Sept. 3, 1963 R. J. MILLER ETAL 3,102,474

SONIC PULSE GENERATING DEVICE

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FIG. 1

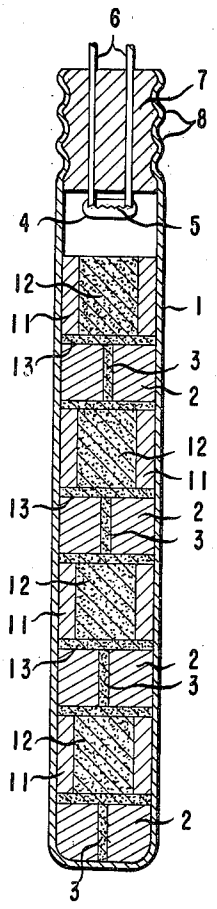
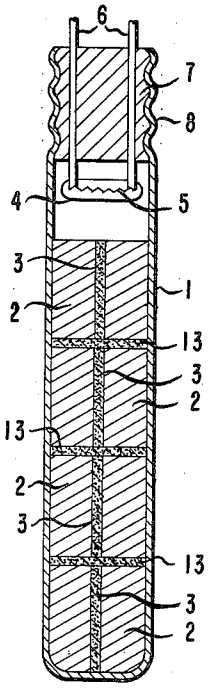


FIG. 2



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FIG. 3

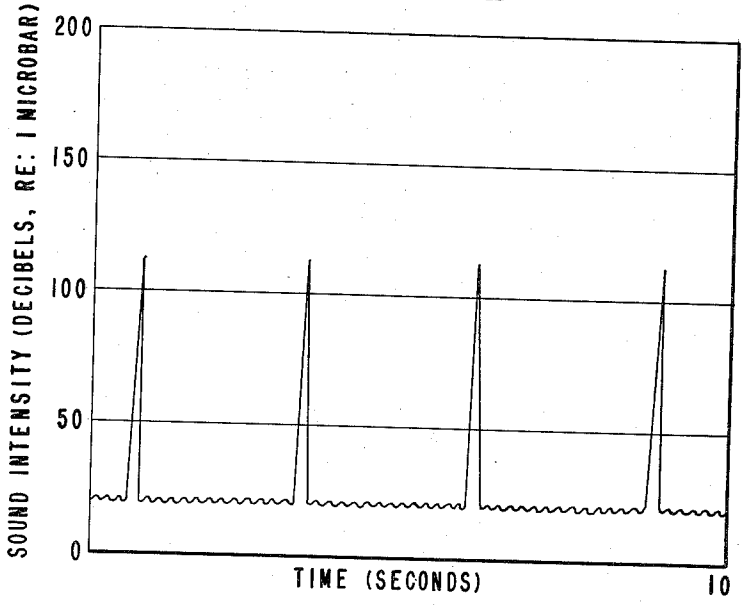
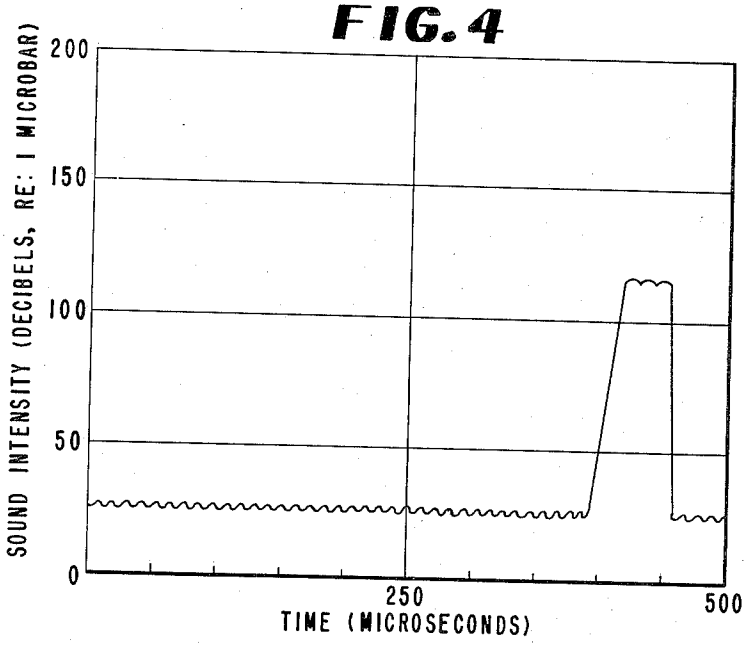


FIG. 4



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SONIC PULSE GENERATING DEVICE

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The present invention relates to a device for generating a sonic pulse, which device is particularly adapted for use under water.

