Dec. 21, 1965

A. M. HOUSE

3,224,368

DUAL LINER SHAPED CHARGE

Filed Sept. 10, 1964

FIG. 4

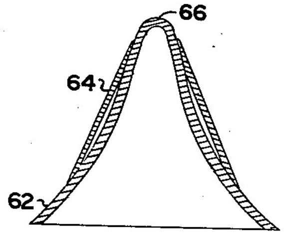
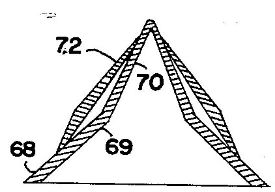


FIG. 5



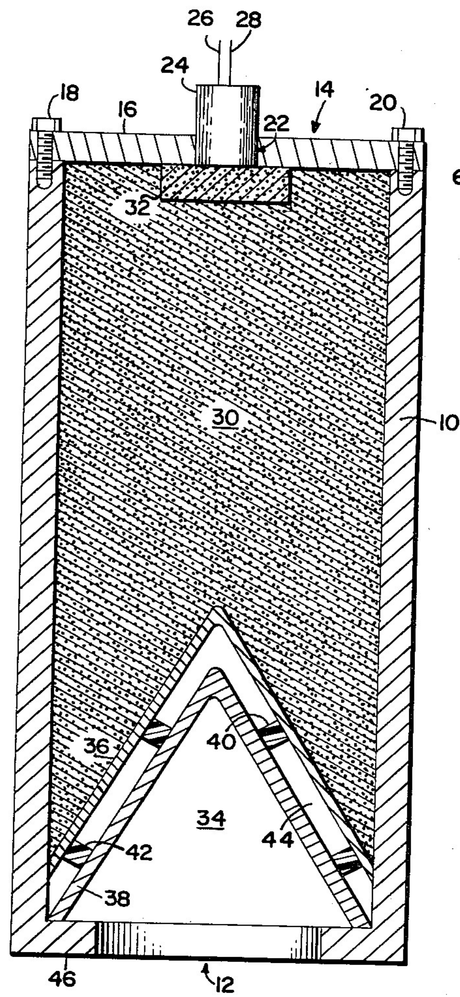


FIG. 1

FIG. 2

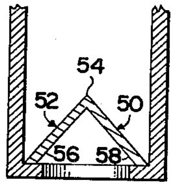
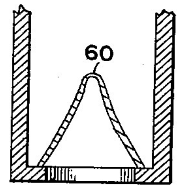


FIG. 3



INVENTOR.
ALFRED M. HOUSE
BY Charles J. Ungemach
ATTORNEY

United States Patent Office

3,224,368

Patented Dec. 21, 1965

3,224,368

DUAL LINER SHAPED CHARGE

Alfred M. House, Hopkins, Minn., assignor to Honeywell Inc., a corporation of Delaware

Filed Sept. 10, 1964, Ser. No. 395,431
9 Claims. (Cl. 102—24)

This invention relates in general to improved shaped charge devices, and more particularly relates to a dual liner shaped charge device having an open space between the liners to improve the penetrating effectiveness of the device.

It was discovered many years ago that the effectiveness of an explosive charge could be enhanced by forming a cavity in the face of the charge. If the cavity is formed in a symmetrical manner about an axis, the cavity tends to direct the force of the explosion along the axis. A greater portion of the energy from the explosion can thus be directed in a specific direction at a specific target. Although a wide variety of cavity configurations are available to the designer, either the conical or the more cup-shaped cavity is most commonly used.

The effectiveness of a shaped charge is further enhanced by lining the cavity with an inert material, as for example metal or glass. Upon detonation of the explosive charge, a high velocity pencil-like jet of tremendous energy is formed from the liner material and is projected along the axis of the liner. Because of its high velocity and high energy content, this jet is capable of penetrating solid material virtually instantaneously. In munition applications the shaped charge device is thus used to destroy armored vehicles by penetration of the protective armor. In the drilling of oil wells, the shaped charge device is used to penetrate the well casing and adjoining earth formations.

