possible to vary the hole diameter between about .33" to .75" solely by controlling the number of rings. The hole size increases as the number of such rings is increased.

In this arrangement, the aligning member-receiving ring 15 with recess 16 is identical with the type shown in FIGURE 1. Rings 34a and 34b are then slipped over the shell 17 encasing charge 11, and as many additional rings 34c, 34d, etc., applied as will produce the hole size desired. Shell 17 is preferably of thin sheet metal, metal foil, or armor plating with a thin metal shell which will form a firm mechanical connection between the explosive charge and the surrounding case structure and which will contain the explosive charge and prevent contamination by atmospheric moisture. This makes it possible to determine hole size in accordance with the needs of the particular location under the ready control of the operator through the utilization of one basic explosive body or pellet.

Advantages of the hereinbefore described shaped...
charge construction of this invention and a possible explanation of the reasons therefor, are as follows:

If the case enclosing the shaped charge body is constructed of a continuous uninterrupted body, upon detonation of the charge therein the case is ruptured in an irregular and erratic manner, with breaks possibly developing in the case for a considerable distance in advance of the explosive wave. This erratic and irregular manner of rupture of the case possibly results in a comparable irregular and erratic fracture and deformation of the explosive charge ahead of the explosive wave which in turn would result in a similarly nonsymmetrical production of the gaseous products of the detonation relative to the longitudinal axis of the shaped charge body. This action together with the resultant nonsymmetrical support of the products of the explosion by the surrounding case would thereby result in defective action of the shaped charge.

In the instant embodiment of this invention, however, it is believed that this undesirable action is eliminated by providing a case structure which, as hereinbefore described, is composed of a plurality of coaxial, substantially separate, ring members which closely encircle the exterior surface of the shaped charge and which ring members by reason of their being substantially separate are able to collapse and rupture very quickly, and as the explosive wave progresses forwardly through the shaped charge body. The result of this action is the insulation that the surrounding case will have for all practical purposes, remain intact around the unexploded portion of the shaped charge body until the explosive wave has progressed forwardly therepast. The rupture of one ring will not be carried forward into the next forwardly adjacent ring until the pressure therein also reaches the ring-fracturing value. This affords an over-all effect of a series of momentary but appreciable additional periods of confinement for the explosive charge during which a more efficient build-up of pressure and a better form of the body of gaseous products may be maintained, together with an increased rate of detonation of the explosive, which results in the formation of a perforating jet of increased volume and velocity and of superior form.

Another important advantage which resides in the shaped charge construction of this invention is as follows: As a result of the increased efficiency of the shaped charge construction of this invention, a reduced amount of explosive may be employed without sacrificing any performance characteristics or penetrating power. As a result of this reduction in the quantity of explosive, the danger to the housing or so-called shaped charge perforating gun is greatly reduced. The so-called gun damage is found to be still further reduced when the shaped charge case is constructed from a plurality of rings in the manner of the invention herein disclosed. This latter result appears to be due largely to the greater ability of the gun body to absorb a succession of separate lesser shocks and impacts as the rings rupture progressively, as contrasted with its ability to absorb the entire shock of much greater magnitude which occurs when a conventional type of shaped charge case is employed.

Referring to FIGURES 5 and 6, the well perforator apparatus shown has a liquid-tight, thick-walled, cylindrical, steel housing including a tubular section 36. The bottom of the tubular section is closed by a bull plug 37. The top of the tubular section is closed by a cable head 38 coupled to the top of the tubular section through an intermediate sleeve member 39. A conductor cable 40 containing an insulated conductor 41, is anchored to the cable head 38 and serves as a means for lowering the perforator apparatus into the well and for conducting electric firing current to the firing means of the perforator. Typical cable head construction suitable in this connection is illustrated in U.S. Patent No. 2,043,541 to Turecek. The electrical conductor 41 is connected through the cable head 38 and through an insulated electric conductor 42 to an electric detonator cap 43. The cap is secured within the upper end of a tubular fuse terminal union 44, which is in turn supported centrally within the upper end of the housing section 36 by means of a centrally perforated diaphragm 45. A suitable fuse 6, such as the fuse described with reference to FIGURE 1, which is threaded through the rear end portions of the shaped charge unit, is connected to the upper end of the fuse terminal union 44 adjacent to or in contact with the cap 43.

The housing section 36 has a series of longitudinally spaced, radially directed openings or ports 46 therethrough, each port being enlarged on the outside end by a short counterbore 47 to receive a port seal disc 48. Such series of ports 46 (only two of which are shown in FIGURE 5, duplicate portions thereof having been omitted) may be arranged along the housing in any desired pattern.

