United States Patent [19]

Conger

[11] **3,796,159**

[45] **Mar. 12, 1974**

[54] **EXPLOSIVE FISHEYE LENS WARHEAD**

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[73] Assignee: **The United States of America as represented by the Secretary of the Navy,** Washington, D.C.

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[21] Appl. No.: **524,352**

[52] **U.S. Cl.**..... **102/67,** 102/56, 102/DIG. 2

[51] **Int. Cl.**..... **F42b 13/48,** F42b 1/00

[58] **Field of Search** ..... 102/7.2 R, 8, 9, 10, 16, 102/56–59, 63, 64, 67–69, 89, 23 CW

[56] **References Cited**

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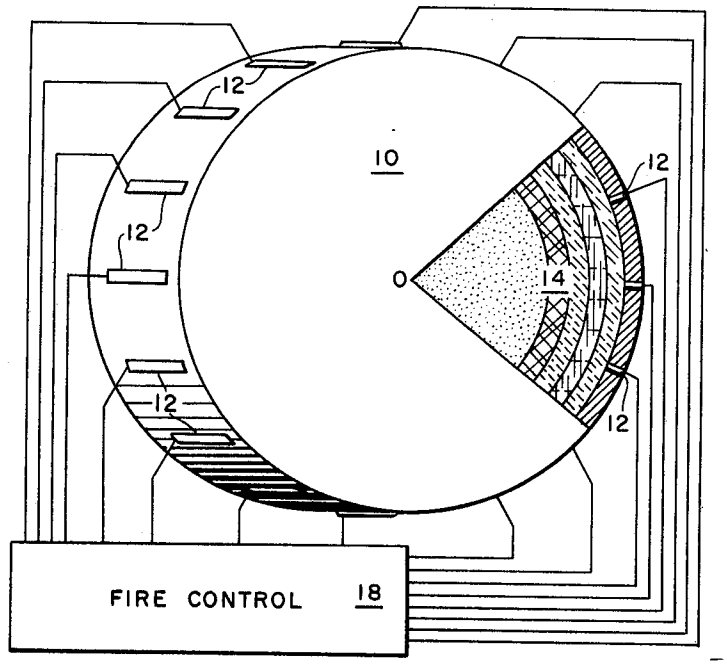
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[57] **ABSTRACT**

An aimable warhead in the form of an explosive cylindrical lens with detonators spaced about its circumference for simultaneously aiming and firing the warhead in any direction by selectively firing a detonator on a side thereof opposite to the direction of aim and focusing the detonation waves in the aimed direction.

