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SHAPED EXPLOSIVE DEVICE AND TYPE METAL LINER FOR THE CAVITY THEREOF

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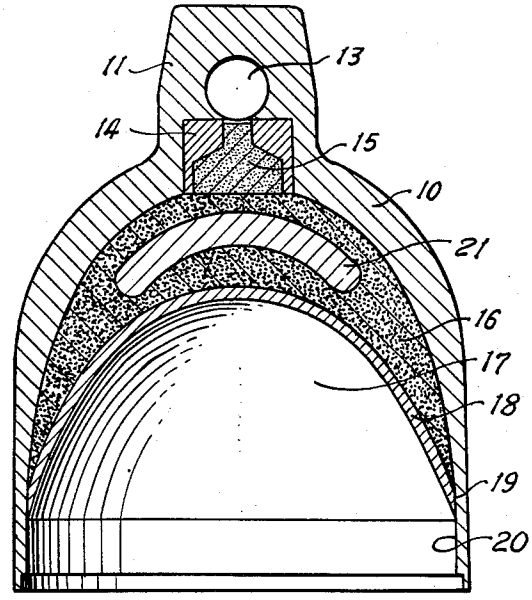


Fig. 1

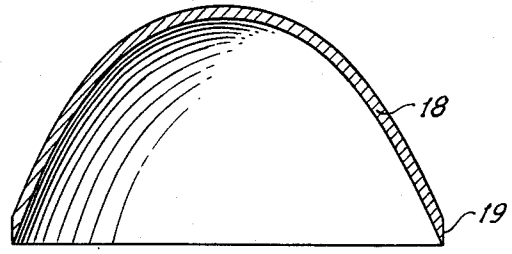


Fig. 2

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SHAPED EXPLOSIVE DEVICE AND TYPE METAL LINER FOR THE CAVITY THEREOF

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This invention relates to shaped explosive charge devices and liners for the cavities thereof. More particularly, the invention relates to shaped explosive charge devices especially adapted for perforating wells, such as oil, gas, or water wells.

After a well has been drilled in the earth traversing an earth formation containing oil, for example, the well is cased down through the formation of interest. The casing is cemented in place by an annulus of cement placed between the casing and the well bore. To complete the well, a perforating apparatus is lowered into the casing to the level of the formation of interest and actuated to perforate the casing, the annulus of cement, and the earth formation so that the oil can enter the casing from the formation and be brought to the surface of the earth. A type of perforating apparatus commonly used employs lined, shaped charge perforator units that are detonated by a signal from the surface of the earth that is transmitted to the perforating apparatus over the cable by which the apparatus is suspended in the well. The perforator units are aligned to direct the jets produced upon detonation through the casing and the cement and into the formation.

The conventional shaped charge unit used for this purpose has an inert cavity liner made from a metal, such as copper. The copper liner is fairly thin. Upon detonation of the charge, the liner forms a jet of metallic particles having extremely high energy. However, not all of the liner is disintegrated to form the jet. A substantial residue is compressed into the form of an elongated slug or carrot which is projected by the explosion generally along a trajectory which follows the trajectory of the jet. Frequently, the slug follows the jet into the perforation in the earth formation and lodges in the perforation, thus plugging or partially plugging the perforation and interfering with or preventing flow of oil through the perforation into the casing. Sometimes, the slug fails to enter the perforation and falls to the bottom of the well as debris.

In those perforating practices, in which a mechanism is positioned in the well below the level at which perforations are to be made, the mechanism being subject to damage or inactivation from debris, it is essential that the perforating apparatus leave absolutely no debris in the well. Hollow carrier perforators are capable of retaining most of the debris produced upon detonation of the shaped charges contained therein, but the carriers do not in all cases retain the slugs or carrots. Accordingly, a lined shaped charge which produces no slug finds important uses in well completion operations.