A need exists for a sonic pulse producing device adapted for use in calibrating the pulse-receivers of echo-ranging systems and for rapidly and accurately measuring the velocity of sound in water at various depths and temperatures.

According to this invention, a device for generating an easily distinguished sonic pulse comprises a shell having one closed and one open extremity, a plurality of cylinders positioned axially within the cylinder in snug peripheral engagement with the cylinder wall, said cylinders having a central core running axially therethrough, each of the cores being loaded with a high velocity detonating explosive and each of the cylinders being separated by a length of deflagrating composition, and an ignition assembly sealed in and closing the open extremity of the shell. In one particularly preferred embodiment of the invention, at least a portion of the length of deflagrating composition separating the individual cylinders is enclosed within a heavy-walled tube of a ductile material such as lead; the heavy walled tube having an outer diameter substantially equal to the inner diameter of the shell.

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

FIGURES 1 and 2 are sectional elevations of the sound-generating assembly of the present invention, showing modifications of the assembly.

FIGURES 3 and 4 are graphic representations of the pressure-time characteristics of the sonic pulse obtained upon detonation of the explosive charge in the device of the instant invention. FIGURE 3 is the pressure-time curve characteristic of that given by the device of FIGURE 1, while the curve of FIGURE 4 is typical of that produced by a device such as illustrated in FIGURE 2.

In all figures, identical parts are indicated by the same symbols.

The sonic pulse generating device shown in FIGURE 1 includes as components thereof a shell **1**, cylinders **2** having a central core of a high-velocity detonating explosive **3** contained within the bore of shell **1**, heavy-walled tubes **11** containing a deflagrating composition **12** in the axial bore thereof are interposed between the cylinders **2** and a layer of a deflagrating composition **13** is at each end of the heavy-walled tube. A high resistance bridge wire **4** surrounded by a coherent mass or bead of an ignition composition **5** is attached to and held in position by lead wires **6** which are held by and passed through a sealing plug **7** of resilient material which is sealed in and closes the extremity of shell **1**. Circumferential crimps **8** in the cylinder maintain the plug **7** in proper position.

In FIGURE 2, the cylinders containing a high velocity detonating explosive in their central core are separated by layers **13** of uncontained deflagrating composition.

In FIGURES 3 and 4, the intensity of the sonic pulse as expressed in decibels with reference as plotted as the ordinate whereas the time is plotted as the abscissa. Upon actuation of the device (at 0 time) the sound intensity remains at an almost constant level as represented

by a substantially horizontal line during the initiation and a subsequent initiation lag. Upon actuation of the high velocity detonating explosive there is a sharp increase in the sound intensity as shown by an essentially vertical line. The sonic pulse is represented by a single spike which occurs as the detonation impulse is propagated through the charge. When the detonation ceases, the sound intensity decreases rapidly to its original level. The sound intensity is maintained at essentially its original level during the burning of the deflagrating composition, then increases rapidly upon actuation of the high velocity detonating explosive in the subsequent cylinder. When the deflagrating charge is contained in a heavy-walled tube, as is the case for the device whose sonic pulse is shown in FIGURE 3, the sonic pulse as shown by single spikes are separated by time intervals corresponding to the burning rate of the contained deflagrating composition. For a device in which an uncontained layer of deflagration composition separates the explosive charge containing cylinders, due to the rapid burning rate of the uncontained composition the propagation impulse will more rapidly be transmitted between the cylinders and the sound intensity will not return to its original level before the next detonation begins.

In operation, electric current applied to the lead wires **6** of the ignition assembly passes through a high-resistance bridgewire **4** producing heat sufficient to effect combustion of the ignition composition **5** in contact with the bridgewire. This combustion actuates the detonation of the high-velocity explosive charge **3** contained in the bore of the first cylinder with the formation of a detonation front. A pressure front (shock wave) is developed out of this detonation front and is propagated as a sonic pulse through the fluid surrounding the unit and is detected by a pressure-time detecting device, e.g., a piezoelectric gauge connected to an oscilloscope.

