Oct. 13, 1959 A. BLANCHARD ET AL 2,908,222

APPARATUS FOR DETONATING SHAPED EXPLOSIVE CHARGES

Filed May 25, 1953

FIG.1.

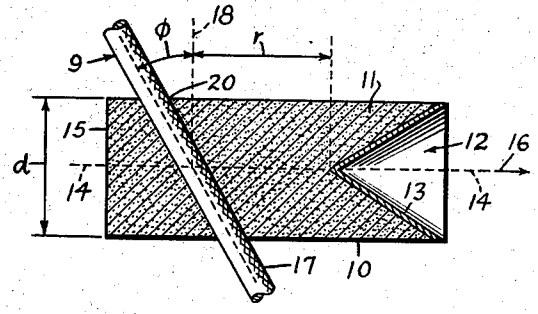


FIG.2.

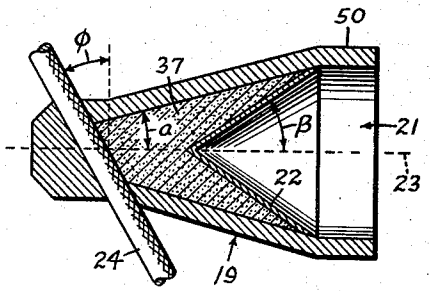


FIG.3B.

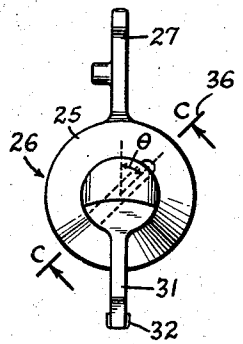
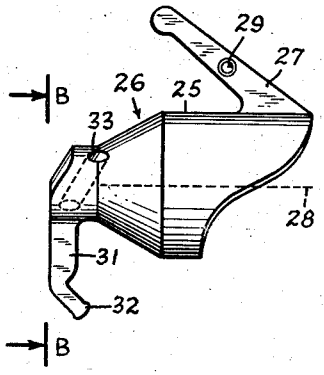


FIG.3A.



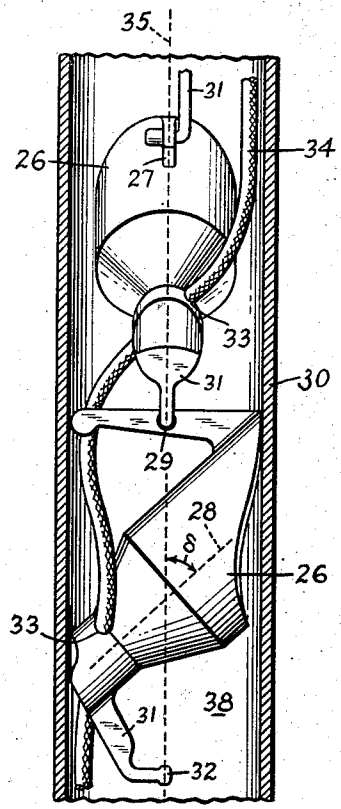
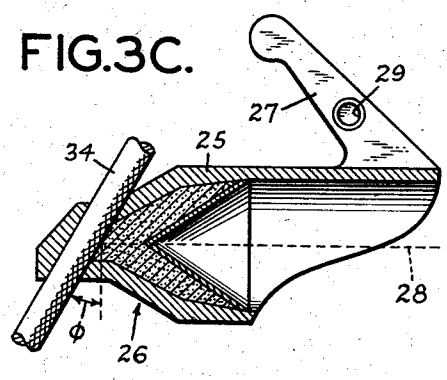


FIG.4.

FIG.3C.



INVENTORS.
ANDRE BLANCHARD
JAMES B. SHORE
BY
Campbell, Brumbaugh, Freer & Graves
THEIR ATTORNEYS.

