Feb. 16, 1965 P. J. BRYAN 3,169,479

EXPLOSIVELY ACTUATED HOLE CUTTER

Filed Aug. 30, 1962

FIG. 1

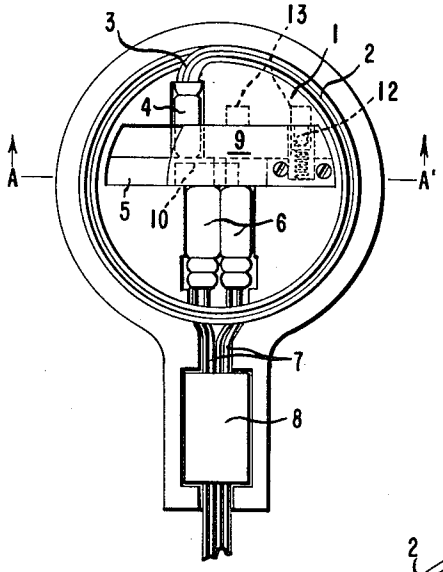


FIG. 2

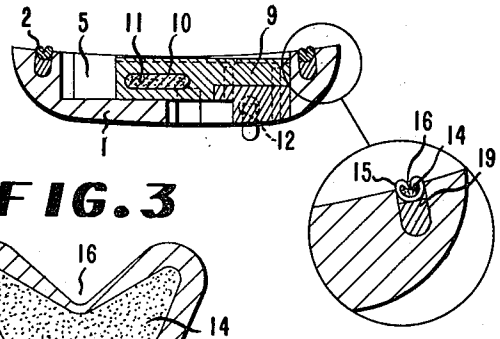


FIG. 3

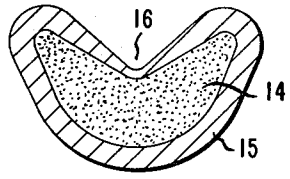


FIG. 4

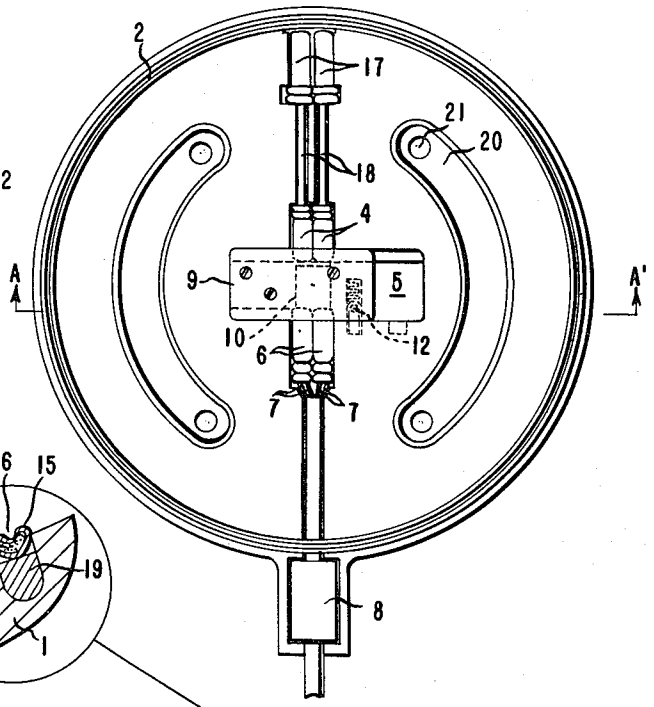


FIG. 5

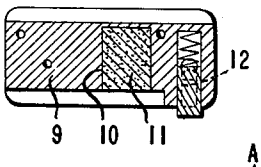
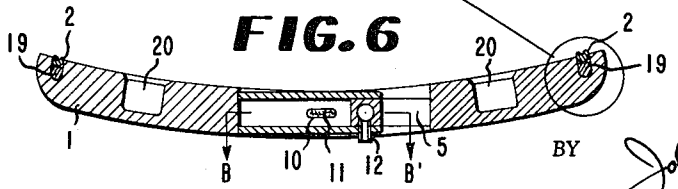


FIG. 6



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EXPLOSIVELY ACTUATED HOLE CUTTER

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4 Claims. (Cl. 102—24)

This invention relates to cutting devices and, more particularly, to a device for explosively cutting an aperture.