Heretofore, various shaped explosive charge well perforating units have been made available which produce no slugs or, at most, very small slugs. French Patent No. 1,018,278, October 15, 1952, Societe de Prospection Electrique, describes well perforating shaped charge units having cones made from a metal having a low vaporization temperature such as zinc or magnesium. The liners are described as volatilizing completely upon explosion of the charge, and not reforming into a block but simply depositing upon the walls of the perforation without plugging the perforation. McLemore, in "The Oil and Gas Journal" for December 28, 1946, pp. 268 to 271, describes well casing perforating shaped explosive charges having

soft-metal liners that disintegrate completely while going through the cement, concrete, or sand. In U.S. Patent No. 2,605,703, issued August 5, 1952, to Lawson, there are described liners of continuous or uninterrupted metal of extremely soft or ductile metal, or of metals of such low melating points and thinness as to disintegrate by fusion, melting, or fluxing. Rinehart and Cocanower, in "Journal of Applied Physics," May 1959, pp. 680 to 682, have described further work on carrotless shaped charge well perforating units having lead liners and liners made from a whole group of low melting point metals and alloys.

The heretofore known liner materials are not satisfactory in all respects. Copper yields a carrot. Zinc and magnesium do not give desirably great penetration depths and their melting points are somewhat high. Lead, while it does not produce a carrot, is soft and, hence, difficult to form to the exact dimensions required of a liner. It is well-nigh impossible to maintain a lead liner in shape when it is pressed by a high pressure ram into granular explosive material in the loading operation. Also, lead liners do not give as deep penetration as may be needed.

It is, therefore, an object of the invention to provide a shaped charge liner which does not form a carrot and which produces perforations of great depth.

A further object of the invention is to provide a shaped explosive charge liner that is easily fabricated to the desired size and shape and that maintains accurate dimensions throughout the operations involved in loading it into a shaped explosive charge.

A still further object is to provide a liner for a shaped explosive charge that is simple and inexpensive to make.

Another object is to provide a lined shaped explosive charge device for perforating wells that is carrotless and capable of producing desirably deep penetration.

The foregoing and other aims, objects and advantages of the invention are realized in a liner for a shaped explosive charge cavity, the liner being made of type metal, such as an alloy of lead, antimony and tin in proportions and amounts to be set forth more fully hereinafter. The shaped explosive charge device of the invention includes a body of explosive material, especially compressed granular explosive material such as cyclonite, having a cavity formed in a face thereof and a liner of type metal lining the walls of the cavity.

The invention will be described by way of example with reference to the drawings in which:

FIG. 1 is an axial sectional view of a shaped explosive charge well perforating unit embodying a liner in accordance with the principles of the invention; and

FIG. 2 is a detail view of the liner.

Referring to the drawings, particularly to FIG. 1, the shaped explosive charge well perforating unit shown has a case 10, which may be made of die-cast zinc base alloy. The case is generally cup-shaped with walls gradually thickening to the rear. An integral boss 11 is formed at the rear of the case and a transverse Primacord hole 13 is provided in the boss. A booster cup 14 is received in an axial recess immediately forward of the Primacord hole. The booster cup contains a charge of booster explosive 15.

A main explosive charge 16 is seated in the case forwardly of the booster charge. The main charge conforms to the shape of the inside of the case and has a paraboloidal cavity 17 formed in the front face of the charge. Seated in the cavity 17 is a liner 18 that is in intimate contact with the entire face of the cavity. The rim 19 of the liner has an interference fit with the inner wall of the case. The front section 20 of the inner wall of the case is cylindrical.

Embedded in the main charge is a barrier 21 in the form of a concavo-convex, disk-shaped body of steel or the like. This barrier modifies the explosive action with-

in the main charge to produce a jet from the liner that has enhanced perforating power.

The foregoing illustrated and described perforating unit is typical of barrier charges now well known in the art and such charge units, per se, form no part of the present invention. Units of the foregoing barrier type are disclosed and claimed in the copending U.S. patent application of Thomas C. Poulter, Serial No. 786,888, filed January 14, 1959, now U.S. Patent No. 3,100,445, for "Shaped Charge and Method for Firing the Same," which is a continuation-in-part of the application of Thomas C. Poulter, Serial No. 439,564, filed June 28, 1954, now abandoned, for "Shaped Charge." The application of Thomas C. Poulter, Serial No. 786,888, now U.S. Patent No. 3,100,445, is assigned jointly to two corporations owning all of the capital stock of the assignee of the present application. The present invention may not only be embodied in a barrier-type shaped charge, as illustrated, but in other shaped charges that do not employ barriers.