United States Patent Office 2,908,222 Patented Oct. 13, 1959

2,908,222

APPARATUS FOR DETONATING SHAPED EXPLOSIVE CHARGES

Andre Blanchard and James B. Shore, Houston, Tex., assignors, by mesne assignments, to Borg-Warner Corporation, Chicago, Ill., a corporation of Illinois

Application May 25, 1953, Serial No. 357,312

9 Claims. (Cl. 102—20)

The present invention relates to the detonation of shaped explosive charge devices and more particularly to new and improved means for increasing the efficiency of shaped explosive charges detonated by detonating means such as an explosive fuse, for example.

Shaped explosive charges relying on the "Munroe Effect" to generate highly penetrative jets are well known. Such shaped charges may in general comprise a cylinder of explosive material, one end of which is hollowed out and lined with a thin metallic liner. The charge is detonated at the other end and the explosive wave traveling in the explosive material causes the liner to collapse and form the penetrating jet from the hollowed end. In certain operations requiring the use of a series of shaped explosive charges, detonation by an elongated explosive fuse placed perpendicularly to the axis of the charges has been conventional.

For example, in the perforation of oil and gas wells, a plurality of shaped charges are longitudinally disposed in a cylindrical housing adapted to be lowered into a well, so that the explosive jets will be directed at the wall of the well. An explosive fuse passing perpendicularly to the axes of the charges is employed for detonation. Although the penetration requirements of the jets from such shaped charges is high, the size of the charges is necessarily limited by the diameter of the housing. Accordingly, any substantial increase in penetration of the jets resulting from increased shaped charge efficiency, rather than from increased amounts of explosive charge, is highly desirable.

Therefore, one object of this invention is to provide increased efficiency in the discharge of shaped explosive charges.

A further object of the invention is to provide novel apparatus for increasing the efficiency of shaped explosive charges detonated by an explosive fuse.

Another object of the invention is to provide for increased efficiency of shaped explosive charges employed in the perforation of oil and gas wells.

Still another object of the invention is to provide shaped explosive charges of increased efficiency which permit simplified loading of gun housings employed in the perforation of oil and gas wells.

These and other objects of the invention are attained by propagating a detonating wave transversely of an explosive charge at the rear thereof such that the line of propagation of the wave makes an acute angle with respect to the longitudinal axis of the charge. The direction of propagation of the detonating wave is such that the latter has a forward component and tends to produce in the explosive charge a detonation wave front substantially normal to the longitudinal axis of the charge. As a result, the efficiency of the charge is increased. Further in certain uses such as well casing perforating in which a detonating fuse is used, it simplifies the loading of the charge units in the carrier employed to position them in a bore hole.

Further objects and advantages of the invention will be

more fully understood when the following description is read in connection with the accompanying drawings in which:

Fig. 1 is a view, partially in longitudinal section, of a shaped explosive charge embodying the present invention;

Fig. 2 is a cross-sectional view of a shaped explosive charge device modified in accordance with the invention;

Fig. 3A is a side view of a second form of shaped explosive charge device in which the present invention may be employed;

Fig. 3B is a rear view of the charge shown in Fig. 3A taken from the line B—B, looking in the direction of the arrows;

Fig. 3C is still another view, partially in longitudinal section, taken through the line C—C in Fig. 3B, looking in the direction of the arrows;

Fig. 4 shows a series of charges of the type illustrated in Figs. 3A, 3B and 3C, assembled in a housing for use in oil and gas wells, for example.

Fig. 1 shows a typical explosive charge utilizing the principles of the "Munroe Effect," known as a shaped explosive charge. A cylindrical block 10 of explosive material 11 has fitted in the front end 12 thereof a thin, metallic, conically shaped liner 13, concentric about the axis 14 of the cylinder 10. In general, the explosive material 11 is adapted to be detonated in the vicinity of the rear end 15. This produces a detonation wave traveling in the direction of the front end 12, which, upon reaching the liner 13, causes a highly penetrative jet to be formed along the axis 14 in the direction indicated by the arrow 16.