As stated, the sonic pulse developed is due to the transmission of the pressure front developed upon detonation of the explosive charge through the fluid surrounding the unit. This sonic pulse is characterized by a sharp peak of maximum intensity. By provision of a slow-burning composition **13** between successive cylinders of detonating explosive **3**, successive peak which occur at times corresponding to the delay intervals are produced. If the successive cylinders of high explosive are separated by a fast-burning composition, or by a very short length of the slower burning composition, a sonic pulse characterized by a long series of closely spaced peaks is produced, the number of peaks being determined by the number of cylinders containing a core of high explosive provided. By increasing the duration of the delay interval, the spacing between each successive pulse is similarly increased.

The confinement of the explosive charge is critical to the invention. The metal cylinder **2** will contain as a continuous central core a high velocity detonating explosive **3** in an amount insufficient to rupture the walls of the external shell upon its detonation, when the device is immersed in water. If the shell were to rupture, the escaping gases resulting from the decomposition of the explosive would form a gas bubble, and the oscillation of the gas bubble would cause the formation of the well-known bubble pulse, which would obsure the clarity of the desired pulse. Any high velocity detonating explosive which will propagate detonation in lengths under ¼-inch can be used. Such explosives include lead azide, pentaerythritol tetranitrate, picryl sulfone, tetryl, nitromannite and the like. Lead azide is preferred because of its ease of ignition.

The outer diameter of the cylinder **2** containing the detonating explosive must be such that this cylinder will fit snugly into the shell **1** provided leaving a substantially

negligible open space between the cylinder and the tube. If the cylinder does not fit snugly, the acoustical properties of the unit may be detrimentally effected, e.g., reverberations may occur causing undesirable sonic noise. Naturally, the outer diameter and the length of the cylinder are adjusted in relation to the explosive loading required and the inner diameter of the shell. The cylinder is constructed of a material which is nonreactive with the detonating explosive. Ductile metals such as lead, aluminum, tin, silver, copper, magnesium, or their ductile alloys may be used and are preferred. Various polymeric materials or plastic having the requisite strength may also be used.

Preferably, the material used for the shell is of thin gage copper, commercial bronze, or another copper alloy; or aluminum, although other metals and plastics having sufficient structural strength may be used as well. The shell wall must be of a thickness and strength such that it will not rupture upon detonation of the explosive charge when the assembly is submerged. Obviously, the thickness of the shell wall will depend upon the explosive loading, with the greater explosive load requiring the thicker shell. In general, we have found that with explosive loadings of 0.5 to 28 grains per foot the shell wall will have a thickness of 0.005 to 0.03 inch. At thicknesses less than 0.005 or greater than 0.03 inch, loading and crimping of the shell is more difficult, the thinner shell being too fragile and the thicker shell too resistant to crimping. The length of the shell depends upon the size and number of charges and the number and length of deflagrating elements to be incorporated into the unit.

A variety of ignition assemblies can be sealed into the shell, for example by means of a resilient plug of conventional design used in electric blasting caps, through which the customary lead wires are introduced. Suitable ignition assemblies include a bridgewire and bead arrangement, a bridgewire inserted into a mass of a loose ignition composition, an "exploding" bridgewire, and an arc-firing system in which the bridgewire is eliminated. The ignition assembly may be actuated by lead wires extending to a source of electric current at the surface of the water or the lead wires may be attached to a water-actuated wet battery or to a pressure-sensitive battery which will fire the charge at a predetermined depth. An electric current of approximately 1.5 amperes is sufficient to initiate the ignition means involving a bridge wire.

To provide sequential firing action of each detonating explosive charge, a delay train of the desired interval is provided between each of the successive charges. Such trains, which are conventional in delay initiators, comprise a length of a deflagrating composition, e.g. boron and red lead, silicon and red lead, or barium peroxide and selenium among others. In the preferred embodiment, the deflagrating composition is contained within a heavy-walled tube such as of lead or aluminum. When the deflagrating composition is thus confined, we prefer to provide a thin layer 13 of the same or an equivalent deflagrating composition at each end of the heavy walled tube 11 to facilitate the ignition of the small core of deflagrating composition and the initiation of the small core of detonating explosive in the next cylinder. The provision of such layers eliminates the need for great precision in aligning the respective small diameter cores of deflagrating composition and detonating composition. When the delay train consists of a length of uncased deflagrating composition, no problem of aligning cores exists.

