Dec. 22, 1964 H. R. CRAWFORD 3,162,121

EXPLOSIVE CHARGE ASSEMBLIES

Filed Oct. 31, 1960

FIG.1.

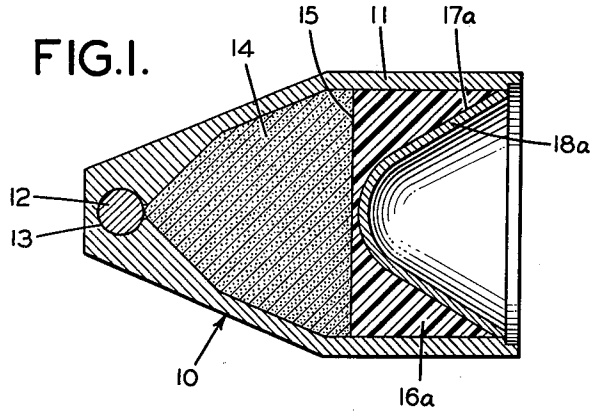


FIG.2.

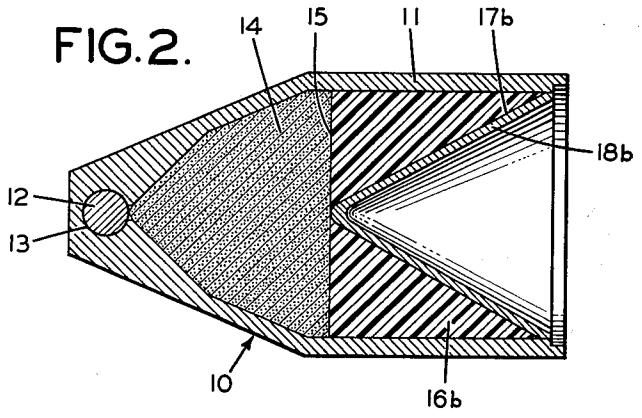
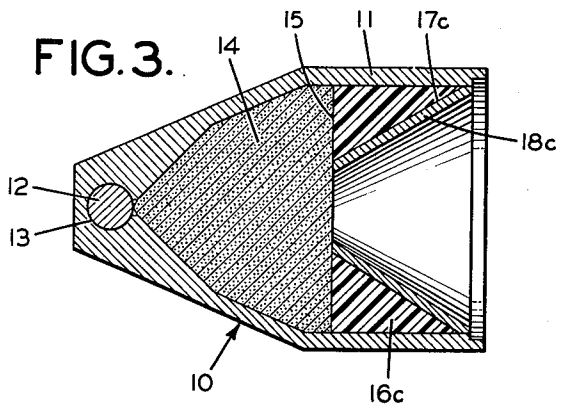


FIG.3.



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EXPLOSIVE CHARGE ASSEMBLIES

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This invention relates to an explosive charge assembly. More particularly, the invention relates to an explosive charge assembly for both military purposes and for perforating oil well casings and well boreholes.

The principle of the hollow charge or shaped explosive charge has been known for many years. The disclosure of this principle has been known since at least about 1792 and publications such as the May 1888 issue of "Scribner's Magazine" has discussed the principle. The principle became known as the Munroe effect in England and the United States and as the Neumann effect in Germany. In general, this principle or effect takes advantage of concentrating the forces from an explosive charge into a smaller area by providing a concave hollowing or shaping of the face of the explosive directed toward the area to be penetrated.

Early in World War II a number of military weapons appeared based on a modification of the hollow charge principle. This modification resulted from the discovery that by lining the face of the charge having the hollowed area or cavity with a thin metal liner it became possible to perforate armor plate, concrete walls, or other structures, with a surprisingly small weight of explosive charge. Very often these new weapons took the form of a projectile with the lined hollow charge in the nose of the projectile. The hollow charge principle was employed in a number of light, low velocity, antitank weapons, including the well-known rocket-propelled Bazooka. Such projectiles had the advantage over the previous military projectiles in that their ability to perforate was practically independent of their striking velocity. Even hand placed or statically detonated hollow explosive charges were at least as effective in perforating armor plate as previous projectiles which detonate upon impact.

The scientific principles involved in these military devices of World War II are discussed by Birkhoff et al. in "Journal of Applied Physics," vol. 19, pages 563–582 (June, 1948). The application of the hollow charge principle was not limited to military explosives but was logically extended to oil well perforating charges. An example of such a construction is that disclosed by Davis et al. U.S. Patent No. 2,399,211; Muskat et al. U.S. Patent No. 2,494,256, and Lawson Patent No. 2,605,703, among others.