When detonating a series of shaped explosive charges, it has become common practice to thread an elongated explosive fuse 17, such as primacord, through the rear portion of each charge 10 along an axis 18 perpendicular to and intersecting the axis 14. This has the disadvantage of providing a detonation wave front that is not normal to the axis of the charge, due to the small time interval necessary for the detonation wave produced by the fuse 17 to travel through the charge 10. Therefore, the desired dynamic symmetry, a condition obtained when the detonation wave front in the charge 10 is normal to the axis thereof, is destroyed.

In order to restore dynamic symmetry, according to the invention, a predetermined amount of geometrical dissymmetry is introduced into the shaped charge device. This may be accomplished by passing the explosive fuse 17 through the material 11 at an angle ϕ with respect to the perpendicular axis 18. The fuse 17 is detonated at such a location, for example, the portion 9, that the detonating wave traveling therein first reaches the explosive material 11 at the point 20 on the fuse 17 which is farthest removed from the liner 13. The optimum angle ϕ for maximum charge efficiency will depend on the relative rates of detonation of the explosive materials used in the charge 10 and in the fuse 17; on the distance r between the fuse 17 and the apex of the liner 13; on the diameter d of the explosive material 11 and the general external configuration of the charge 10; and on the shape and weight of any container which may be provided for the explosive material 11. The optimum angles ϕ for the many types of shaped explosive charges in use today may be determined by simple experimentation. In general, angles ϕ less than 45° will give improved efficiency, defined as penetration of the jet per unit of explosive material 11 employed. Specific angles ϕ found advantageous with certain types of shaped explosive charges will be discussed hereinafter.

In Fig. 2 there is shown a typical shaped explosive charge in which the present invention may be incorpo-

rated. This shaped explosive charge is of the type disclosed in Fig. 5 of the copending application Serial No. 123,003, filed October 22, 1949, by A. Blanchard for "Shaped Charge Perforating Apparatus," now abandoned. Approximate dimensions and specifications for a practical charge **19** of the type shown in Fig. 2 may be as follows: the container **50** may be 2½' inches in length, and 1½ inches overall diameter at the base **21**, manufactured from lead ⅛ inch thick opposite the liner **22**, with an angle α of 15° with respect to the axis **23** of the charge **19**; the liner **22** may be cone shaped, manufactured from thin copper, with an angle β of 27° with respect to the axis **23**; the explosive material **37** may be 12 grams of a cyclonite base composition; and the apex of the liner **22** may be ⅜ inch from the primacord fuse **24** along the axis **23**. The optimum angle ϕ for maximum efficiency of the charge **19** is of the order of 15° to 25°, though improved results will be obtained with angles up to 45°.

In Figs. 3A, 3B and 3C are shown detailed views and in Fig. 4 an assembly view of shaped charge apparatus of the type disclosed in the copending application Serial No. 209,598, filed February 6, 1951, by H. S. Robertson for "Method and Apparatus for Perforating Well Casing and the Like," modified in accordance with the present invention. In Fig. 3A, the container **25** of the shaped charge device **26** carries a bracket **27** which lies in a plane including the longitudinal axis **28** of the charge and is disposed perpendicularly to the outer wall of the container **25**. In the bracket **27** is formed a hole **29** which is so placed as to lie on the longitudinal axis **35** of a cylindrical housing **38** having a wall **30**, as shown in Fig. 4, when the charge **26** is inserted therein. Attached to the rear portion of the container **25** is a second bracket **31** opposite to and lying in the plane of the bracket **27**. The bracket **31** carries a pin **32** which is adapted to be inserted in the hole **29** in the bracket **27** of another container **25**. A detonating fuse **34** may be passed through a port **33** having an axis **36** and formed in the rear portion of the container **25**.

