United States Patent

Bailey et al.

[15] **3,675,575**

[45] **July 11, 1972**

[54] **CORUSCATIVE SHAPED CHARGE HAVING IMPROVED JET CHARACTERISTICS**

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[73] Assignee: **The United States of America as represented by the Secretary of the Navy**

[22] Filed: **May 23, 1969**

[21] Appl. No.: **828,450**

[52] **U.S. Cl.** .... **102/24 HC**, 102/56

[51] **Int. Cl.** **F42b 1/02**

[58] **Field of Search** .... 102/24 HC, 56

[56] **References Cited**

UNITED STATES PATENTS

2,972,948	2/1961	Kray	102/56
3,054,938	9/1962	Meddick	102/24 HC
3,135,205	6/1964	Zwicky	102/56
3,235,005	2/1966	Delacour	102/24 HC

FOREIGN PATENTS OR APPLICATIONS

624,117	7/1961	Canada	102/24 HC
1,140,971	3/1957	France	102/24 HC

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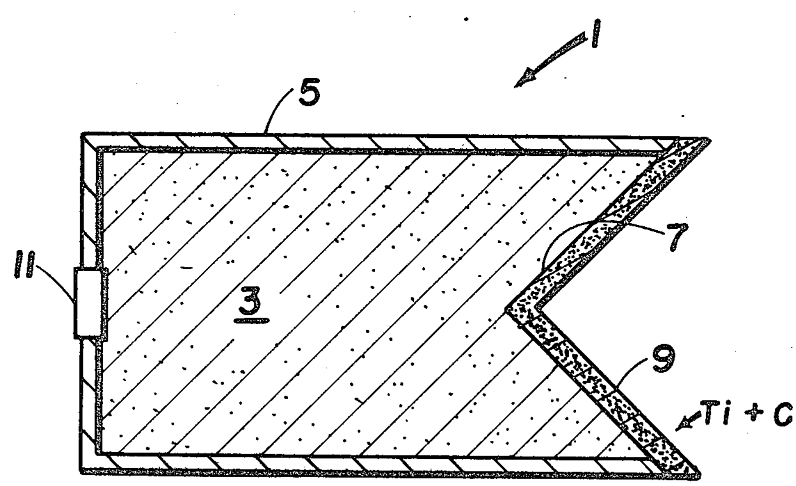
[57] **ABSTRACT**

The present invention provides a high penetration shaped charge coruscative ordnance device which produces a slug-free jet of improved effective length, thereby maximizing penetration and enhancing vaporific effects. Substantially, the invention improves the length of the jet by utilizing a powdered stoichiometric mixture of coruscative reactants such as Ti+C in a pressed conical liner. Additionally, jet density may be improved by inclusion of a high density material in the mixture.