In accordance with the present invention, the liner 13 is made of type metal. A preferred type metal alloy for this purpose contains 83% lead, 12% antimony, and 5% tin. Alloys containing as little as 56% to 60% lead and 4% to 30% antimony with the balance being tin are also useful for making the liners of the invention. Other alloys containing up to 90% lead with the balance being antimony and tin are effective as the liner material. In general, the liners of the invention are fabricated from type metal alloys containing from 56% to 93% lead, from 4% to 30% antimony, and from 3% to 40% tin. Incidental impurities may be and usually are present in small amounts, generally totaling less than 1%.

Some type metals contain a small amount of copper, ordinarily less than 2% to 3%, which gives added hardness to the alloy. A small amount of copper in the alloy may be advantageous and is within the purview of the invention. One such copper-containing alloy has the following analysis: 58% lead, 15% antimony, 26% tin, and 1% copper. Another such alloy contains 70% lead, 18% antimony, 10% tin and 2% copper.

It has been found that a solid type metal liner gives best performance when it is thicker than a solid copper liner which is optimum for a particular shaped charge unit. The type metal liner should be about twice as thick as a copper liner of optimum thickness. In one charge constructed in proportion to the charge illustrated in FIG. 1, the optimum thickness for the type metal liner, which had a diameter of 1.697 inches at the widest part, was found to be 0.050 inch. In an otherwise identical charge, which had a copper liner instead of a type metal liner, the optimum liner thickness was 0.030 inch. In general, where a type metal liner is substituted for a copper liner in a shaped charge unit, the type metal liner should be from one and one-half times to three times the thickness of the copper liner.

The best mode contemplated of carrying out the invention will be explained with reference to the drawings. A shaped charge unit is made in strict accordance with the drawings. The inside diameter of the case 10 at the front end is 1.69 inches, with the other dimensions of the unit being in the proportion of 1.69 inches to the inside diameter of the front end of the case as shown in the drawings. The case is die cast from a zinc base alloy. A booster cup containing 0.45 gram of compressed unwaxed cyclonite is inserted in the booster cavity. Four grams of cyclonite which has been coated with about 3% to 5% microcrystalline wax is loaded into the case. A steel barrier one inch in diameter is positioned centrally in the case on top of the four gram charge of waxed cyclonite. Fifteen grams of waxed cyclonite of the same composition is loaded on top of the barrier. A type metal cone made from an alloy of 83% lead, 12% antimony, and 5% tin having a thickness of 0.050 inch is manually inserted in the case and rotated to distribute uniformly the waxed cyclonite in the case. The unit is then pressed under a force of 32,000 lbs. using a die to support the case and a punch which fits the hollow of the liner to complete the charge unit.

The charge unit, equipped with a Primacord fuse and detonator, was fired into a target having a face plate of steel ⅜ inch thick backed up by a column of cement 12 inches long. At a clearance from the face plate ½ inch, the jet formed upon detonation of the charge penetrated the steel face plate and perforated the column of cement for a depth of 10⅛ inches from the front of the face plate. The diameter of the hole in the face plate was ⅜ inch. No outwardly facing burr was formed around the rim of the hole in the face plate. No carrot was found in the target.

Firings of a number of similar perforating units confirm the fact that such units do not form carrots or slugs, as none are ever found in the resulting perforations or in the chambers in which the units are fired.

From the foregoing description, it is seen that this invention provides a shaped explosive charge unit and a liner therefor in which the objects of the invention are realized.

I claim:

1. A shaped explosive charge unit comprising:
(*a*) a body of explosive material having a cavity formed in a face thereof; and
(*b*) a liner lining the walls of said cavity, said liner comprising an alloy consisting of from 56% to 90% lead, from 2% to 30% antimony, from 3% to 40% tin, and from nil to 2% copper with incidental impurities.

2. A shaped explosive charge unit comprising:
(*a*) a body of explosive material having a cavity formed in a face thereof; and
(*b*) a liner lining the walls of said cavity, said liner comprising an alloy consisting of about 83% lead, 12% antimony, and 5% tin.

3. A shaped explosive charge unit comprising:
(*a*) a body of explosive material having a cavity formed in a face thereof; and
(*b*) a liner lining the walls of said cavity, said liner comprising an alloy consisting of from 56% to 60% lead, from 4% to 30% antimony, and from 10% to 40% tin with incidental impurities.

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