The sound produced by the detonation of the enclosed explosive charge of this invention is in the form of a series of "pings" free of secondary reverberations. The assembly functions well in water at temperatures ranging from the freezing point of the water to the boiling point of water. When units as herein described are fired in air, the sound is of lower intensity and the shell is expanded further than is observed for an identical shell fired in water. A unit satisfactory for use in accordance with this invention may rupture when fired in air because of the lesser confinement offered by air, thus the strength required is that which will resist rupture when the assembly is submerged in water, regardless of the depth of the water.

In order to illustrate the present invention, reference is now made to the following examples.

Example 1

A sound-generating unit was assembled as shown in FIGURE 1. The shell was of commercial bronze and was $5\frac{27}{32}$ inches long with an outer diameter of 0.274 inch and an inner diameter of 0.261 inch. A ¼-inch long lead tube having an outer diameter of 0.258 inch and containing as its central core lead azide drawn to 1.5 grains per foot was inserted into this shell and pressed into place by a 100 pound force exerted by a press pin. Immediately above this charge, a thin layer consisting of 1.5 grains of a deflagrating composition comprising a 2.5/97.5 mixture of boron/red lead was loaded and above this mixture was placed a ⅞ inch long heavy-walled lead tube having an outer diameter of 0.257 inch and containing a column of an 82/16/2 mixture of barium peroxide, selenium, and talc. The heavy walled tube was then seated by a contoured explosive press pin. A layer of 1.5 grains of the boron/red lead mixture was loaded above the delay carrier and the next lead azide unit was pressed into place. The above procedure was followed until four lead azide units, four heavy-walled tubes and seven layers of boron/red lead were loaded in the order shown in FIGURE 1. An open space of one inch was left between the uppermost delay unit and a rubber plug assembly in which a 0.0019-inch diameter 80/20 nickel/chromium bridgewire was soldered to the lead wires separated to provide a ⅛-inch span and projecting ⅛ inch from the base of the rubber plug. The bridge wire was surrounded by a bead comprising a 75/20/5 mixture of the lead salt of dinitroorthocresol, potassium chlorate, and selenium in a matrix of polyvinyl acetate. The lead wires contained in the rubber plug are of 20-gage copper insulated by nylon. After the rubber plug was in place, three peripheral crimps were made in the shell wall to seal in the plug.

The lead wires of the thus assembled device were connected to a source of electricity and the assembly was lowered to a depth of six feet into a testing ditch filled with cold water at a distance of 3 feet from a piezoelectric gage connected to a conventional oscilloscope through a 150 foot coaxial cable. When current was applied through the lead wires to fire the device, the pressure-time curve observed on the oscilloscope indicated that the maximum sound level obtained from each charge was 115 decibels (re: 1 microbar) and that the pulses were generated at 2.4 second intervals. The overall functioning time for the unit was 9.5 seconds.

The unit was retrieved after firing; measurements showed that the shell was uniformly expanded to an outer diameter of 0.276 inch and that no ruptures occurred in the shell wall.

Example 2

A sound-generating unit was assembled as shown in FIGURE 2. The shell for this unit was of annealed bronze which is $3\frac{15}{16}$ inches long and had an outer diameter of 0.310 inch and an inner diameter of 0.260 inch. A ¼ inch long lead tube having an outer diameter of 0.258 inch and containing as its continuous core lead azide drawn to a loading of 16 grains per foot was inserted into this shell and pressed into place by a 100 pound force exerted by a press pin. Immediately above this charge a thin layer consisting of 1 grain of a 2.5/97.5 mixture of boron and red lead was loaded and above this layer another lead azide unit was pressed into place. The above procedure was followed until four of the lead azide units and three layers of boron/red lead were loaded in the order shown in FIGURE 2. A clearance of one inch was allowed between the uppermost lead azide unit and a beaded rubber plug assembly as described in Example 1.

When this unit was tested in water by the procedure described in Example 1, the pressure-time curve on the oscilloscope indicated that the maximum sound intensity was 125 decibels (re: 1 microbar) and the pulse length was 30.7 milliseconds. The shell was uniformly expanded to an outer diameter of 0.395 inch.