While the hollow or "shaped" explosive charge construction has many advantages, it also has substantial and serious limitations and disadvantages. In general, this type of charge construction is extremely sensitive to variations in the dimensions and configuration of its components. It is usually necessary to design a suitable apparatus by means of trial and error until particular dimensions and configuration of the components have been found to achieve satisfactory results. Even minor alterations in configuration and dimensions can cause a drastic reduction in the effectiveness of the device. The configuration and dimensions of the metal liner is of particularly great importance in apparatus employing the hollow explosive charge construction. Even where an optimum design has been developed, the reproducibility of apparatus employing this construction is somewhat unsatisfactory.

Also, explosive charges employing the hollow charge principle are highly sensitive to the standoff distance between the metal liner of the explosive charge and the adjacent area to be penetrated or perforated. When an optimum stand-off distance is not achieved or is substantially exceeded, satisfactory results are not obtained.

Another shortcoming of hollow charge explosive devices has been the difficulty in constructing a device whereby the metal liner will conform exactly to the shape of the hollowing of the explosive charge. This frequently requires delicate shaping operations.

It is accordingly an object of the present invention to provide an improved explosive charge assembly which is free from the disadvantages of assemblies employing the hollow charge principle.

It is another object of the invention to provide an explosive charge assembly suitable for military purposes which employs no hollowing of the explosive charge, but employs instead an explosive charge having a substantially planar or flat face directed to the area to be penetrated or perforated.

It is also an object of the present invention to provide an explosive charge assembly for perforating oil well casings and oil well boreholes employing a planar face of the explosive charge oriented toward the area to be perforated.

It is an additional object of the invention to provide a novel process for perforating materials and oil well borehole casings which does not require the employment of an explosive charge utilizing the hollowing charge principle.

It is also another object of the invention to provide an explosive charge assembly which is not sensitive to variations in the dimensions and configuration of the components of the device, including the explosive charge, metal liner and lens element.

The above-enumerated objects, as well as other objects, together with the advantages of the invention, will be readily comprehended by persons skilled in the art upon reference to the present description, taken in conjunction with the accompanying drawing.

In the drawing:

FIGURE 1 is a longitudinal cross-section of a preferred construction of an apparatus of the invention, showing the parts, in the form of an explosive charge assembly suitable for perforating oil well casings and oil well boreholes;

FIGURE 2 is a longitudinal cross-section of another form of the apparatus of the invention suitable for use in perforating oil well casings and oil well boreholes;

FIGURE 3 is a longitudinal cross-section of a third form of the apparatus of the invention suitable for use in perforating oil well casings and oil well boreholes.

In the three figures of the accompanying drawing, the apparatus and its parts are shown in a scale one and one-half times the actual size. It should be recognized that it is the practice in printing patents in the United States to reduce the size of the drawings by approximately 25%.

The objects of the present invention are accomplished by employing an explosive charge assembly in which the explosive material has a substantially planar face or surface oriented toward the opening of the assembly housing and facing toward the area which is to be perforated or penetrated. Adjacent to the substantially planar face of the explosive charge is the substantially planar face of a nonexplosive lens element with the lens having a concave hollowing facing away from the explosive charge. Superimposed over the concave hollowing of the lens element is a metallic liner. The features and construction of the apparatus of the invention will be characterized and explained in greater detail hereinbelow.

In order to describe the apparatus of the invention more clearly, reference will be made to FIGURES 1, 2, and 3 of the accompanying drawing wherein like parts will be similarly numbered. While the apparatus of the invention will be discussed primarily in connection with explosive charge assemblies suitable for perforating oil well casings and oil well boreholes, it is not intended that

the invention shall be limited to such applications. It is intended that the apparatus of the invention shall be directed to military and industrial explosive charges as well. It is believed recognized by those skilled in the explosive art that the demands of military and industrial explosive charges are less acute and rigorous than those for perforating apparatus for use in oil well casings and boreholes. The major difference between military and industrial explosives on one hand and oil well explosives on the other is one of size, with oil well explosives being, in general, substantially smaller than the others. Thus, the discussion of the apparatus of the invention in connection with the preferred embodiment illustrated in the drawing is done by way of illustration only and is not to be regarded in any way as a limitation in the scope of the invention.