In accordance with this invention, a device for forming an opening, for example in tank walls, is provided which may be safely handled and positioned and thereafter readily converted to an armed state.

The preferred embodiment of this invention will comprise:

(*a*) A saucer-shaped housing, said housing having a substantially marginal annular channel concentrically disposed in its concave surface,

(*b*) A linear shaped charge mounted in said channel, said charge comprising a flexible tube of essentially V-shaped cross section having a core of detonating explosive composition, said charge being positioned in said channel to permit continuous exposure to the inverted longitudinal surface of said tube,

(*c*) A primer mounted in said housing in propagating relationship to said charge, said primer containing a cap sensitive explosive composition,

(*d*) An initiator mounted in said housing in spaced relationship to, and in alignment with, said primer, and

(*e*) An arming means slidably mounted in said housing between said initiator and said primer, said arming element being adapted to (1) transmit an initiation impulse from said initiator to said primer or (2) to refuse transmittal to said initiation impulse.

By the phrase "substantially marginal annular channel" as used herein is meant a channel set back a suitable distance from the periphery of the housing which contains it. This annular channel defines the aperture which the user desires to make since it houses the linear shaped charge. Thus, while a circular aperture is usually desirable, the cutting device of this invention is not limited thereto since the channel in the housing may be of any configuration which conforms to the desired aperture.

By the phrase "essentially V-shaped cross-section" as used herein is meant that the cross section of the linear charge is substantially symmetrical with respect to a plane perpendicular to the surface to be cut and has at least one uniformly inverted continuous longitudinal surface defined by an angle of from about 75° to about 120°; however, the complete cross section may be curvilinear or polygonal in nature while retaining a substantially symmetrical configuration throughout.

In one embodiment of this invention, one end of the length of linear shaped charge will be inserted directly into the primer. In another preferred embodiment of this invention, initiation of the detonation explosive in the linear shaped charge is effected through the tube wall and an auxiliary initiator actuated by the primer is used to strengthen the initiation impulse.

In order to describe the invention in greater detail, reference now is made to the accompanying drawings wherein:

FIGURE 1 is a plan view of one embodiment of this invention;

FIGURE 2 is a cross-sectional view of the device of FIGURE 1, taken through lines A–A';

FIGURE 3 is an enlarged cross-sectional view of one embodiment of the linear shaped charge of this invention;

FIGURE 4 is a plan view of an alternative embodiment of this invention;

FIGURE 5 is a partially cut away view of the arming switch 9 of FIGURE 4, taken along line B–B' of FIGURE 6;

FIGURE 6 is a cross-sectional view of the device of FIGURE 4, taken along lines A–A'.

In FIGURE 1, 1 designates a saucer-shaped housing in which is accommodated a coiled length of encased detonating explosive 2, i.e., a linear shaped charge. An uncoiled end 3 of the linear shaped charge is inserted into primer 4. The primer 4 is positioned within the housing, contiguous to orifice 5 which provides spacing between the primer 4 and initiators 6. Electrically-actuated initiators 6 are positioned contiguous to the opposite side of orifice 5 in a position in alignment with primer 4. Lead wires 7 extend from the initiator through electrical connector 8 to a source of firing current (not shown). Slidable within orifice 5 is arming switch 9, i.e., the arming means, having chamber 10 for a cap-sensitive explosive charge formed in one extremity. The remaining portion of the switch is solid. Communicating between arming switch 9 and housing 1 is a locking means involving spring actuated pin 12 engageable with catches 13 in the housing 1.

In FIGURE 2, taken along lines A–A' of FIGURE 1, the elements are as in FIGURE 1 with the exception that charge 11 of a cap-sensitive explosive composition is shown within the chamber 10 in arming switch 9. The circled insert shows, in greater detail, the linear shaped charge and a resilient backing material 19.