The penetrating effectiveness of a lined shaped charge device is dependent upon the interaction of a multitude of factors. The size and composition of the explosive charge, the configuration of the cavity, the construction of the liner, the method of detonation, and the standoff distance of the charge from the target are but a few of these factors. Each of these factors influence the penetrating effectiveness of the jet and each can be optimized only with respect to the other factors. A change in one factor will often necessitate changes in other factors to again achieve optimum performance. For this reason it is extremely difficult to predict the effect of changing the configuration of a shaped charge device. A test of the device itself is the only sure method of determining the efficacy of any new configuration.

When the object of research is to increase penetration, however, it is generally conceded that an increase in velocity of the jet is directly related to an increase in penetration. The high velocity jet exerts an overwhelming pressure on the target material that literally causes the target material to flow away from the path of the jet. The temperature of the jet and the products of combustion following the jet is believed to be only secondarily responsible for penetration of the target. If the assumption that increased jet velocity causes increased penetration is true, any change in design that will increase jet velocity is desirable.

The jet that is formed from the lined shaped charge consists almost entirely of material from the liner. When the explosive charge is detonated, a detonation wave proceeds through the charge and first impinges upon the apex of the liner. Although apex of the liner is thus extruded first along the axis of the liner, due to its low velocity, the remainder of the liner generally exceeds its velocity and forms the main working portion of the shaped charge jet.

While studying the effect of the detonation wave or shock wave upon the liner, it was determined that the shock wave actually passes through the liner before the liner begins to collapse. The passage of the shock wave through the liner imparts energy to the liner in the form of a rapid build-up in pressure that will cause it to collapse. The amount of pressure that will be built up in the liner is related to the velocity of propagation of the shock wave through the liner. Different materials, such as copper and aluminum, each have a different impedance to the propagation of a shock wave through the material. For a given shock wave velocity, a higher peak pressure will be built up in a material that has a higher impedance to the propagation of the shock wave. The higher the peak pressure built up in the liner, the higher will be the amount of energy imparted to the liner and the higher will be the velocity of the jet. A copper liner, which has a higher impedance to propagation of the shock wave than does an aluminum liner of similar configuration, will thus absorb more energy and form a higher velocity jet than will an aluminum liner.

The shaped charge device according to this invention provides means to absorb in the liner material, more of the energy from the initial shock wave and thereby increase the velocity of the jet. The structure necessary to achieve this result includes a first liner lining the cavity of the shaped explosive charge, and a second liner mounted in front of the first liner so as to leave a gap between the liners. In the preferred embodiment of this invention, the first liner is a conical aluminum liner and the second liner is a conical copper liner. Spacing means constructed of plastic or other suitable material are placed between the liners to provide an air gap between them. As previously noted, the shock wave passes more rapidly through the aluminum liner than through the copper liner, thus building up less pressure in the aluminum liner.

The purpose of this structure is to increase the amount of energy imparted to the forward copper liner. This result is accomplished by the described structure as follows. The shock wave first impinges upon the aluminum liner adjacent the shaped charge cavity. The impedance of the liner to propagation of the shock wave causes a build-up of pressure in the first liner, effectively absorbing energy from the shock wave. The shock wave passes through the first liner before the first liner collapses, and then impinges upon the second or forward liner. The passage of the shock wave through the forward liner causes the build-up of a large peak pressure therein as previously described. The two liners are spaced a distance apart such that as the pressure reaches a peak in the forward liner, the first or rear liner collapses against the forward liner, thereby transferring the energy stored therein to the forward liner. This additional energy imparted to the forward liner causes an increase in the velocity of the jet and a resultant increase in penetration.

A primary object of the present invention is therefore to increase the penetrating effectiveness of a standard single-liner shaped charge device by mounting a second liner in front of and coaxial with the first liner, and separated from the first liner by an open space.

