Feb. 7, 1967 A. A. VENGHIATTIS 3,302,567

SHAPED-CHARGE BOOSTER

Filed March 9, 1964

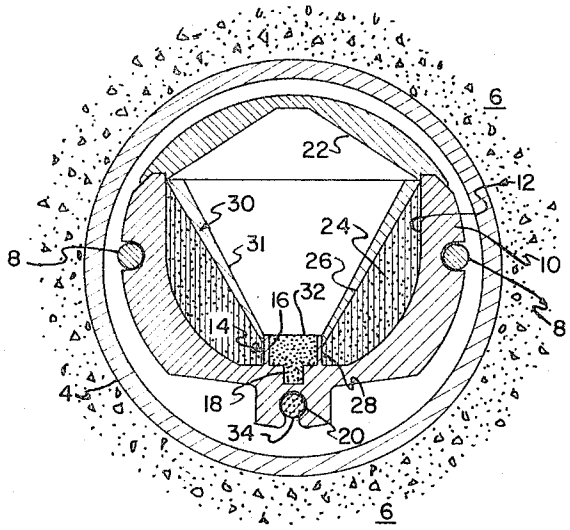


FIG. 1

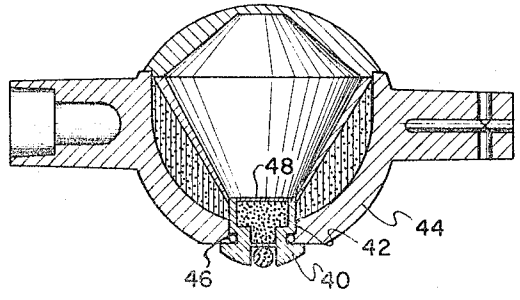


FIG. 2

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United States Patent Office

3,302,567
Patented Feb. 7, 1967

3,302,567

SHAPED-CHARGE BOOSTER

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Filed Mar. 9, 1964, Ser. No. 350,331
2 Claims. (Cl. 102—24)

This invention relates to shaped charges and, more particularly, to new and improved method and apparatus for initiating the detonation of capsule charges.

Shaped charges, and particularly capsule charges, are widely and effectively used as cutting or perforating devices in the petroleum industry and in many other well known applications. A shaped charge comprises a block or cylinder of explosive material, into the front face of which a conical recess is formed. A suitable liner of non-explosive material covers the face of the recess whereby, upon detonation of the explosive material, explosive forces traveling in the direction of the liner transforms part of the liner material into a high velocity jet which travels along the axis of the recess. In practice, this jet is capable of penetrating many inches of steel. Shaped charges have been used extensively in the perforating of casings in well bores. The jet penetrates both the steel casing and the cement sheath surrounding the casing and also the formation. It is very desirable that the penetration in the formation be as deep as possible, and also that the size of the penetration is as great as possible, to provide as large an avenue as possible for the fluid in the formation to flow in the well bore.

One of the common types of shaped charges used in perforating of wells is that known as the capsule charge, in which the shaped charge is contained within an individual, expendable, fluid-tight housing, having a cavity in which the charge is located. While the detonation of the charge is usually initiated by a primacord, the detonation force of the primacord is generally insufficient to cause proper detonation of the charge. Accordingly, a booster is placed in the rear of the charge with the primacord detonating the booster and the booster then detonating the explosive forming the charge. It has been customary in the shaped charge art, particularly in capsule charges, to have the booster located axially of the apex of the conical indentation in the face of the charge. Such method of boostering results in a spherical detonation wave. Therefore, the surface of initiation of detonation is very small. The force of the resulting jet depends upon the proper detonation of the explosive material forming the charge; therefore, improved initiation of the charge is most desirable. This is particularly true for capsule charges since the size of the capsule housing is limited by the size of the well bore or tubing into which it is inserted, which in turn limits the size of the explosive charge. Accordingly, it is an object of the present invention to provide the optimum initiation of the largest possible shaped charge which can be built in a given space.