A shaped charge unit, such as shown in FIGURE 1, having the ring members 20a, 20b, etc., is mounted opposite each of the ports 46 and positioned so that the jet-shaped blast projected from the forward, concave end of the unit will pass through the center of the port. In order to position and accurately maintain each such shaped charge unit in axial alignment with its respective port 46, the inner wall of the tubular housing section 36, diametrically opposite each port 46, is provided with suitable means to engage and support the rear end portion of the shaped charge unit. Preferably, such means takes the form of a radially directed, generally cylindrical recess 49, and the rear end portion 2 of the shaped charge case is formed to fit within such recess. The forward end of the shaped charge unit may be supported by any suitable means adapted to hold the rear end of the shaped charge case securely seated within the recess 49 and at the same time maintain accurate alignment of the axis of the shaped charge with the center of the port 46. For this purpose, a retainer 50 may be employed. The retainer is in the general form of a hollow, truncated cone, with end portions 51 and 52 for making telescoping engagement with the annular recess 16 formed within the forward end of the shaped charge unit, and with the inside surface of the inner end portion of the port 46, respectively, and a coaxial, frusto-conical, tubular, interconnecting portion 53 extending between these end portions. The interconnecting portion 53 is preferably of flexible, resilient material, such as rubber, to enable one end portion thereof to be collapsed or telescoped within the other end portion for initial installation of the shaped charge unit within the bore of the tubular housing section 36, as more fully described in the hereinbefore mentioned U.S. Patent No. 2,707,917 to Will H. Lindsay, Jr., et al.

It will be understood that the shaped charge units of FIGURES 2, 3 and 4, and other units in accordance with the invention, may be similarly mounted in a hollow housing in the manner illustrated in FIGURES 5 and 6.

In operation of the apparatus of FIGURES 5 and 6, an electric potential is applied to the conductor 41, which is transmitted down through the conductor cable 40 from the top of the borehole to the cable head, through conductor 42 within the cable head, and through the electric detonator cap 43 to ground. The resultant detonation of the cap in turn detonates the fuse 6, the explosive wave of which travels through the full length of the fuse from top to bottom at high velocity. This explosive wave fires the shaped charge units in rapid succession. The resultant perforating jets pierce the seal discs 48 and the surrounding well casing and earth formation, thus perforating the well.

It is to be understood that the foregoing is illustrative only and that the invention is not limited thereby, but may include various modifications and changes made by those skilled in the art without distinguishing from the scope of the invention as defined in the appended claims.
What is claimed is:

1. In a shaped charge perforating apparatus for use in a well borehole including a liquid-tight, generally cylindrical housing having a longitudinal axis and adapted to be lowered into a well borehole, at least one shaped explosive charge perforating unit mounted in said housing, said unit including a body of high explosive material formed with a forwardly facing concavity symmetrical about an axis transverse to the longitudinal axis of the housing, and with a surrounding exterior surface coaxial with the axis of said concavity and extending rearwardly from adjacent the forward edge portion of said concavity to the inner end of the latter, a liner lining the walls of said concavity, a metal case about said body of high explosive material, and means at the rear of said body of high explosive material for detonating the latter, said perforating unit being adapted to fire a perforating jet through a wall of said housing into the surrounding wall of the well, said body of explosive material being adapted to fracture said case and to scatter its fragments forcefully against the inner walls of said housing, the improvement for reducing damage to said housing caused by the scattered fragments of said case which comprises said metal case having an annular wall portion disposed about said surrounding exterior surface of said body of high explosive material, said wall portion having a plurality of longitudinally spaced-apart, annular grooves extending laterally through a major portion of its thickness to form several substantially separate, solid ring members, said wall portion comprising several substantially separate, solid ring members being longitudinally disposed with adjacent ring members substantially abutting each other, said ring members being coaxial with the axis of said concavity and closely encompassing said body of high explosive material along its substantially entire longitudinal length, said ring members being adapted to be ruptured successively as the explosive wave progresses forwardly through said body of high explosive material upon detonation of the latter.