This object and other objects of the present invention will become apparent from the following description when considered in conjunction with the accompanying drawing in which:

FIGURE 1 is a sectional view of the dual-liner shaped charge device taken along the longitudinal axis of the device;

FIGURE 2 is a sectional view of a standard shaped charge device having a single conical liner;

FIGURE 3 is a sectional view of a standard shaped charge device having a trumpet liner;

FIGURE 4 is a cross sectional side view of a trumpet liner surrounded by a truncated conical liner, the liners being separated by an air gap; and

FIGURE 5 is a sectional side view of an alternate embodiment of a dual liner shaped charge device.

FIGURE 1 discloses the preferred embodiment of the dual liner shaped charge device. The device is enclosed in a right circular cylindrical steel casing **10** having a first open end **12** and a second open end **14**. End **14** is covered by a circular plate **16** that is attached to casing **10** by a plurality of screws such as **18** and **20**. Located at the center of plate **16** is an opening **22** into which is inserted an electrical detonator **24**. Extending from detonator **24** are leads **26** and **28**.

A source of power (not shown) would be connected to leads **26** and **28** when detonation of detonator **24** is desired. Electrical detonator **24** is disclosed for illustrative purposes only, since any standard detonator and booster charge could be used as well.

Mounted within casing **10** is the main explosive charge **30**. Charge **30** is a material such as composition B, which requires a relatively high-order shock for detonation. Mounted adjacent opening **22** is a smaller explosive lead charge **32**. Lead charge **32** is preferably a material such as RDX, which will detonate upon receipt of a lower order shock than that required to detonate main charge **30**.

The detonation of detonator **24** by an electrical pulse will therefore ignite lead charge **32** which in turn will cause detonation of main charge **30**.

Formed in the front end of charge **30** adjacent opening **12** in casing **10** is a concave conical cavity **34**. Conical cavity **34** is symmetrical about the longitudinal axis of casing **10** and charge **30**.

Mounted directly adjacent cavity **34** in contact with the surface thereof is a first metal liner **36**. Metal liner **36** also has a conical configuration to conform to the configuration of cavity **34**. In the preferred embodiment of this invention, liner **36** is constructed from aluminum, although many other inert metallic or non-metallic substances could also be used. As used in this specification, the term "inert" is synonymous with the term "non-explosive."

Mounted between first liner **36** and first open end **12** is a second metal liner **38**. Liner **38** is composed of copper in the preferred embodiment, but again other inert materials could be utilized as will be recognized by those skilled in the art. Liner **38** is also conical in shape and is mounted symmetrically about the longitudinal axis of casing **10**.

Liner **38** is separated from liner **36** by a pair of plastic spacing rings **40** and **42**. An air gap **44** is thus provided between the liners. The use of plastic spacing rings is not critical to the invention since any structure that will provide an air gap between the two liners would be an equivalent spacing means.

It is noted that the diameter of first open end **12** is reduced as compared to the diameter of casing **10** because of an inwardly folded edge **46** of casing **10**. The purpose of folded edge **46** will become apparent when the method of assembling the unit is discussed.

To assemble the device, second liner **38** is inserted in casing **10** through second open end **14**. The base of liner **38** thus rests against edge **46** to prevent movement of liner **38** in a lateral direction. The apex of conical liner **38** thus lies directly on the longitudinal axis of casing **10**. Plastic spacing devices **40** and **42** are bonded to the surface of liner **38** to retain them in the position shown. Liner **36** is then inserted through upon end **14** and is firmly pressed into contact with spacing means **40** and **42** to align as described for liner **38**. Explosive charge **30** is then poured in as a liquid and allowed to harden. Charge **30** thus conforms exactly to the configuration of the casing and liner. Lead charge **32** is placed in position and then plate **16** is connected to casing **10** to seal the device. Once again it is noted that the mechanical method of assembling the device can be varied without departing from the invention.