It has been found that, instead of initiating the detonation of the explosive with the spherical wave of an axial booster, if a cylindrical wave is generated, the energy which is usually absorbed by the container can be used to detonate the explosive; and, accordingly, the advantage of having a larger booster without using the space required for it results. Therefore, there is an increased utilization of the amount of explosive in the charge. It is better initiated and accordingly better utilized. Also, the cylindrical shock wave sent out by a cylindrical booster develops into full strength (velocity, pressure) more rapidly than the shock wave generated by an axially placed booster, because of the geometry inherent to capsule charges used in oil well perforating. This again aids in improving the initiation of the explosive material forming the charge with resultant improvement in the jet.

It is another object of the present invention to provide a booster for a shaped charge which will more efficiently detonate the explosive in the shaped charge, resulting in a greater jet.

It is still another object to provide a shaped charge with a booster which provides a cylindrical shock wave and, accordingly, a more efficient detonation of the explosive forming the charge.

It is a further object to provide a booster for a shaped charge which will provide a fully developed detonation wave beginning practically with its initiation.

It is a still further object to provide a method of initiating the detonation of shaped charges by the generation of a cylindrical wave.

The shaped charge of the present invention has a cup-shaped housing in which is positioned a main charge formed of a block of explosive material having a frusto-conical inner face which terminates in a cylindrical passage. A metal liner covers the frusto-conical inner face. Positioned in the cylindrical passage is a booster. Surrounding the cylindrical booster is a thin, cylindrical metal liner. Positioned to the rear of the booster is a passage in which is located the primacord. Detonation of the primacord results in the initiation of detonation of the booster providing a cylindrical detonation wave which efficiently initiates the detonation of the main charge.

The novel and improved method of boostering comprises: forming a capsule shaped charge with a recess at the apex of the explosive portion and generating in such recess a cylindrical shock wave to provide optimum initiation of the main charge.

The present invention, both as to its organization and manner of operation, and further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a cross sectional view of a well bore having a perforator incorporating a capsule charge of the present invention;

FIG. 2 is a cross sectional view of an alternative form of capsule charge incorporating the invention.

Referring now to the drawings, and in particular to FIG. 1, the invention is there illustrated in connection with a capsule charge **24** of the type which is used for perforating small diameter oil well tubing. As can be seen, the well bore has steel tubing **4** around which there is a cement sheath **6**. It is a function of the charge **24** not only to penetrate the tubing and cement, but to form a channel in the formation through which the oil may flow. Therefore, it is desirable that the force of the jet developed by the charge **24** be as great as possible. However, there are often definite size limitations, particularly in slim tubing, which may require a charge having an outside no larger than $1\frac{11}{16}$". While the charges **24** are transported by a carrier **8** which may consist of just two wire strips or in other cases be linked together, all of which are well known in the art, the housing of the carrier must be such that it can travel without hanging up through the tubing.

The capsule charge has a housing **10**, having a generally semispherical, cup-shaped interior **12**. At the base of the interior there is a boss **14** which has two adjoining, coaxial, cylindrical bores **16** and **18**. These bores **16** and **18** are also coxial with the center line, which extends through the interior of the housing **10**. Coaxial with the bores **16** and **18** is a C-shaped recess **20**, the open portion of which faces the exterior of the housing **10**. The housing **10**. The housing **10** may be made of any suitable material, preferably a frangible material, such as aluminum, and has a thickness which will withstand the well pressures to which the charge may be subject. A press-fit cap **22** covers the opening of the cup-shaped interior

surface 12. Once the cap 22 is in position, the housing is fluid-tight, and all well fluid will be excluded from the interior of the shaped charge units prior to firing. As mentioned, the outer dimensions of the housing 10 must be such as to permit uninterrupted travel through the tubing 4.