2. In a shaped charge perforating apparatus for use in a well borehole including a liquid-tight, generally cylindrical housing having a longitudinal axis and adapted to be lowered into a well borehole, at least one shaped explosive charge perforating unit mounted in said housing, said unit including a body of high explosive material formed with a forwardly facing concavity symmetrical about an axis transverse to the longitudinal axis of the housing, and with a surrounding exterior surface coaxial with the axis of said concavity and extending rearwardly from adjacent the forward edge portion of said concavity to the inner end of the latter, a liner lining the walls of said concavity, a metal case about said body of high explosive material, and means at the rear of said body of high explosive material for detonating the latter, said perforating unit being adapted to fire a perforating jet through a wall of said housing into the surrounding wall of the well, said body of explosive material being adapted to fracture said case and to scatter its fragments forcefully against the inner walls of said housing, the improvement for reducing damage to said housing caused by the scattered fragments of said case which comprises said metal case having an annular wall portion disposed about said surrounding exterior surface of said body of high explosive material, said wall portion having a plurality of longitudinally spaced-apart, annular grooves extending laterally through a major portion of its thickness to form several substantially separate, solid ring members, said wall portion comprising several substantially separate, solid ring members being longitudinally disposed with adjacent ring members substantially abutting each other, said ring members being coaxial with the axis of said concavity and closely encompassing said body of high explosive material along its substantially entire longitudinal length, said ring members being adapted to be ruptured successively as the explosive wave progresses forwardly through said body of high explosive material upon detonation of the latter.

3. In a shaped charge perforating apparatus for use in a well borehole including a liquid-tight, generally cylindrical housing having a longitudinal axis and adapted to be lowered into a well borehole, at least one shaped explosive charge perforating unit mounted in said housing, said unit including a body of high explosive material formed with a forwardly facing concavity symmetrical about an axis transverse to the longitudinal axis of the housing, and with a surrounding exterior surface coaxial with the axis of said concavity and extending rearwardly from adjacent the forward edge portion of said concavity to the inner end of the latter, a liner lining the walls of said concavity, a metal case about said body of high explosive material, and means at the rear of said body of high explosive material for detonating the latter, said perforating unit being adapted to fire a perforating jet through a wall of said housing into the surrounding wall of the well, said body of explosive material being adapted to fracture said case and to scatter its fragments forcefully against the inner walls of said housing, the improvement for reducing damage to said housing caused by the scattered fragments of said case which comprises said metal case having an annular wall portion disposed about said surrounding exterior surface of said body of high explosive material, said wall portion comprising several substantially separate, solid ring members being longitudinally disposed with adjacent ring members substantially abutting each other, said ring members being coaxial with the axis of said concavity and closely encompassing said body of high explosive material along its substantially entire longitudinal length, said ring members being adapted to be ruptured successively as the explosive wave progresses forwardly through said body of high explosive material upon detonation of the latter.

4. In a shaped charge perforating apparatus for use in a well borehole including a liquid-tight, generally cylindrical housing having a longitudinal axis and adapted to be lowered into a well borehole, at least one shaped explosive charge perforating unit mounted in said housing, said unit including a body of high explosive material formed with a forwardly facing concavity symmetrical about an axis transverse to the longitudinal axis of the housing, and with a surrounding exterior surface coaxial with the axis of said concavity and extending rearwardly from adjacent the forward edge portion of said concavity to the inner end of the latter, a liner lining the walls of said concavity, a metal case about said body of high explosive material, and means at the rear of said body of high explosive material for detonating the latter, said perforating unit being adapted to fire a perforating jet through a wall of said housing into the surrounding wall of the well, said body of explosive material being adapted to fracture said case and to scatter its fragments forcefully against the inner walls of said housing, the improvement for reducing damage to said housing caused by the scattered fragments of said case which comprises said metal case having an annular wall portion disposed about said surrounding exterior surface of said body of high explosive material, said wall portion comprising several substantially separate, solid ring members being longitudinally disposed with adjacent ring members substantially abutting each other, said ring members being coaxial with the axis of said concavity and closely encompassing said body of high explosive material along its substantially entire longitudinal length, said ring members being adapted to be ruptured successively as the explosive wave progresses forwardly through said body of high explosive material upon detonation of the latter.

5. In a shaped charge perforating apparatus as defined in claim 3, the further improvement which comprises said plurality of longitudinally spaced-apart, annular grooves being formed in the outer periphery of said annular wall portion of said case.
6. In a shaped charge well perforating apparatus as defined in claim 3, the further improvement which comprises said plurality of longitudinally spaced-apart, annular grooves being formed in the inner periphery of said annular wall portion of said case.

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CERTIFICATE OF CORRECTION

Patent No. 3,021,784

Lorrain D. Meddick

February 20, 1962

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 7, line 36, for "letter" read -- latter --; column 8, line 31, for "entrie" read -- entire --; same column, line 51, for "and" read -- said --.

Signed and sealed this 24th day of July 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents
UNITED STATES PATENT OFFICE
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