The operation of the device disclosed in the drawing is as follows. Detonator **24** is detonated to in turn ignite lead charge **32** and main charge **30**. The detonation of charge **30** thus proceeds from second end **14** toward first end **12**. The detonation wave formed by the detonation of charge **30** is directed in a forward direction by the confining walls of casing **10**. The detonation or shock wave first impinges upon liner **36**, causing a build-up of a peak pressure within the liner, the size of which is determined by the velocity of the shock wave and the propagation characteristics of liner **36**.

The shock wave passes through liner **36** before the liner collapses. The shock wave then impinges upon liner **38**, causing a build-up of pressure within liner **38**. As previously noted, liner **38** must be composed of a material having a higher impedance to the propagation of the shock wave than the material in liner **36**. This causes a higher peak pressure within liner **38** but the shock wave is transmitted at a lower velocity. Liner **38** thus takes longer to collapse after the first impingement of the shock wave than does liner **36**. The air gap provides a delay between the time liner **36** collapses and the time it strikes liner **38**. This delay is necessary to obtain maximum coupling with the explosive and the corresponding maximum energy absorption in the second liner. Since a higher peak pressure at a lower particle velocity is achieved in the second liner (**38**), a longer time occurs between the shock loading of liner **38** and its collapse. The combination of the more rapid collapse of liner **36** plus the delay occasioned by the air gap causes liner **36** to impinge upon liner **38** just as it is also collapsing. The surplus energy stored in liner **36** is added to the energy container in liner **38** to increase the velocity and total energy content of the jet.

If the impedance characteristics of the liners were reversed, the combination would actually be detrimental to the formation of the jet. In that case the first liner may collapse and form a jet that is independent from the jet formed by the second liner. The velocities of these two jets would be such that interference between the two jets would destroy their ability to achieve reasonable penetration in the target material.

Although my invention has been described in conjunction with the dual conical liner embodiment disclosed in FIGURE 1, other dual liner configurations can also utilize the inventive concept. Some problems that can arise and means to combat them will now be discussed.

In FIGURE 2 a standard single liner shaped charged device is disclosed. Upon detonation of such a device, the greatest transfer of explosive energy to the liner occurs in the general area denoted by the arrows **50** and **52**. The apex **54**, although it is struck by the shock wave first, does not absorb as much energy as that portion of the liner marked by arrows **50** and **52** since only a single wave strikes the apex while higher energy interacting detonation waves strike the lower portions. The liner material from apex **54** can actually impede the formation of a jet because of the smaller amount of energy imparted to it unless the proper configuration is selected. The base of the liner at **56** and **58** is also somewhat less effective in forming a high velocity jet because of the small amount of space for the explosive material between the base of the liner and the casing.

In conventional single liner devices, these problems are often minimized by using a trumpet shaped liner as disclosed in FIGURE 3. The thickness of the liner may be varied so that only a small amount of linear material is carried by the apex **60**. This reduces interference problems between the material in the apex of the liner and the material in the sidewalls of the liner during formation of the jet. The trumpet shape also provides more space for explosive material between the base of the liner and the casing. This type of liner configuration thus improves the velocity gradient in the jet by imparting a more equal amount of energy to each portion of the liner.

Referring again to FIGURE 1, it can be seen that the dual conical liner configuration, although improving the energy transfer characteristics along much of the liner, does add additional liner material at the apex and at the base of the cone. It is difficult to achieve good energy coupling at the apex because of the difficulty in matching liner impedances and air gap at this point. It can be seen that the base of liner **38** is almost ineffective since the amount of explosive between the base and the casing is reduced even more than is usual with this type of liner, by liner **36** and air gap **44**.

The solution to these problems is to vary all the parameters involved to achieve maximum energy transfer at all points along the liner. For any given shock wave velocity and energy level, there will be an optimum relationship between the impedances of the two liners, and the air gap. The amount of energy absorbed by a liner and the time required for it to collapse can be varied by changing the liner material or by changing the thickness of the liner. The air gap will be selected so that the first liner will collapse into the second liner at the time most effective to couple together the energy from each liner.