In FIGURE 3, which is an enlarged cross-sectional view of the linear shaped charge 2, the tubular metal casing 15 is provided with a continuous inverted longitudinal surface (shown in cross-section by 16) which provides an essentially V-shaped characteristic structure. The core 14 is of detonating explosive and is continuous, running the length of casing 15.

In FIGURE 4, the elements are as in FIGURE 1 with the exception that auxiliary initiators 17, connected to primers 4 by a length of low-energy connecting cord 18, abut the sidewall of the linear shaped charge. Semicircular grooves 20 with securing means 21 are provided as means of attaching the housing to the surface to be cut.

In FIGURES 4 and 5, it may be noted that the arming switch 9, i.e., arming means, has a length at least twice the diameter of the primer 4. At least half this length is solid and the remaining portion provides chamber 10 in which cap-sensitive explosive composition is contained. Spring actuated pin 12 provides means for releasably locking the switch in position with the solid portion adjacent the primer (safe) and in position with chamber 10 adjacent the primer (armed).

In FIGURE 6, the device of FIGURE 4 is shown in cross-section through lines A–A' with charge 11 shown in the aperture of the arming switch.

In operation, housing 1 containing the length of linear shaped charge, initiator and arming switch is attached to the surface, for example of a tank, in which the opening is to be cut with the lined cavity of the detonating explosive facing the surface to be cut. When the solid extremity of the arming switch is between primer 4 and initiator 6 firing current applied to electrical connector 8 and transmitted to the initiator 6 through lead wires 7 does not initiate the primer 4 even though initiator 6 emits an initiation impulse. However, when the switch is moved to a position wherein chamber 10 in the switch which contains the cap-sensitive explosive composition lies between primer 4 and initiator 6, i.e. the device is converted to an armed state, the initiation impulse will be propagated by the cap-sensitive explosive composition 11,

in chamber 10, thereby actuating the cap-sensitive composition in primer 4. Actuation of this primer subsequently initiates the core of detonating explosive directly as in FIGURES 1 and 2 or through low-energy connecting cord 18 and auxiliary initiator 17 as in FIGURES 4 and 5. As the detonation impulse proceeds through the length of the detonating explosive, sharply defined cutting action results owing to the well-known "cavity-effect" or "Munroe-effect" without attendant destruction or distortion of adjacent portions of the surface being cut. The cut section of the tank wall then is easily removed leaving a well-defined opening of the desired configuration.

The linear shaped charge provides within a single casing a cavitied, i.e., shaped, core of a detonating explosive, a liner for the cavity formed by virtue of the inverted longitudinal surface of the casing, and standoff means. For versatility in using and assembling the device of this invention, it is advantageous that the casing, or tube, and core of detonating explosive be flexible in all directions so that the elongated charge may be bent into any desired outline without materially affecting the shape of the inverted longitudinal surface, or cavity, which preferably is maintained within the angular limits mentioned to achieve optimum cutting action. When this flexibility is desired, the casing will be formed of a ductile metal which is flexible at the thicknesses and temperatures employed; exemplary materials for the casing include lead, unannealed copper, aluminum, aluminum-on-copper laminated compositions and flexible alloys of such metals. When less flexibility can be tolerated, the casing can be formed of a thin metal such as steel, cast iron and the like. The sidewalls of the casing serve as standoff means to hold the explosive core and the cavity away from the surface to be cut by the proper distance for optimum penetration. Naturally, the height of these sidewalls and accordingly the standoff will be determined by the explosive loading of the linear shaped charge. However, in general, this height will not exceed about 0.1 inch. The sidewalls of the lower portion of the casing preferably are thicker than the thickness of the upper portion of the casing as shown in FIGURE 3 to permit this standoff and to reinforce the cavitied portion of the charge. The upper section of the casing is reinforced by the contained explosive and the sidewalls are made thinner for compactness and flexibility.