5 Claims, 3 Drawing Figures



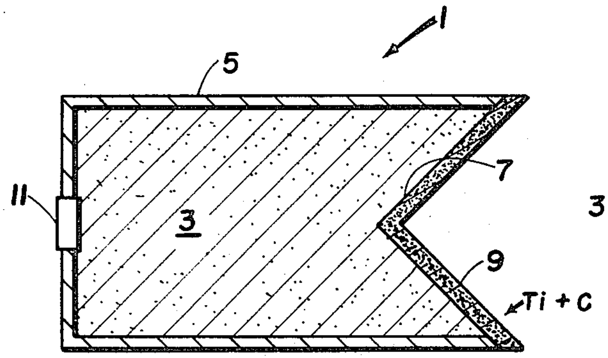


FIG. 1

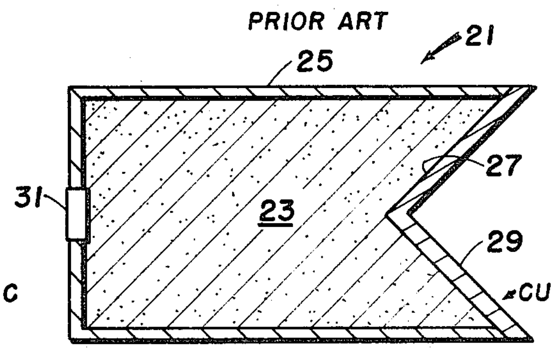


FIG. 2

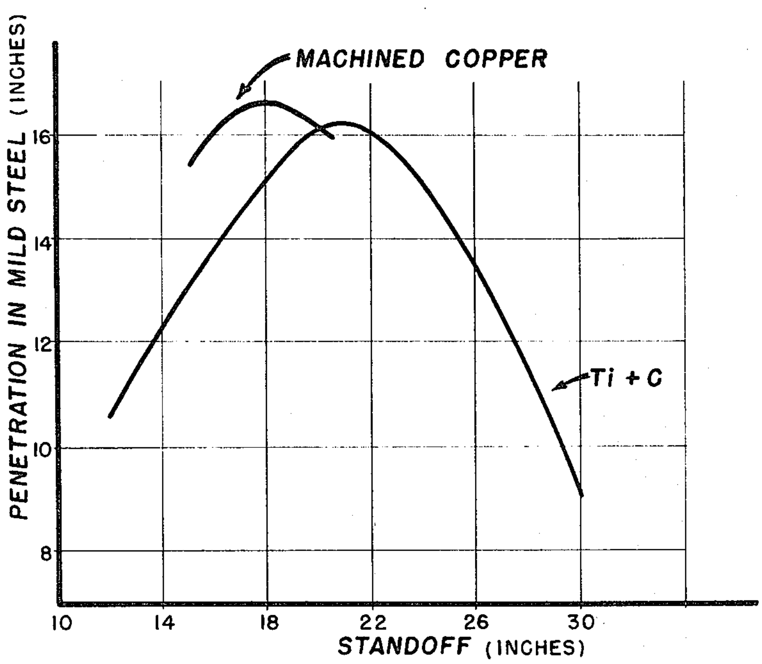


FIG. 3

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CORUSCATIVE SHAPED CHARGE HAVING IMPROVED JET CHARACTERISTICS

BACKGROUND OF THE INVENTION

A. Field of the Invention

The invention relates generally to shaped charge explosive devices and more particularly to a high penetration shaped charge coruscative warhead which produces a slug-free jet having improved length.

B. Description of the Prior Art

Shaped charge warheads have long been known in the art. Indeed, a coruscative warhead is shown in several embodiments in the U.S. Pat. to Zwicky, No. 3,135,205, in which the use of coruscative material is claimed to improve performance by increasing the velocity of the jet and by causing reactive target interaction with the jet. Zwicky uses pressed layers of material to form a laminated conical liner, thereby providing a density gradient across the liner thickness. The device of Zwicky does not prevent the formation of a slug which follows the explosive jet and immediately fills the hole produced by said jet, with the result that the vaporific effect that would be produced inside the target will not occur.

Venghiattis in U.S. Pat. No. 3,255,659 provides improvements to a copper-lined shaped charge by varying the thickness of the liner. Such an arrangement is utilized to eliminate the usual following slug.

The U.S. Pat. to Poulter, No. 3,136,249, provides a slug-free shaped charge for perforating a well. The important feature of the patent is the provision of a lead-copper liner having a metallographic structure consisting of copper dendrites with the spaces between the dendrites filled with lead.

A further example of the prior art is seen in U.S. Pat. No. 3,147,707 to Caldwell which also claims operability without a following slug. An alloyed metal liner of such low melting point metals as lead, antimony, and tin is described by the patent.

While the aforementioned and other examples of the prior art provide useful explosive devices, the present invention in its several embodiments will be seen to advance the state of the art by improvement of the length and density of the jet. As is the case with several of the references cited hereinabove, the present shaped charge coruscative device does not produce a slug.

SUMMARY OF THE INVENTION

A coruscative material is one of a group of chemical compounds which react exothermically to form solid and liquid reaction products. Due to the high volumetric energy contents theoretically available in these materials, an appreciable mass of self-reacting coruscative material is seen to enhance the performance of a shaped charge explosive device. Particularly, the present invention envisions the use of coruscative material as lining means for a shaped charge device, thereby providing a slug-free high penetration device. The improved performance over prior warheads is attributable to the production of a high density jet having improved length.

Shaped charges of various geometries may readily be used as an integral part of the coruscative device disclosed by the present invention. Disposition of the coruscative material into contact with the high explosive shaped charge is effected by the provision of pressed conical liners contiguous to the explosive charge. The conical liner is formed of a stoichiometric mixture of reactive coruscative material which is pressed into the desired shape. A high density material, such as molybdenum, tungsten, etc., may be added in powdered form to the coruscative mixture to provide improvement to the jet density. In either event, the conical liner is uniformly dense throughout, that is, no density gradient exists in any portion of the homogeneous liner. By utilizing the coruscative material as a liner for a relatively much larger mass of high explosive, the high energy exothermic coruscative reaction is efficiently initiated, thereby affording a greater probability that the reaction will proceed at a sufficiently rapid rate to allow completion of the reaction and thus to insure the maximum utilization of the energy present in the reaction.

A primary object of the invention, therefore is to provide a shaped charge device which will produce a high density jet of improved length that will not be followed by a slug, with the result that maximum penetration and vaporific effect will be attained.