One alternate embodiment of this invention is disclosed in FIGURE 4. A trumpet liner **62** that corresponds to second liner **38** of FIGURE 1 is surrounded by a first truncated conical liner **64**. The apex **66** of liner **62** is not covered by the first liner so that a smaller amount of liner material is present at the apex as compared to the device in FIGURE 1. Apex **66** could also be made thinner as in FIGURE 3 to further reduce the amount of liner material thrown into the jet by the relatively inefficient apex area. The trumpet liner configuration also provides much more explosive material surrounding the base of the liner than is possible with the configuration of FIGURE 1. Added to these improved features is the dual liner air gap concept. The air gap and added liner increase the energy transfer along the main central area of the liner without adding excess liner material at the apex or reducing the space available for explosive material at the base.

In FIGURE 5 there is disclosed a different embodiment of my invention in which more of the above mentioned parameters have been varied. The second liner **68** is a dual angle conical liner having a relatively thick, wide angle bottom portion **69** and a more thin, narrow angle upper portion **70**. The thin walled upper portion **70** again reduces the amount of material thrown into the jet by the apex of the liner and the material that is present is thrown at a higher velocity. A first liner **72** surrounds the central portion of liner **68**. Liner **72** is thicker near its center than at either end. This thicker central portion will absorb more energy from the shock wave than will the thinner ends.

The shock wave first impinges on the apex of liner **68** in FIGURE 5. The small mass apex collapses very quickly to form part of the jet. The strength of the shock wave as transmitted to the liner increases at it passes from the apex toward the base, reaching a peak near the center of the liner and declining near the base because of the smaller amount of explosive material near the base. The thickest portion of liner **72** is placed in the area where the greatest amount of explosive energy is available. The largest air gap is also in that area so that the correct matching of shock wave velocity, liners and air gap is achieved.

The optimum results are achieved when a high velocity jet is formed in which the velocity gradient throughout the length of the jet is small. By maximizing the effect of the detonation wave on each portion of the liner from the apex to the base as described herein, better penetration can be achieved.

While I have shown and described specific embodiments of this invention, further modifications and improvements will occur to those skilled in the art. I desire it to be understood, therefore, that this invention is not limited to the particular form shown and I intend in the appended claims to cover all modifications which do not depart from the spirit and scope of this invention.

I claim as my invention:

1. A shaped explosive charge device, comprising:
(a) a cylindrical casing having first and second open ends, and being symmetrical about a longitudinal axis extending between said ends;
(b) a shaped explosive charge mounted in said casing, said charge having a concave conical cavity formed in one end thereof at a predetermined distance from said first open end, said cavity being symmetrical about said axis;
(c) an aluminum liner lining said cavity;
(d) a conical copper liner mounted in said cavity between said aluminum liner and said first open end, said copper liner being symmetrical about said axis;
(e) spacing means mounted between said liners to establish and maintain said liners at a fixed distance apart to provide an air gap between said liners; and
(f) means for detonating said explosive charge.

2. A shaped explosive charge device, comprising:
(a) a casing;
(b) an explosive charge in said casing having a concave cavity formed in a front end thereof;
(c) a first metallic liner lining said cavity;
(d) a second metallic liner mounted adjacent said first liner on the opposite side thereof from said explosive charge, said second liner having a higher impedance to the propagation of a detonation wave than said first liner;
(e) means for spacing said liners a predetermined distance apart to provide an open space therebetween; and
(f) means for detonating said explosive charge.

3. A shaped explosive charge device, comprising:
(a) a casing;
(b) an explosive charge in said casing having a concave cavity formed in a front end thereof;
(c) means for detonating said charge mounted in a rear end thereof, said charge being confined by said casing such that upon being detonated a detonation wave proceeds from said rear end to impinge upon said cavity;
(d) a first liner composed of an inert material lining said cavity;
(e) a second liner composed of an inert material mounted opposite said first liner from said charge; and
(f) means mounted between said liners to establish and maintain an open space therebetween, said second liner having a greater impedance to the propagation of said detonating wave than said first liner, said first liner storing a portion of the energy provided by the passage of said detonation wave and subsequently collapsing against said second liner to increase the amount of energy imparted to said second liner.