The apparatus of the invention as illustrated by the three figures of drawing comprises an explosive charge gun **10**, illustrated in the drawing in the form of a longitudinal cross-section thereof. The gun **10** comprises a housing **11** composed of any material capable of protecting the explosive charge from damage during handling. The housing material is preferably composed of a soft metal, such as lead or zinc, which gives increased confinement to the explosive detonation. Other materials have been employed as the housing material in devices of this kind and it is not contemplated that the nature of the housing material shall be limited. The housing **11** shown contains a centrally located fuse **12** in the opening **13**. The fuse is desirably of a suitable material such as the well-known Primacord fuse containing PETN (pentaerythrityltetranitrate) or RDX (cyclotrimethylenetrinitramine) explosive. Packed adjacent to the fuse **12** in the opening **13** is the main mass of explosive charge **14** having a substantially planar face or surface **15**. The nature of the explosive charge may vary, but a detonating explosive which is preferably of high density, such as a pressed or cast solid organic nitrate or nitro compound, is generally suitable. While any detonating explosive is generally satisfactory, high velocity or high order explosive charges are most suitable. Compressed PETN is one suitable material and compressed or cast blends of PETN with TNT, for example, in 50–50 mixtures, is also quite suitable. Similarly, RDX is a suitable explosive as are its high density mixtures with TNT, one suitable blend consisting of 80 parts of RDX in 20 parts of TNT. The foregoing explosive materials are particularly suitable since they possess high strength and upon detonation produce a high velocity detonation front, reaching maximum velocity very rapidly.

The constructions shown by the three figures of drawing differ only in the configuration and dimensions of the lens element and metal liner. In FIGURE 1 the lens element **16***a* is made of polymethylmethacrylate with a planar face adjacent to the planar face **15** of the explosive charge **14**. The lens element has a concave cavity **17***a* facing away from the explosive charge **14** and covering the cavity **17***a* is a metal liner **18***a*, of an alloy of 90% lead and 10% antimony, being in the form of a truncated cone, with the cone walls meeting the walls of the housing **11** at angles of 30°, and having a curved apex of ⅜ inch radius. This construction has been found to be particularly effective with the use of 20 grams of RDX as the explosive charge.

FIGURE 2 illustrates another construction in which the lens element **16***b* is made of polymethylmethacrylate and the cavity **17***b* is covered by a lead alloy conical liner **18***b*.

The construction of FIGURE 3 of the drawing shows the use of a bisected conical lens and metal liner. The lens element **16***c* forms two parts and the metal liner **18***c* covering the concave cavity **17***c* is made of lead antimony alloy. This construction is less desirable since it leaves some of the explosive charge exposed.

While it is not intended to be bound by any theory or mechanism by which the apparatus of the present invention provides beneficial results, it is believed that upon the detonation of the explosive charge **14** by the fuse **12** a high velocity detonation wave is initiated flowing almost instantaneously from the fuse through the explosive charge and its substantially planar surface and the parallel facing planar surface of the lens elements **16***a*, **16***b* and **16***c* in the form of a shock wave. It is desirable that the material of the lens element be of a low density and possess physical properties such as those of acoustical impedance, compressability and elasticity which closely match those of the explosive. The net effect here is that the shock wave is not reflected or diffused at the substantially planar or flat explosive-lens element interface, i.e., no energy is lost since the shock wave has passed through the interface without substantial interference. The shock wave is transmitted and focused somewhat by the concave cavity of the lens element and upon the shock wave reaching the metallic body of the concave metal liners **18***a*, **18***b* and **18***c*, the energy of the shock wave is accepted whereupon the liner becoms deformed and accelerated to form a hypervelocity stream of metal particles. It is desirable that the metal liner have a poor acoustical impedance, compressability and elasticity match with the material of the lens element so that maximum energy release will be obtained. The hypervelocity stream of metal which is produced from the metal liner provides the mass which is of importance in providing satisfactory penetration of the area which is subjected to the effects of the apparatus.

A desirable lens element material may be characterized as one which has a low density and will transmit a shock wave while a desirable liner material may be characterized as one which has a high density and substantially accepts the shock wave energy.

The lens member is produced from a non-explosive substance which has a high transference or conductance of the shock wave. It is desirably of a non-metallic solid material of a low specific gravity, such as preferably below about 2.5. Among the most satisfactory lens element materials are the polymeric or plastic solid materials, wood and glass. Among the suitable polymeric materials are molded polymethylmethacrylate, nylon, polyethylene, polyvinyl chloride, urea-formaldehyde resins, polystyrene, polyester resins, etc., and copolymers and mixtures of the foregoing resins.

The concave metal liner is desirably of a substance which is a poor conductor or transfer agent of the shock wave. It desirably has a high mass or specific gravity and is desirably of a metal melting below about 500° C. Among the suitable materials for the concave metallic liner are copper, aluminum, steel or brass. Desirably a low-melting metal having a melting point of 500° C., such as zinc, Babbitt metal, lead, cadmium, zinc, solder, and alloys of these materials. The low melting metals are preferred because they have less tendency to produce a "carrot" or slug of metal in the area penetrated or perforated.