The primary or main explosive charge, as indicated at 24, comprises a body of explosive material conforming in exterior contour with the cup-shaped interior surface 12 of the housing 10, and has an interior, forwardly diverging, frusto-conical inner surface 26. The axis of the frusto-conical inner surface 26 is coaxial with the axis of the explosive charge 24. The explosive material also has a cylindrical passage 28, which is adjacent the small end of the frusto-conical surface 26 and which telescopes over the cylindrical surface of the boss 14. The explosive material 24 is preferably cast or otherwise consolidated or pelletized to proper density, as is well known in the art, and may be formed of a high explosive substance, such as, for example, RDX explosive (desensitized cyclotrimethylenetrinitramine).

A liner 30, having been formed of a suitable nonexplosive material, preferably metallic, is positioned against the frusto-conical surface 26 of the explosive charge 24. The exterior surface of the liner conforms to the frusto-conical interior surface 26. If desired, the inner surface 31 of the liner may taper toward the small end. Also, the liner 30 may be formed of a powdered metal, which has been formed and consolidated in the required shape. A liner of this type has improved perforating effectiveness and efficiency and eliminates the formation of a metal slug. Such a liner is fully described and disclosed in my copending application, Serial Number 159,052, filed February 13, 1961, and now abandoned. Naturally, other types of liners, well known in the art, may be utilized.

Positioned in the cylindrical bores 16 and 18 of the boss 14 is a booster charge 32 formed of high explosive material such as cyclotrimethylenetrinitramine, commonly known as Cyclonite, which is more sensitive than the explosive material of the main charge 24. If desired, both the main charge 24 and the booster 32 may be formed of Cyclonite. However, as a rule the booster 32 is more sensitive and more easily detonated.

Positioned in the recess 20 is an elongated, detonating fuse 34, which is preferably of an explosive or detonating type such as, for example, that known commercially as "PETN" plastic covered primacord.

The first initiation of detonation is by the primacord. However, a primacord can only fully detonate a certain size of charge, and, therefore, it has been almost universal practice to use a booster to assure full detonation of the main charge. Generally, such a booster is located axially to the rear of the main charge and generates a spherical shock wave which initiates detonation of the main charge. Due to the inherent space requirements of capsule charges used for oil well perforating, most capsule type charges are poorly initiated. In order to have a sufficiently large main charge, maintain optimum standoff and angle of interior surface of the charge, the space for a booster is very limited. Accordingly, the detonation from such booster is not of optimum size for full detonation of the main charge. In the present invention, instead of using an axially located booster, the booster 32 is located adjacent the small end of the frusto-conical inner surface of the main charge. The cylindrical booster can be built in a size large enough to be the situs of a sizeable detonation. Instead of initiating detonation by a spherical wave, the booster 32 utilizes a cylindrical wave which expands radially into the adjacent surface of the main charge. With an axial booster generating a spherical wave, the surface of initiation is very small but with a cylindrical wave generated by a cylindrical booster, the surface of initiation is larger. It has been found desirable, in order to assure proper detonation, that the booster 32 have a minimum cylindrical area opposing the main charge 24 equal to the cross-sectional area of the opening in the main charge.

Accordingly, the advantages of having a larger booster is obtained without losing the space required for it. Also, better efficiency results since the cylindrical wave fully develops rapidly; whereas, the detonation wave generated in current boosters is not provided with enough length, with respect to its diameter, to develop into its full strength because of inherent lack of space.

While the explosive material in the main charge is highly compacted, the explosive material in the booster is usually lightly compacted; and, in the type of booster disclosed in FIG. 1, the small section located in the cylindrical bore 18 is even less compacted because of loss of pressure. Therefore, due to decrease in compaction, the small end of the booster 32 is more sensitive than the large portion. Accordingly, the detonation of the booster is in two steps. The initial detonation is in a restricted area which results in detonation of the main body of the booster which in turn initiates the detonation of the main charge. The design of the booster is such that the detonation efficiency is very high since detonation propagates from the lesser density explosive to the higher density explosive. Using the smaller bore 18 also permits the use of a thinner wall between the end of the bore 18 and the outer portion of the casing, thereby assuring a good transmission of the detonation of the primacord through the wall of the housing. If a booster with a diameter of the bore 16 were used, a thicker wall would be needed between the end of the booster and the exterior of the housing to assure that it could withstand well pressure. On the other hand, if a booster the size of the portion in the bore 18 was used there would be a loss in detonation. Accordingly, the larger portion of the booster in bore 16 gives more excitement area to detonate the main charge.