In order to provide shaped charges **26** of optimum efficiency with maximum ease of loading in the housing **38**, the fuse **34** passing from one charge to another should preferably assume the form of a portion of a helix. To provide such a configuration, certain angles must be considered. Thus, an angle δ between the axes **28** and **35**, as shown in Fig. 4, is determined in accordance with the aforementioned Robertson application, and may be of the order of 50°. The angle ϕ, shown in Fig. 3C, is chosen as described above for maximum efficiency of the shaped charges. By placing the fuse **34** at an angle ϕ and the axes **36** of ports **33** parallel to the tangent plane to the wall **30** of the housing **38**, the aforementioned helical positioning of the fuse will be obtained if the following relationship between the angles involved is observed:

$$\tan \phi \ (\tan \delta) = \cos \theta \qquad (1)$$

where θ is the angle shown in Fig. 3B between the plane of the brackets **27** and **31** and the plane defined by the axis **36** of the port **33** and the longitudinal axis **28** of the charge. It is obvious that angle θ must be varied to satisfy the relationship (1), since the angles ϕ and δ are fixed by other considerations set forth above. In this instance, the angles ϕ and δ may be of the order of 23° and 50°, respectively. In order to satisfy relationship (1), the angle θ should be of the order of 60° for the preferred helical fuse path when utilizing the charge shown in Figs. 3A, 3B and 3C. It is to be understood that these angles are not critical but they may be varied over a reasonable range without seriously impairing the loading and operation of this unit.

In operation, the fuse **34** is detonated at its lower end, causing the charges **26** to be sequentially detonated. The highly penetrative jets that are generated pierce the wall **30** and the well casing in which the housing **38** is disposed with greater efficiency than in the past, since the detonation wave front in each charge **26** travels substantially symmetrically about the longitudinal axis **28**. Such dynamic symmetry results from the angular positioning of the fuse **34** in the charge **26**, as described above.

The invention, therefore, provides a novel shaped explosive charge device of increased efficiency which is constructed to allow simplified loading into containers adapted to be lowered into wells, for example. Thus, better penetration coupled with less time-consuming preparation for well perforation are two of the primary advantages gained by utilizing the invention.

It is to be understood that the shapes of the containers described herein are illustrative only, and other charges having other configurations may employ the invention as, for example, the charges described in the aforementioned Blanchard application.

It will be understood that the several illustrative embodiments disclosed herein are susceptible of numerous modifications in form and detail within the scope of the invention. Therefore, the embodiments described above and shown in the drawing are not to be regarded as limiting the scope of the following claims.

We claim:

1. A shaped explosive charge device comprising a container symmetrical about an axis, a generally cylindrical body of explosive material in said container and hollowed out at one end, a liner fitted at said one end of the explosive material, said container, material and liner being grouped concentrically about said axis, an elongated detonating fuse having a straight line portion of uniform cross-section in contact, over a substantial distance transversely of said axis, with said material at the end of said container remote from said liner and disposed at an acute angle to said axis, and means for detonating said fuse at one end to first detonate the portion of said material contiguous to the portion of said fuse most remote from said liner.

2. A shaped explosive charge device as defined in claim 1 wherein said acute angle is greater than about 45°.

3. A shaped explosive charge device comprising a container, a generally cylindrical body of explosive material in the container, and a liner concentrically positioned with geometric symmetry about the axis of said generally cylindrical body of explosive material, said material being hollowed out to receive said liner and said container being provided with a transverse port at one end remote from said liner and open at the other end and constructed to cooperate with said liner and said explosive material for focusing shock waves generated upon detonation of said material through said open end, a detonating fuse having a straight portion of substantially uniform cross-section positioned in said transverse port contiguous to said material over a substantial distance transversely of said axis, said fuse straight portion passing through said axis at an acute angle thereto, and means for detonating said fuse at one end to first detonate the portion of said material contiguous to the portion of said fuse most remote from said liner.