The essential configuration of the lens element is that it have a substantially planar or flat surface adjacent to the substantial planar surface of the explosive charge and at its opposite end a hollowing or concave cavity. The essential configuration of the metal liner is that it have a concave cavity and be contiguous with the concave cavity of the lens element. The cavities of the lens element and the metallic liner may take any form including conical, hyperbolic, parabolic, ellipsoidal, hemispherical, pyramidal, and variations of these. The metal liner is desirably placed contiguous with the concave cavity of the lens element with the apex of the metal liner in close proximity or adjacent to the planar surface of the explosive charge. It is not necessary that the liner be in contact with the explosive charge, as in the case of the hollow charge devices of the prior art.

The metal liner may vary in thickness. Desirably the

liner is thick enough to absorb sufficient shock wave energy so that it provides a hypervelocity stream of metal. It should not be so thick that its large inertia prevents formation of a hypervelocity stream of metal.

One of the important advantages of the apparatus of the present invention is that it is substantially free from sensitivity to alterations in the dimensions and configuration of its components. Excellent results can be obtained regardless of variations in the dimensions and configuration of the components, so long as the essential planar interface exists between the explosive charge and the lens element and so long as the lens element and the concave metal liner are adjacent to each other and of the same relative configuration. Thus, the apparatus of the invention will provide reproducible results over a wide range of dimensions and configurations. Also, explosive charge assemblies in accordance with the present invention are not sensitive to variations in standoff distance between the metal liner and the adjacent area to be penetrated.

Since the apparatus of the present invention is not sensitive to variations in dimensions and configuration of its components, the maximum energy of the explosive shock wave can readily be transmitted to provide maximum penetration. The limiting factor is the supply of shock wave energy which the explosive charge will provide and not the particular efficiency or configuration of the lens element-liner combination. This is a point of major difference between the explosive charge assembly of the present invention and devices based on the hollow charge principle. Simply by enlarging the area of the contact between the explosive charge and the lens element at the adjacent substantially planar interface, the energy supply can be materially increased. Since the area of a circle increases as the square of its radius, by multiplying the radius of the substantially planar interface between the explosive charge and the lens element by two, it is possible to increase the available energy by four times. The lens element and particularly the metallic liner serve to focus this energy and produce a highly effective hypervelocity force.

Military explosive charge assemblies in accordance with the present invention may be utilized in a way with which those skilled in the art are familiar and may be employed in the same way that corresponding devices employing the hollow charge principle have been used.

For oil well casing perforating, the explosive charge assemblies of the invention may be employed in accordance with techniques well known to those skilled in the art. The apparatus of the invention may be employed merely to perforate oil well casings or boreholes or they may be employed to perforate casings or boreholes as part of a process of fracturing the earth formation. Desirably, by employing the explosive charge assemblies of the present invention in the fracture initiating apparatus disclosed in the pending U.S. application of Bruce Gilbert, Ser. No. 675,424, now Patent No. 3,101,057, filed July 31, 1957, to replace the corresponding hollow charge assemblies disclosed therein, excellent results may be obtained upon subsequent treatment of the oil well with a fracturing fluid in accordance with the process as that disclosed in U.S. patent application of Bruce Gilbert, Ser. No. 700,144, now Patent No. 3,058,521, filed December 2, 1957. It is intended to incorporate the disclosures of these two copending applications in their entireties.

Illustrative of the results which may be obtained employing the explosive charge assemblies of the present invention is an oil well field test which will be described hereinbelow. It should be understood, however, that this is done solely by way of example and is intended neither to delineate the scope of the invention nor limit the ambit of the appended claims.

Field Test

Employing explosive charge assemblies in accordance with the construction illustrated by FIGURE 1 of the drawing, having a housing 11 with a Primacord fuse 12 and an explosive charge 14 of 20 grams of RDX having a planar interface 15 between the explosive charge 14 and the lens element 16*a*, made of a styrene-methylmethacrylate copolymer, and a concave metal liner of a lead alloy (90% lead, 10% antimony, having a melting point of 270° C.), an oil well, having a casing of 5½ inches diameter, was subjected to the firing of 48 of said explosive charges spaced four per foot with spiral 120° phasing. The firing took place at a depth of 3782 feet to 3794 feet. After firing the explosive charge assemblies, the firing mechanism was removed from the well and the oil well subjected to a fracturing treatment with 14,000 gallons of residual crude oil containing 1.2% by weight of sodium dodecylbenzene sulphonate containing sodium sulfate as an inert filler. The residual crude oil contained 42,000 lbs. of sand to function as a propping agent. The fracturing fluid accomplished a breakdown at 3600 lbs. per square inch pressure and thereafter the fracturing fluid was injected at a pressure of 2,000 lbs. per square inch at an average injection rate of 25 bbls. per minute. The initial potential of the thus fractured oil well was 106.87% of that which could be anticipated. Based on comparative tests under virtually identical circumstances the explosive charge assemblies of the present invention provided similar results with regard to breakdown and injection pressures of those obtained using similar charges employing the hollow charge principle.