The detonating explosive composition can be any of those conventionally used in shaped charges. Exemplary of these are pentaerythritol tetranitrate (PETN), cyclotrimethylenetrinitramine (RDX), tetryl, TNT, cyclotol and the like. The explosive loading will preferably be from about 5 to about 250 grains per foot. When thermal stability is a prime consideration, the detonating explosive will be of a more thermally stable composition, for example, of tetranitrodibenzo-1,3a,4,6a-tetraazapentalene, at loadings of about 5 to about 250 grains per foot.

When flexibility of the device is desired for example for versatility in use, the housing 1 is flexible to about the same degree as the encased detonating explosive so that it may be bent or bowed to conform to curvatures in the tank walls. In such cases, exemplary structural materials for the housing include pliable metals such as lead, zinc, tin, and the like and elastomeric or resinous substances and the like. When the device is to be used flat or the housing is preformed to a predetermined curvature of the tank, the housing may be of a more rigid substance, e.g. a metal-reinforced resin, i.e., a metal-filled epoxy resin.

The initiator, primer, electric wires and electrical connector can be inserted into preformed hollows in the housing or alternatively can be potted in the housing. The encased detonating explosive preferably fits into a channel or trough in the housing having a depth and width slightly greater than that of the casing so that the cavity can be held as near as possible to the surface to be cut without distortion or deformation of the charge. If the cavitied portion of the detonating explosive is separated from the surface to be cut by a distance greater than 0.040 inch, cutting efficiency is diminished. The housing can be held adjacent the surface to be cut by conventional means such as, for example, by adhesives or by screws.

For added flexibility in use, a resilient material, e.g., an elastomeric substance such as a natural or a neoprene rubber, can be placed in the channel receiving the linear shaped charge in order to assure contact of the linear shaped charge with the surface to be cut in spite of irregularities on the surface. When the device of this invention is to be exposed to weather, as a waterproofing means, a low density, closed cell foamed composition, e.g., polyurethane foam, can be placed in the cavity of the linear shaped charge. Such compositions protect the cavity from moisture yet do not interfere with the cutting action of the charge.

Detonation of the explosive core of the linear shaped charge can be initiated by either end initiation wherein the end of the shaped charge is inserted into one extremity of the primer or through the sidewall using an auxiliary initiator abutting the sidewall to intensify the initiation impulse.

For optimum safety when this device is disarmed, the length of the switch should be at least twice the diameter of the primer. Preferably, for ease in machining and assembling the orifice which defines the spacing between initiator and primer and in which is contained the arming switch will be generally parallelepiped or ellipsoidal in configuration, although any configuration providing the requisite spacing may be used. Exemplary structural materials for the arming switch, i.e., for the portion of the switch designed to block an explosive impulse, include mild steel, stainless steel, copper, aluminum, and alloys of such metals. While we do not wish to be limited by theory, it is believed that such materials disperse the initiation impulse imparted to them with an accompanying absorption of energy so that the impulse transmitted therethrough is insufficient to actuate the primer charge. When the device is to be armed, the switch may be moved manually or by means actuated from a remote firing site to a position where the cap-sensitive explosive charge lies between the primer and the initiator. Exemplary cap-sensitive explosive charges which may be used in the arming switch include PETN, RDX, HMX, tetryl, TNT, and the like.

The electrical initiator can be any of the conventional instantaneous or delay initiators available such as those fired by a bridgewire in an ignition composition, a bridgewire and bead arrangement, an "exploding" bridgewire or an arc firing system. Obviously, for nonhazardous operation, the initiator will be spaced from the linear shaped charge by a distance greater than the gap-sensitivity value of the detonating explosive in the core of the linear shaped charge.

For added reliability a pair of initiators, primer, and/or auxiliary initiators can be used to convey the initiation impulse to the linear shaped charge.

The following examples are illustrative of specific embodiments of this invention.