It is also an object of the invention to provide a shaped charge device utilizing reactive materials which form solid and liquid reaction products for enhancing performance.

Another object of the invention is to provide a shaped charge explosive device having a high density jet of improved length.

A further object of the invention is to dispose a mixture of "coruscative" material contiguous to a shaped charge warhead for producing a jet of improved effective length.

A still further object of the invention is to provide a high density material, such as molybdenum, within a mixture of coruscative material disposed contiguous to a shaped charge body thereby improving jet density and maintaining the improved effective length of the jet.

Further objects and advantages will become apparent in light of the following description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a section of the shaped charge explosive device having a coruscative liner according to the present invention;

FIG. 2 is a section of a prior art shaped charge device having a copper liner; and

FIG. 3 is a standoff versus mild steel penetration curve for the devices of FIGS. 1 and 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Coruscative materials which react exothermically are seen to release more energy per unit volume of reactants than is available from conventional high explosives. The familiar thermite welding process involves a typical coruscative reaction:

$$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3 + Q$$

where Q represents the heat/gram·mole of total reactants and, for the thermite reaction, equals 181.5 kcal per gram·mole. An interesting comparison between a coruscative reaction and the explosive reaction of a substance such as nitroglycerine, $C_3H_5N_3O_9$, is seen in the heat per unit volume, q_v, released during the respective reactions. The thermite reaction given above liberates 4.03 kcal/cm^3 of reactant, while the q_v for the explosion of nitroglycerin is only 2 40 kcal/cm^3.

A more useful reaction for the purposes of the present invention has been found to be the coruscative reaction between titanium and carbon to form the carbide:

$$Ti + C \rightarrow TiC + Q$$

where Q equals 110 kcal/gram·mole of reactants. The heat per unit volume, q_v, obtainable with the titanium-carbon reaction is spectacular, 6.70 kcal/cm^3. Conventional high explosives such as TNT, Tetryl, and PETN have much lower volumetric energy contents.

Due to the high volumetric energy content exhibited by coruscative mixtures such as titanium-carbon, it has been desirable to utilize these materials to improve the performance of explosive devices. However, such a reaction is not always easily initiated, it being often difficult to initiate the reaction and to cause it to go to completion fully and effectively. Titanium, for example, is relatively unreactive under ordinary conditions, combining with carbon only at elevated temperatures.

The present invention, however, utilizes effectively a coruscative reaction for enhancing target penetration by a shaped charge high explosive device. In one embodiment, a titanium-carbon liner, which is caused to react by the initiation of the high explosive body of the device, produces a jet of greater length than has been previously obtainable. The depth of target penetration by a shaped charge at an optimum standoff distance is expressed in simplified form by the following equation:

$$\text{Penetration} = l\left[\frac{\lambda\rho_j}{\rho}\right]^{1/2} \qquad (1)$$

where

l = the effective length of the jet
$\lambda = 1$
ρ_j = jet density, and
ρ = target density

Thus, it can be seen that target penetration is improved by the production of a jet having a large "l," that is, a jet which remains continuous as it lengthens with standoff, and a high density, ρ_j, the density being understood to equal the density of the charge liner.

Selection of a liner material must be considered in light of the information contained in the penetration equation (1). An equally important consideration is the selection of a liner material for preventing formation of a following slug which, in most shaped charge devices, trails the jet and may seal the puncture created by the jet. The present invention addresses such problems.

Although it is to be understood that the present invention may be utilized with shaped charge devices of varying geometries, for the purposes of this disclosure a simplified shaped charge device is shown at **1** in FIG. **1**. The shaped charge device comprises a cylindrical body **3** composed of high explosive material, such as 75/25 Octol, and has a suitable casing **5**. A conical cavity **7** is formed in one end of the high explosive body **3**, the cavity **7** having a liner **9** disposed contiguous to the surface thereof. The angle of the cavity **7** is shown to be 60°although the invention is not limited thereto. The shaped charge geometry described is well-known in the art. Provision for detonation of the high explosive body **3** is accomplished by means of a detonating pellet **11**, which may conveniently be composed of CH-6 or tetryl. The detonating pellet **11** may be situated on the body **3** in dispositions other than that indicated in the figure and may be detonated electrically, mechanically, or by any of the large number of methods common to the art.

The liner **9** is comprised of coruscative materials such as titanium and carbon, the reactive characteristics of which have previously been described. A particular composition which has proven suitable as an improved shaped charge liner is a stoichiometric mixture of titanium and graphite. Titanium and graphite in powdered form is readily pressed into an acceptable conical liner under a vacuum of 5–10mm Hg. State-of-the-art pressing techniques for high explosive materials are conveniently followed in producing the coruscative liners.

