Aug. 30, 1966 W. T. BELL 3,269,467

SHAPED CHARGE APPARATUS

Filed June 11, 1964 2 Sheets-Sheet 1

Fig. 1

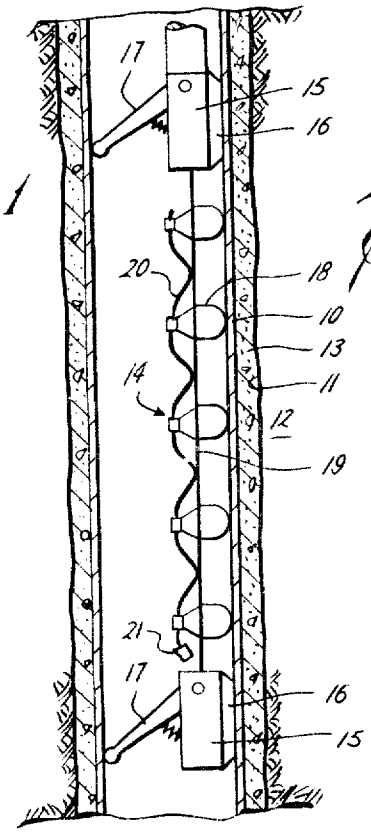


Fig. 2

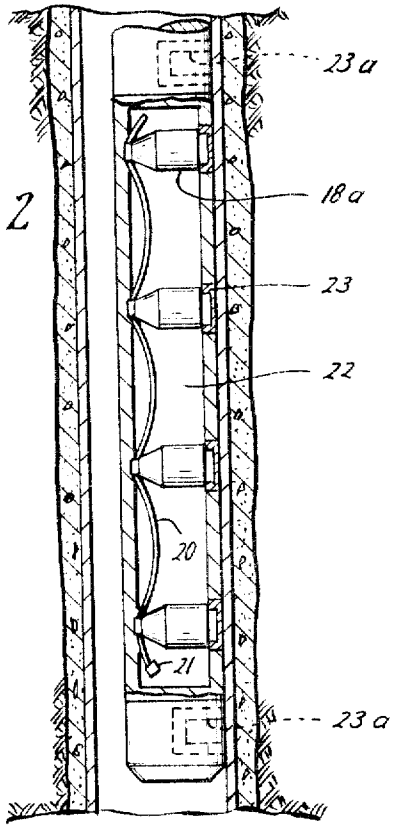


Fig. 7

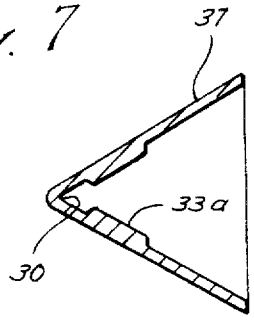


Fig. 8



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Aug. 30, 1966 W. T. BELL 3,269,467

SHAPED CHARGE APPARATUS

Filed June 11, 1964 2 Sheets-Sheet 2

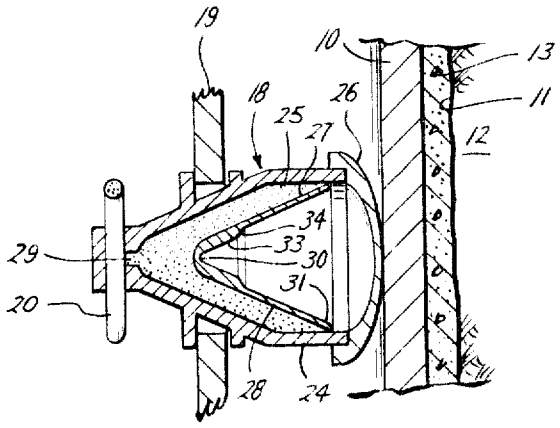


Fig. 3

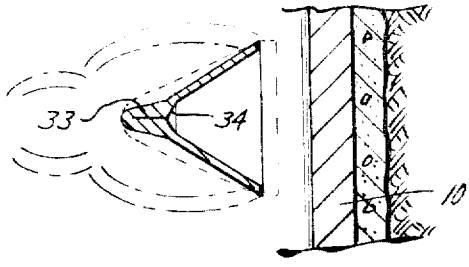


Fig. 4

Fig. 5

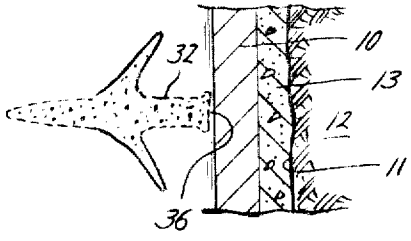
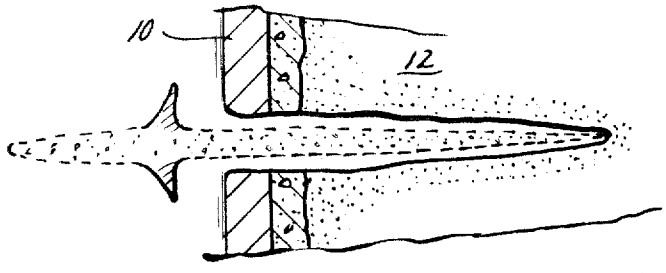