The utilization of the cylindrical type booster 32 also result in a further advantage in that in the same space or ring diameter a charge of larger caliber can be used, since the conical surfaces do not go to an apex but are only frusto-conical, permitting an optimum angle of the interior surface of the main charge. Accordingly, utilizing cylindrical wave boostering as a method of initiating the detonation of the main explosive charge results not only in more efficient detonation of the main charge but also results in being able to have a larger caliber charge, with a resulting larger jet and a larger diameter of penetration, in a housing of a predetermined ring diameter.

In FIG. 2, instead of having the boss 14, there is a separate booster container 40 which fits into a passage 42 in the rear portion of a link type housing 44. An O-ring 46 between the wall of the passage 42 and the wall of the booster container 40 prohibits any well fluid from entering the interior of the housing 44. The wall of the booster container may be in the order of .005 of an inch. Also, in order to further reduce space requirements, a reduced size primacord has been utilized. This primacord is known as MDF and is presently fabricated by E. I. du Pont de Nemours. The cylindrical booster may be provided with a metallic lid 48 to increase the lateral strength of the detonation of the booster. In all other respects the capsule charge shown in FIG. 2 is similar to that shown in FIG. 1.

As can be seen from the foregoing, the present invention provides a new and novel method and apparatus for initiating the detonation of a shaped charge. This is accomplished by using a main charge having a cylindrical passage adjacent the smaller end of the frusto-conical inner surface. In the passage there is placed a cylindrical booster which, upon detonation, generates a cylindrical wave which, in turn, initiates the detonation of the main charge. The cylindrical wave has been found to more efficiently and effectively detonate the main charge of explosive, resulting in a jet of greater force and greater diameter than the initiation by an axial booster.

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. A shaped charge comprising:
a housing having a cup-shaped interior;
a main charge of explosive material positioned in said cup-shaped interior;
said main charge having an exterior surface mating with the interior wall of the housing and a frusto-conical inner surface and a cylindrical passage adjacent the small end of the frusto-conical inner surface;
a nonexplosive liner covering the frusto-conical inner surface;
a thin cylindrical member opposing said cylindrical passage;
a solid cylindrical booster formed of high explosive material completely filling said cylindrical member, the minimum cylindrical area of the booster opposing the cylindrical portion of the passage of the main charge being at least as great as to the cross sectional area of the passage of the main charge; the booster terminating in a portion of smaller diameter that approaches the exterior wall of the housing, and
means adjacent the exterior wall of the housing to initiate the detonation of the small diameter of the booster, the detonation of the booster resulting in cylindrical shock waves which detonates the main charge.

2. A capsule-type shaped charge comprising:
a housing having a cup-shaped interior and a cylindrical passage at the bottom;
main charge formed of explosive material positioned in said cup-shaped interior;

said main charge having a frusto-conical inner surface terminating in a cylindrical passage adjacent the small end of the frusto-conical inner surface;
a metal liner covering the frusto-conical inner surface;
a cylindrical sleeve positioned in the cylindrical passage of the housing and extending into the cylindrical passage of the main charge, the cylindrical sleeve having a counter bore, the large diameter opposing the passage in the main charge;
means sealing the sleeve with the passage in the body;
a cap closing the cup-shaped interior of the housing;
a solid cylindrical booster formed of high explosive material completely filling the counter bore of said cylindrical sleeve, the minimum cylindrical area of the booster opposing the cylindrical portion of the passage of the explosive material being at least as great as the cross sectional area of the cylindrical passage; and
means to initiate detonation of the booster, the detonation of the booster resulting in cylindrical shock waves which detonate the main charge.

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