4. A shaped explosive charge device, comprising:
(a) a casing having first and second open ends, and being symmetrical about a longitudinal axis extending between said ends;
(b) a shaped explosive charge mounted in said casing, said charge having a concave cavity formed in one end thereof at a predetermined distance from said first open end, said cavity being symmetrical about said axis;
(c) a first liner lining said cavity;
(d) a second liner mounted in said cavity between said first liner and said first end, said second liner being

symmetrical about said axis and having a greater impedance to the propagation of a detonating wave than said first liner;

(e) spacing means mounted between said liners to establish and maintain an air gap between said liners; and

(f) means for detonating said explosive charge.

5. In a shaped explosive charge device:

(a) a shaped charge of explosive having a cavity formed therein;

(b) a first liner lining said cavity;

(c) spacing means mounted on said first liner opposite said charge; and

(d) a second liner having a configuration similar to said first liner mounted on said spacing means, said second liner having a greater impedance to the propagation of a detonating wave than said first liner, said liners thereby having an open space between them.

6. In a shaped explosive charge device:

(a) a shaped charge of explosive having a cavity formed therein;

(b) a first liner lining said cavity;

(c) a second liner having an impedance to the propagation of a detonating wave that is greater than said first liner; and

(d) means for mounting said second liner adjacent said first liner such that an open space is provided between said liners.

7. In a shaped explosive charge device designed to provide a high velocity jet upon detonation:

(a) a shaped charge of explosive having a cavity formed therein;

(b) a first liner lining said cavity; and

(c) a second liner having a greater impedance to the propagation of a detonating wave than said first liner mounted adjacent said first liner so as to provide a variable depth air gap between said liners, the depth of the air gap being varied so that the jet velocity is maximized for the entire jet and the velocity gradient is minimized.

8. In a shaped explosive charge device:

(a) a shaped charge of explosive having a cavity formed therein;

(b) a trumpet shaped liner mounted in said cavity having an apex portion, a central portion and a base portion; and

(c) a truncated conical liner mounted on the central

portion of said trumpet liner between said trumpet liner and said cavity, the apex portion and the base portion of said trumpet liner thereby extending from opposite open ends of said conical liner, said liners having a variable depth air gap between them that corresponds to the velocity gradient exerted sequentially along said central portion during detonation of said explosive.

9. In a shaped charge device:

(a) a charge of explosive having a concave cavity formed therein, said cavity having an apex portion, a central portion and a base portion, the detonation of said explosive causing a high velocity shock wave to impinge sequentially upon said apex portion, said central portion and said base portion, the velocity of said wave reaching a peak in said central portion;

(b) a first liner of inert material mounted adjacent at least a portion of said cavity, said first liner having a selected impedance to the propagation of said shock wave so that a pressure is built up in each portion thereof that corresponds to the velocity of the shock wave impinging thereon, the thickness of said liner being varied to allow a maximum build-up of energy therein consistent with the smooth collapse of said liner to aid in the formation of a jet having a maximum velocity throughout and a minimum velocity gradient; and

(c) a second liner of inert material mounted opposite said first liner from said cavity so that an air gap is provided between at least selected portions of said liners, said second liner having a higher impedance to the propagation of said shock wave than said first liner so that a higher pressure is built up therein and the collapse of said second liner occurs within a longer time after the impingement of said shock wave than does the collapse of said first liner, said second liner being of varying thickness to provide a smooth sequential collapse of said liner from said apex to said base to form said jet, the depth of said air gap being varied to provide a variable added delay to the time required for said first liner to collapse and impinge upon said second liner, said first liner thereby collapsing and striking said second liner at the instant of collapse of said second liner to increase the energy imparted to the jet.

No references cited.

BENJAMIN A. BORCHELT, *Primary Examiner.*