Fig. 6



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United States Patent Office 3,269,467 Patented August 30, 1966

3,269,467

SHAPED CHARGE APPARATUS

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Filed June 11, 1964, Ser. No. 374,480
3 Claims. (Cl. 175—4.51)

This invention relates to perforating methods and apparatus and, more particularly, pertains to new and improved perforating methods and apparatus employing shaped explosive charges.

Shaped charges are widely and effectively used as perforating devices in well bore completions. Usually a shaped charge intended for such a purpose includes a block of explosive material which has a conical recess in its front face. This recess receives a liner having a suitable thickness and composition so that upon detonation of the explosive material, the explosive shock wave traveling toward the liner eventually collapses the liner and a high velocity perforating jet is formed along the axis of the recess. Because of the high velocity and energy content of the perforating jet it is capable of penetrating the wall of the casing lining the well bore, the cement sheath surrounding the casing and the earth formations therebeyond. It has been of concern recently that the perforating jet in the penetration of the casing of the forming of an entry hole also tends to extrude the material of the casing about the penetration or entry hole into the bore of the casing thereby forming a burr or projection which can be objectionable. The reason for extrusion of the metal is the high radial pressures exerted on the casing while the hole is being formed. The burr is objectionable since it interferes with the sealing action of a "ball sealer" which is used in fracturing operations to isolate zones.

It is, therefore, an object of the present invention to provide new and improved methods and apparatus for perforating in a well bore whereby there is no burr formed on the entry hole through the casing.

This and other objects of the invention are obtained by producing an explosive force or perforating jet with a forward penetrating portion formed to punch an entry hole to size upon penetration. This is accomplished by forming the apex portion of a charge liner with a shape and thickness to provide a thick forward portion of a perforating jet which on entering the casing does not result in formation of the usual burr and is substantial to the size of the entry hole desired.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention both as to its organiaztion and manner of operation, together with further objects and advantages thereof, may best be understood by reference to the following description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a longitudinal view of an expendable shaped explosive charge perforating appaartus constructed in accordance with the invention and shown disposed in a well bore;

FIG. 2 is a longitudinal view of a carrier shaped explosive charge perforating apparatus constructed in accordance with the invention and shown disposed in a well bore;

FIG. 3 is a view in longitudinal cross section of a shaped explosive charge perforating apparatus constructed in accordance with the invention;

FIG. 4–6 are views representing various stages or conditions existing at sequential times during the operation of the shaped charge of FIG. 3.

FIG. 7 is a liner modification illustrating another form of the present invention; and

FIG. 8 is a view of a perforating jet shape resulting from use of the liner of FIG. 7.

In FIG. 1 of the drawings, there is illustrated a casing **10** in a well bore **11** which traverses earth formations **12**. A column of cement **13** is disposed between the casing and well bore. Shaped charge apparatus **14** can be suspended in the casing in any usual manner and includes a number of fluid-tight shaped charge capsules **18** which are attached to a rigid retrievable carrier **19** such as rods or a strip. Blasting cord **20** for detonation of the charges is connected to an electric blasting cap **21** which can be electrically ignited in the usual manner from the surface by wires and a power source (not shown).

At suitable locations positioning devices **15** are attached to the carrier **19**. Positioning devices **15**, for example, can be housings with portions **16** brought into contact with the casing wall by means of properly located spring biased arm members **17**. The housing portions **16** are aligned relative to the capsules so as to bring the forward faces of the shaped charge capsules **18** into or nearly into contact with the wall of the casing. To do this, of course, requires the suitable positioning of arms **17** relative to the carrier **19** and capsules **18**.

In FIG. 2, a retrievable, re-usable steel housing carrier **14***a* is illustrated wherein shaped charges **18***a* are disposed within the fluid-tight interior **22** of the housing. Port hole covers **23** through which a perforating jet may pass are located adjacent the forward end of each charge. Carrier **14***a* has permanent magnets **23***a* aligned relative to the port hole covers so as to bring the port hole covers **23** into proximate contact with the wall of the casing.