The terms and expressions employed are used as terms of description and not of limitation, and it is not intended, in the use of such terms and expressions, to exclude any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. An explosive charge assembly comprising a container housing capable of confining an explosive detonation and having an open end and containing a detonatable explosive charge having a substantially planar surface oriented toward the open end of said container housing, a non-explosive lens element having a substantially planar surface adjacent to and in contact with said substantially planar surface of said explosive charge and having a concave cavity oriented toward the open end of said container housing, and a metallic liner superimposed over the concave cavity of the lens element.

2. An explosive charge assembly as defined by claim 1, wherein the explosive charge is a high velocity explosive.

3. An explosive charge assembly as defined by claim 1, wherein the lens member comprises a non-metallic solid having a specific gravity of not more than about 2.5.

4. An explosive charge assembly as defined by claim 1, wherein the lens member is a molded polymeric solid.

5. An explosive charge assembly as defined by claim 1, wherein the metallic liner is of a metal having a melting point of not more than about 500° C.

6. An explosive charge assembly as defined by claim 1, wherein the concave cavity of the lens member and the metallic liner are in the form of a truncated cone.

7. A well borehole casing perforating apparatus comprising a container housing capable of confining an explosive detonation and having an open end and containing a detonatable explosive charge having a substantially planar surface oriented toward the open end of said container housing, a non-explosive lens element having a substantially planar surface adjacent to and in contact with said substantially planar surface of said explosive charge and having a concave cavity oriented toward the open end of said container housing, and a metallic liner superimposed over the concave cavity of the lens element.

8. An explosive charge assembly comprising a container housing capable of confining an explosive detonation and having an open end and containing a detonatable explosive charge having a substantially planar surface

oriented toward the open end of said container housing, a homogeneous, non-explosive lens element having a substantially planar surface adjacent to and in contact with said substantially planar surface of said explosive charge and having a concave cavity oriented toward the open end of said container housing, and a metallic liner superimposed over the cavity of the lens element.

9. An explosive charge assembly comprising a container housing having an open end and being capable of confining an explosive detonation; a detonatable explosive charge disposed in said housing and having a substantially planar surface oriented toward the open end of said housing; a lens element having a substantially planar surface adjacent to and in contact with substantially all of said planar surface of said explosive charge and having a conical concave cavity oriented with the larger end toward the open end of said container housing, said lens element being formed of a non-explosive substance capable of high conductance of shock waves; and a metallic liner superimposed on the cavity side of said lens element.

10. An explosive charge assembly comprising a container housing capable of confining an explosive detonation and having an open end; a detonatable explosive charge disposed within said housing and having a substantially planar surface oriented toward the open end of said housing; a toroidal lens element formed of a non-explosive, non-metallic solid material of low specific gravity and having an annular substantially planar surface adjacent to and in contact with said planar surface of said explosive charge and having a truncated conical cavity, the larger end of the cavity being oriented toward the open end

of said housing, the concave sides of said lens element forming an angle of about 30° with the straight sides thereof; and a metallic liner superimposed over the interior surface of the cavity of said lens element and a portion of said substantially planar surface of said explosive charge.

11. An explosive charge assembly comprising a container housing capable of confining an explosive detonation and having an open end; a detonatable explosive charge disposed within said housing and having a substantially planar surface oriented toward the open end of said container housing; a toroidal lens element formed of a material selected from the class consisting of solid polymers, wood and glass, and having a substantially planar surface adjacent to and in contact with a portion of said substantially planar surface of said explosive charge, and having an interior wall circumscribing a truncated conical cavity and an intersecting exterior wall forming an angle of about 30° with said interior wall, the larger end of said cavity being oriented toward the open end of said container housing; and a metallic liner superimposed over said interior wall of said lens element.

References Cited in the file of this patent

UNITED STATES PATENTS

1,440,601	Holran	Jan. 2, 1923
2,412,967	Church et al.	Dec. 24, 1946
2,667,836	Church et al.	Feb. 2, 1954
2,930,275	Sentz et al.	Mar. 29, 1960
2,972,949	MacLeod	Feb. 28, 1961