4. A shaped explosive charge as defined in claim 3 wherein said acute angle is greater than about 45°.

5. Well casing perforating apparatus comprising a plurality of shaped explosive charge devices spaced longitudinally in a housing and connected by an elongated detonating fuse, each of said charge devices including a container, a generally cylindrical body of explosive material in the container having a hollowed out portion lined with a liner having an axis of symmetry coincident with the axis of said generally cylindrical body of explosive material, connecting devices joined to said container and connecting the same to adjacent containers within the housing, said fuse having straight portions of substantially uniform cross-section located contiguous to said material over a substantial distance transversely of said axis in each of said containers, respectively, and at an acute angle to said axis, said connecting devices

and said fuse orientation being arranged so that the portion of said fuse connecting two adjacent charges forms a portion of a helix, and means for initiating detonation of said fuse at one end to first detonate the portion of said explosive material in each of said devices contiguous to the portion of said fuse most remote from said liner.

6. Well casing perforating apparatus comprising a plurality of shaped explosive charge devics spaced longitudinally in a tubular housing having a first axis and connected by an elongated detonating fuse, each of said charged devices including a container, a generally cylindrical body of explosive material and a liner concentrically positioned with geometric symmetry about a second axis, said container having oppositely disposed connecting brackets in a plane including said first axis and said second axis, said first axis intersecting said second axis at an acute angle, means defining a straight port of uniform cross-section adapted to receive said fuse having a third axis in said container remote from said liner and intersecting at an acute angle the axis of symmetry of the explosive material, said adjacent charges being connected and positioned by said brackets, a plane including said third axis and said second axis being at a first angle with said plane of said connecting brackets, said first angle being determined by an angle between said first and second axes and an angle between said second and third axes so that the cosine of said first angle is substantially equal to the tangent of the acute angle between said first axis and said second axis multiplied by the tangent of the acute angle between said third axis and perpendicular to said second axis lying in the plane of said second and third axes, said brackets and said fuse orientation being arranged so that a section of said fuse connecting two adjacent charges forms a portion of a helix, said fuse contacting said explosive material over a substantial extent of explosive material, and means for initiating detonation of said fuse at one end to first detonate the portion of said explosive material in each of said charge devices contiguous to the portion of said fuse most remote from said liner.

7. A shaped explosive charge device comprising a container symmetrical about an axis, a body of explosive material having the form of an elongated body of revolution in said container and hollowed out at one end, a liner fitted at said one end of the explosive material, said container, material and liner being group concentrically about said axis, an elongated detonating fuse having a straight line portion of uniform cross-section in contact, over a substantial distance transversely of said axis, with said material at the end of said container remote from said liner and disposed at an acute angle to said axis, and means for detonating said fuse at one end to first detonate the portion of said material contiguous to the portion of said fuse most remote from said liner.

8. A shaped explosive charge device comprising a container symmetrical about an axis, a generally cylindrical body of explosive material in said container and hollowed out at one end, a liner fitted at said one end of the explosive material, said container, material and liner being grouped concentrically about said axis, detonating means adapted to detonate said explosive material progressively along a surface of said explosive material remote from said liner, said surface being formed of mutually parallel straight line elements extending a substantial distance transversely of said axis at an acute angle thereto, and means for actuating said detonating means to first detonate said explosive material at said surface at the portion thereof most remote from said liner.

9. A shaped explosive charge device comprising a container symmetrical about an axis, a body of explosive material having the form of an elongated body of revolution in said container and hollowed out at one end, a liner fitted at said one end of the explosive material, said container, material and liner being grouped concentrically about said axis, detonating means adapted to detonate said explosive material progressively along a surface of said explosive material remote from said liner, said surface being formed of mutually parallel straight line elements extending a substantial distance transversely of said axis at an acute angle thereto, and means for actuating said detonating means to first detonate said explosive material at said surface at the portion thereof most remote from said liner.

References Cited in the file of this patent

UNITED STATES PATENTS

2,604,042	Cook	July 22, 1952
2,628,559	Jasse	Feb. 17, 1953
2,669,928	Sweetman	Feb. 23, 1954
2,682,834	Church et al.	July 6, 1954
2,708,408	Sweetman	May 17, 1955

FOREIGN PATENTS

670,625	Great Britain	Apr. 23, 1952
677,824	Great Britain	Aug. 20, 1952