It will be appreciated that the positioning devices as heretofore described can be interchanged so long as the function of bringing a portion of the shaped charge apparatus into proximate contact with the wall of the casing is achieved.

In FIG. 3 of the drawings, a shaped charge **18** is comprised of a hollow container **24** of generally conical form which receives, in close interfitting relation, an explosive charge **25**. A cover **26** is provided for the container to form a sealed capsule shaped charge. The container and cover may be constructed of any fluid-tight, frangible material such as cast iron, glass or the like. The container **18** can be attached to a strip **19**, for example, in any suitable manner for positioning in a well bore. As illustrated in FIG. 3, the forward portion of the shaped charge is disposed in proximate contact with a casing **10**. Positioning means **15** assures the proximate contacting position of the capsules with the casing. It will be understood from the following description how the invention applies to the carrier apparatus of FIG. 2.

In the charge explosive **25** is a hollowed out or conically shaped forward end **27** which receives a closely fitting conical liner **28** constructed, for example, of copper with a suitable thickness or a bi-metal liner. The charge explosive **25** may be detonated in a suitable manner as by the blasting cord **20** disposed at the rear end of the explosive charge **25**, the blasting cap being detonated in the usual manner by the electric blasting cap **21**.

In operation, the blasting cord **20** is detonated and it, in turn, detonates the rear end of the explosive charge **25** through booster explosive **29**. Thus, an explosive shock wave is generated which progressively collapses the liner **28** and develops a perforating jet. The shock wave, which travels from left to right, sweeps along the liner from its apex **30** to its base **31**. The resulting pressures produced on the liner are so large that the liner behaves as a perfect fluid and the pressures cause the walls of the liner to collapse and move inwardly at high velocities. As shown in FIG. 4, the collapsing liner retains practically a conical shape. In the collapse of the liner, the apex of the liner forms a forward jet portions **32** (FIG. 5).

In the present invention, the liner **28** is provided at its apex with a thick portion **33** which gives means to the

apex of the liner to form the shape and size of the leading portion of the perforating jet. In particular, the thick portion **33** has a taper **34** where it joins the liner portion of regular thickness. As shown in FIG. 4, collapse of the apex of the liner involves displacement of the thicker portion **33** to come together with inner portions thereof maintaining the integrity of shape of the taper **34**.

In effect, the leading portion of jet is thus appropriately shaped to change the pattern of plastic flow of metal in the using of a jet with a relatively large cross section which is substantially the size of the opening to be produced in the casing. As shown in FIG. 5, the leading portion **36** is expanded so as to "punch" an entry hole to size in such manner that no burr is formed as shown in FIG. 6.

In FIG. 7, a liner **37** is illustrated where a thicker portion is displaced slightly away from the apex **30** of the liner. As shown in FIG. 8, a perforating jet will result with a forward pilot tip portion **38** in addition to the larger punch portion **26***a*. The tip portion serves to initially pierce a casing to facilitate the penetration by the punch portion **26***a*. Better performance in terms of penetration depth results.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A method for perforating earth formations traversed by a cased well bore comprising the steps of: positioning a shaped charge in proximate contact with the wall of a casing; generating a perforating jet with a pilot portion to penetrate the wall of the casing and initially form an opening therein and a punch portion to produce a full size entry opening without forming a burr on the casing.

2. Shaped charge appaartus for use in a cased well bore comprising: means for positioning said apparatus in proximate contact with the wall of a casing, explosive means in said apparatus having a forward outwardly diverging shaped recess arranged relative to said positioning means for facing the wall of a casing, means for detonating said explosive means to cause a perforating jet to form along a perforating axis and means for generating a pilot portion of said perforating jet to initially form an opening in a casing and a punch portion to subsequently form a larger burr-free opening therein including a hollow solid metal liner having a forward portion of a uniform wall thickness and a thicker rearward portion extending from the apex and having a uniform wall thickness greater than that of said forward portion, said liner portions being bounded by a continuous unbroken external surface and an irregular internal surface including forward and rearward sections parallel to said external surface and joined to one another by an outwardly diverging tapered surface section thereby to permit formation of a perforating jet with a substantially flat forward transverse face greater in size than the remainder of the perforating jet.

3. The apparatus of claim **2** wherein said thicker apex portion is shifted slightly away from the true apex of the liner thereby to form a slim forward jet portion of a length proportional to the distance said thicker apex portion is shifted from said apex preceeding said flat transverse face.

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