EXAMPLE 1

Two cutting assemblies were assembled resembling that of FIGURE 1. In each, a 7.28 inch length of a flexible charge, comprising a flexible cavitied core of RDX at a loading of 15 grains per foot encased in a flexible lead sheathing was shaped into an essentially circular form having a diameter of 2.00 inches, leaving an uncoiled end of one inch. The circular form was placed, cavity upward into a conforming trough in a housing, ½ inch deep, comprised of an essentially circular sheet of an aluminum reinforced epoxy resin which is formed with a rectangular appendage, 1¼ inches long and 13/16 inch wide and with hollows conforming to the shapes of elements to be included in the assembly. At essentially the center of the circular part of the housing was an essentially rectangu-

lar orifice, 1¾ inches long and ⅝ inch wide, the long sides of the orifice being provided with a contoured ⅜ inch deep projection. The arming switch of mild steel, 1 5/16 inch long and ⅝ inch wide, and provided along its long edges with a contoured track mateable with the projection on the long side of the orifice, was provided with a spring-actuated locking pin engageable with catches in the contoured projection on the housing. A chamber ½ inch long, 5/16 inch deep, and ⅛ inch thick, formed near one extremity of the switch was loaded with 4 grains of RDX. When the loaded switch was inserted in the orifice in the housing, the switch was readily slidable in the orifice and readily locked in position by the spring-actuated locking pin. The uncoiled end of the cavitied detonating charge was inserted through an elastomeric grommet into the open end of a primer consisting of a ¾ inch long shell, integrally closed at one end, and containing, in sequence from the closed end, a base charge of 8.2 grains of lead azide and a booster charge of 0.3 grain of RDX in the central aperture of a lead carrier. The primer was fitted into a conforming hollow in the housing with its end contiguous the orifice containing the slidable arming switch. Into hollows on the opposite side of the orifice were fitted two initiators which consisted of ¾-inch long aluminum capsules, integrally closed at one end, and containing in sequence from the closed end, a base charge of 0.8 grain lead azide and a booster charge consisting of 0.7 grain lead azide in the aperture of a tubular lead container, and, closing the shell, a rubber plug holding a conventional beaded bridgewire ignition assembly. The lead wires of these initiators were connected through a conventional electrical connector held on the appendage of the housing to an electrical firing circuit. When firing current was applied to the electrical initiators with the arming switch locked in a position with the solid portion lying between the initiators and the primer, these initiators were fired but the detonation impulse was not transferred to the receptor initiator. Consequently the length of cavitied detonating explosive was not actuated.

The other device was attached to the side wall of an aluminum tank (0.040 inch wall thickness).

The arming switch on the identical device was locked into a position with the cap-sensitive explosive in its chamber lying between the primer and the initiator. When electric current was applied through the lead wires, actuation of the electrical initiators was as above and the initiation impulse was transmitted to the primer which in turn initiated the length of cavitied detonating explosive. A clean, smooth 2-inch diameter opening was cut in the wall of the tubular 0.040 inch thick aluminum.

Similar results were obtained when aluminum and copper were used for the body of the arming switch and PETN was the charge in the aperture of the arming switch.

EXAMPLE 2

A cutting assembly was assembled resembling that of FIGURE 4. In this assembly, the ends of a 18.84-inch length of the flexible linear charge were joined to form a 6-inch diameter circle and the ends taped together. The circular form was placed, cavity outward, in a housing of essentially the same configurations as in Example 1, wherein the circular portion is essentially 6 inches in diameter and the appendage about 2 inches in length. Auxiliary initiators consisting of an aluminum capsule closed at one end and containing in sequence from the closed end, a base charge of three grains of RDX and a booster charge of 0.5 grain lead azide encased in a lead carrier was abutted against the inner sidewall of the linear shaped charge. A length of the low energy connecting cord described in U.S. 2,982,210, extends into and closes the open end of the initiator. The other end of the low energy cord extends into and seals a primer which comprises a tubular aluminum shell closed at one end and containing, in sequence from the closed end, a base charge of 0.7 grain lead azide, and a booster charge of a 0.3 grain of RDX enclosed in a tubular lead carrier. The primers were taped onto the housing with their bases abutting a parallelepiped aperture in the housing (length 2.2 inch, thickness, 0.5 inch) in which is contained an arming device essentially as described in Example 1. On the other side of the cavity containing the arming device a pair of the initiators as described in Example 1 were positioned with their bases contiguous the arming device and the lead wires were connected to the electrical connector. The device was placed on the surface of a steel cylindrical tank (wall thickness 0.031 inch) with the cavity of the linear shaped charge facing the tank wall. The conductive wires from a remote firing source were attached to the electrical connector.