Example 3

A number of sonic-pulse producing units were assembled similar to that described in Example 2, wherein the weight of the explosive charge, the length of the cylinder, and the thickness of the shell were varied as indicated in the following table and the units tested by the procedure described in Example 1. In the tests none of the shells were ruptured and expansion of the shell was uniform.

Distribution of PbN_6 (grains/foot)	Length of cylinder (inches)	Weight of PbN_6 (grains)	Outer Diameter of Shell Before Firing (inches)	Wall Thickness of Shell (inches)	Outer Diameter of Shell After Firing (inches)	Sound Level, Decibels, re: 1 μbar
1.5	¼	0.031	0.274	0.007	0.275	109
1.5	½	0.062	0.274	0.007	0.275	115
1.5	1	0.125	0.274	0.007	0.275	116
3.0	¼	0.062	0.274	0.007	0.275	112
3.0	½	0.125	0.274	0.007	0.275	119
3.0	1	0.25	0.274	0.007	0.275	125
7.0	1	0.583	0.300	0.020	0.318	122
7.0	[1]12	7.0	0.310	[2]0.025	0.362	122
11.6	1	0.96	0.300	[2]0.020	0.355	128
22.7	¼	0.48	0.300	0.031	0.360	
22.7	½	0.961	0.300	0.031	0.370	
22.7	1	1.92	0.300	0.031	0.410	
26.4	¼	0.56	0.300	0.031	0.370	
26.4	½	1.12	0.300	0.031	0.380	
26.4	1	2.24	0.300	0.031	0.420	

[1] (Coiled to a length of 2 15/16 inches.)
[2] (Annealed.)

The lack of violence of the device is apparent. No noise aside from a "ping" was produced by any of the units. Visual inspection of the units showed that no rupture of the shell occurred indicating the absence of shattering effects. This feature is important from the standpoint of preventing injury to the system in which it is to be used, and in insuring nonhazardous operation.

It will be obvious to those skilled in the art that many modifications in the design and use of the sonic-pulse generating device of the present invention are possible without departure from the scope of the present invention. We intend, therefore, to be limited only by the following claims.

What is claimed is:

1. A device for generating an easily distinguished series of sonic pulses free of secondary reverberations which comprises shell having one closed and one open extremity, a plurality of cylinders positioned axially within the said shell in snug peripheral engagement with the shell wall, said cylinders having a central core running axially therethrough, each of said cores being loaded with a high velocity detonating explosive and each of said cylinders being separated by a layer of deflagrating composition and an ignition assembly sealed in and closing the open end of the shell, with the proviso that said high velocity detonating explosive is of such quantity and so distributed that the shell wall is not ruptured by the detonation thereof when said shell is immersed in water.

2. A device for generating an easily distinguished series of sonic pulses free of seconary reverberations which comprises a shell having one closed and one open extremity, a plurality of cylinders positioned axially within the shell from the closed extremity toward the open extremity thereof, each of said cylinders being in snug peripheral engagement with the shell wall and each of said cylinders being constructed of a ductile material and having axially therethrough a core containing a high velocity detonating explosive, a length of deflagrating composition extending longitudinally within the shell between each of the said cylinders, a portion of said deflagrating composition being contained in a heavy-walled tube and an ignition assembly sealed in and closing the open extremity of said shell, said ignition assembly being positioned within the shell in igniting relationship to the nearest of the said deflagrating cores, with the proviso that said explosive is of such quantity and so distributed that the shell wall is not ruptured by the detonation thereof when said device is immersed in water.

3. The device of claim 2 wherein the high velocity detonating explosive is lead azide.

4. The device of claim 2 wherein the high velocity detonating explosive is pentaerythritol tetranitrate.

5. The device of claim 2 wherein the high velocity detonating explosive is picryl sulfone.

6. The device of claim 2 wherein the high velocity detonating explosive is tetryl.

7. The device of claim 2 wherein the high velocity detonating explosive is nitromannite.

8. The device of claim 2 wherein the deflagrating composition is boron and red lead.

9. The device of claim 2 wherein the deflagrating composition is silicon and red lead.

10. The device of claim 2 wherein the deflagrating composition is barium peroxide and selenium.

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