On detonation of the high explosive body **3**, a coruscative reaction is initiated in the liner material, said liner material forming the jet resulting from the detonation of the shaped charge. The coruscative reaction is believed to produce sufficient heat to melt the resultant reaction products, thereby producing a continuous jet which is believed to be a true liquid jet. In this manner a jet of improved effective length which does not have a following slug is produced. As has previously been stated, the Ti+C liner **9** is homogeneous throughout, that is, the liner is uniformly dense throughout the liner thickness.

Comparison of the present invention with a shaped charge explosive device such as is commonly known in the art may be made with the device seen at **21** in FIG. **2**. The explosive device **21** comprises a high explosive body **23**, a suitable casing **25**, and a detonation pellet **31** disposed contiguous to the body of the device. A cavity **27** is disposed in one end of the explosive body **23** and has a liner **29**, that is, the device **21** is identical to the device **1** of FIG. **1** except for their respective liners. The liner **29**, for purposes of comparison, is composed of machined copper, a typical shaped charge liner. On detonation, the device **21** will produce a following slug characteristic of prior art machined metal liners.

Flash radiographic data obtained from detonation of the coruscative device according to the present invention shows a continuous jet with a tip velocity in excess of 30,000 feet per second using 75/25 Octol. Data obtained from detonation of the shaped charge device having the prior art copper liner demonstrates that the coruscative liner has more uniform and more closely distributed material comprising the jet than does the copper liner.

Further evidence of improvement over the prior art is seen in the experimentally obtained penetration data seen in FIG. **3**, which is a standoff versus target penetration curve for the machined copper device **21** and for the pressed Ti+C device **1**, the data in FIG. **3** being obtained in mild steel targets. The data thus presented demonstrate that the length of the coruscative jet produced by the shaped charge device 1 is 50 percent greater than that of the copper jet of the prior art device **21**. Penetration of the Ti—C liner in the mild steel target is 0.91 times that of the copper liner of equivalent mass. In terms of the densities of the two liners, 3.66 gm/cm^3 and 8.95 gm/cm^3 respectively, the effective length of the Ti—C is thus superior to that of the copper jet by a factor of approximately 1.5. The recorded penetration of the Ti—C liner in S.O. aluminum targets, expressed in terms of a normalized copper penetration, is 1.23 at the optimum copper (for a 60° liner) standoff distance of 18 inches.

Addition of a high density material to the pressed coruscative liner is further envisioned by the invention. Copper powder in proportions approaching 20 percent have been added to coruscative liner mixtures without jet degradation, thereby indicating that the simple addition of materials of higher density, such as molybdenum or tungsten, should produce a high density jet. As can be seen again from the penetration equation (1), target penetration is dependent on the effective length of the jet and also on the square root of the liner density. A Ti+C liner having an excess of carbon and comprising 20 percent tungsten powder is seen to have a much greater density than the Ti+C liner or the Ti+C and 20 percent copper liner, since tungsten has a specific gravity of 19.22. Therefore, the coruscative Ti+C liner having the tungsten disposed uniformly therethrough produces a higher density jet, hence greater penetration capability, than obtainable simply with the coruscative mixture. The effective length of the jets produced by the coruscative liners, with or without the additional high density material, remains constant. Thus, the addition of the high density material improves penetration.

As has been described hereinabove, shaped charge jets from pressed liners of coruscative materials, particularly Ti+C in stoichiometric and near-stoichiometric mixtures, demonstrate desirable properties for penetration of various target materials. Improved penetration is especially evident from experimental evidence using mild steel and aluminum targets. Independent of target material, the present invention is seen to provide a shaped charge warhead for producing an extremely high density jet of improved effective length which has no following slug.

We claim:

1. In a high penetration coruscative explosive device, having a body of explosive material formed into a shaped charge and having detonation means associated with said explosive body for detonating the device, an improved liner contiguous to the shaped charge body for producing a slug-less high density jet, comprising,

potentially reactive coruscative materials reactively responsive to the detonation of said body of explosive, and

a high density material selected from the group consisting of copper, molybdenum, and tungsten, said material being homogeneously admixed to a uniform density with the coruscative materials throughout the liner.

2. The improved liner of claim **1** wherein said liner includes the potentially reactive substances titanium and carbon.

3. The improved liner of claim **2** wherein said liner includes said substances titanium and carbon in stoichiometric proportions.

4. The improved liner of claim 1 wherein said liner comprises a coruscative mixture of 80 percent by weight of titanium and carbon in stoichiometric proportions and 20 percent by weight of the high density material.

5. The improved liner of claim 4 wherein said liner is a pressed liner of powdered coruscative material and powdered high density material, the liner being uniformly dense and homogeneous throughout.

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