When firing current was applied to the assembly with the solid portion of the switch between the initiators and the primers, the primers were not actuated even though the electrical initiators functioned properly. When identical initiators were substituted for those fired and the cap-sensitive charge in the arming switch was between the primer and the initiator, the initiation impulse was easily transferred from the electrical initiators to the primer and initiation of cavitied core of detonating explosive effected. A smooth, clean 6-inch diameter opening was cut in the tube wall.

EXAMPLE 3

A number of cutting assemblies were assembled as described in Example 1, with the exception that the loading of the detonating explosive was varied as shown in the following table which indicates the maximum thickness of aluminum plate severed by the charge.

Table

Explosive	Loadings, grains/foot	Maximum Thicknes Plate Severed (inches)
RDX	5	0.072
PETN	5	0.072
RDX	7	0.090
PETN	7	0.090
RDX	10	0.090
RDX	15	0.125
RDX	20	0.163
RDX	40	0.250
RDX	50	0.250
RDX	100	0.367
RDX	150	0.500
RDX	250	0.500

It is to be understood that the foregoing is illustrative only and that the invention is not to be limited thereby, but includes all modifications thereof within the scope of the invention as defined in the appended claims.

What is claimed is:

1. A cutting device which comprises:

(*a*) a saucer-shaped housing, said housing having a substantially marginal annular channel concentrically disposed in its concave surface,

(*b*) a linear shaped charge mounted in said channel, said charge comprising a flexible tube of essentially V-shaped cross section having a core of detonating explosive composition, said charge being positioned to permit continuous exposure to the inverted longitudinal surface of said tube,

(*c*) a primer mounted in said housing in propagating relationship to said charge, said primer containing a cap sensitive explosive composition,

(*d*) an initiator mounted in said housing in spaced relationship to, and in alignment with, said primer, and

(*e*) an arming switch laterally slidable in the space between said initiator and primer and having a length at least twice the diameter of the primer, at least half of said length being solid and adapted to prevent transmittal of an initiating impulse from said

initiator to said primer, the remainder of the switch being provided with a chamber containing cap-sensitive explosive adapted to propagate an initiation impulse from said initiator and thereby actuate said primer, and means for successively locking the solid portion of said switch and said chamber in a position between said initiator and primer.

2. The device of claim 1 wherein said tube is constructed of ductile metal.

3. The device of claim 1 wherein said tube is constructed of lead.

4. A cutting device which comprises:

(*a*) a saucer-shaped housing, said housing having a substantially marginal annular channel concentrically disposed in its concave surface

(*b*) a linear shaped charge mounted in said channel, said charge comprising a flexible tube of essentially V-shaped cross section having a core of detonating explosive composition, said charge being positioned to permit continuous exposure to the inverted longitudinal surface of said tube

(*c*) a primer mounted in said housing

(*d*) an initiator mounted in said housing in spaced relationship to, and in alignment with, said primer,

(*e*) an arming switch laterally slidable in the space between said initiator and primer and having a length at least twice the diameter of the primer, at least half of said length being solid and adapted to prevent transmittal of an initiating impulse from said initiator to said primer, the remainder of the switch being provided with a chamber containing cap-sensitive explosive adapted to propagate an initiation impulse from said initiator and thereby actuate said primer, and means for successively locking the solid portion of said switch and said chamber in a position between said initiator and primer,

(*f*) at least one auxiliary initiator mounted in said housing in propagating relationship to said charge, and

(*g*) a length of low energy detonating cord connecting each of said primers to each of said auxiliary initiators.

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