3 Claims, 4 Drawing Figures



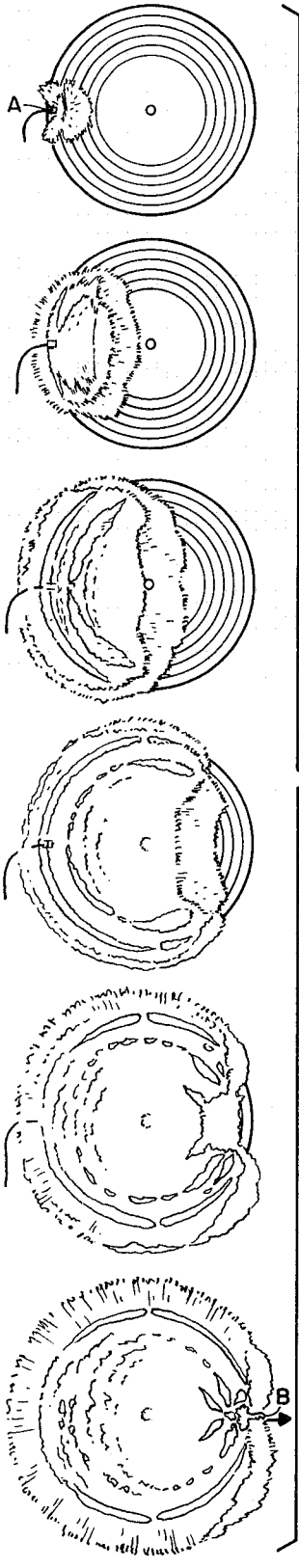


FIG. 2

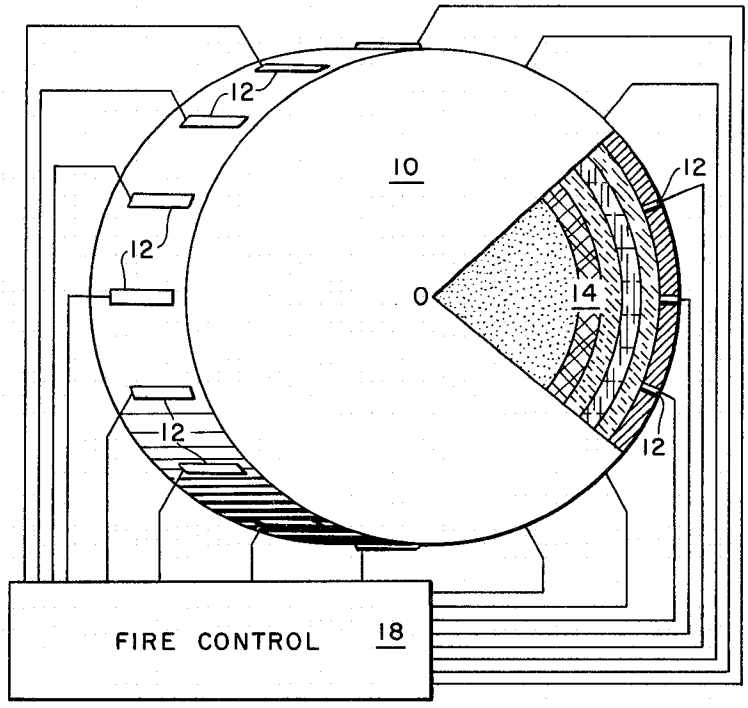


FIG. 1

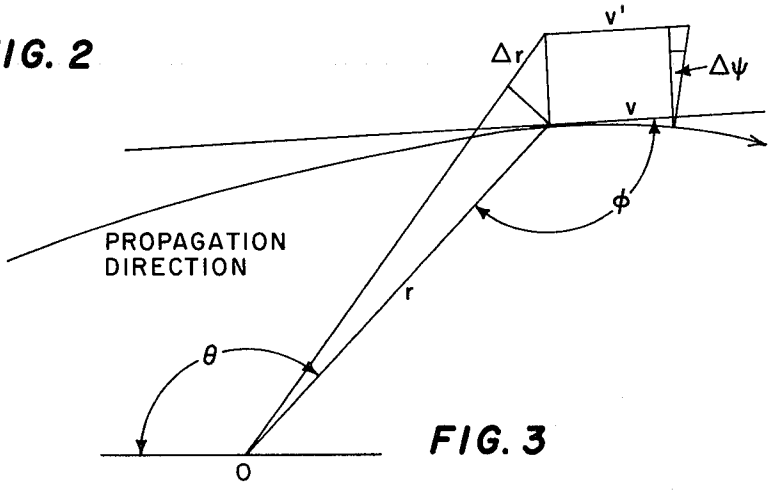


FIG. 3

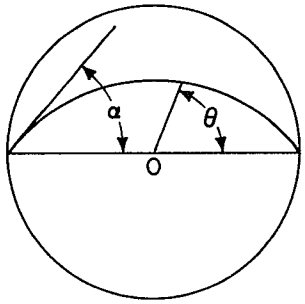


FIG. 4

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EXPLOSIVE FISHEYE LENS WARHEAD

The invention herein described may be manufactured and used by or for The Government of the United States of America for governmental purposes without the payment of any radial royalties thereon or therefor.

The present invention relates to fragmentation or blast warheads and the like, and more particularly to an explosive "fisheye" cylindrical lens.

This invention is related to copending application, Ser. No. 524,351 filed Feb. 1, 1966 for Explosive Luneberg Lens Warhead.

When detonated, warheads currently used on guided missiles produce a fragment pattern that is either spherically or cylindrically symmetric about the warhead. Although the transfer of energy from the explosive to the fragments is efficient, only a small fraction of the fragments will intercept the target, assumed to be airborne, and therefore the overall efficiency of this type of warhead is low. A greater efficiency would be obtained if most of the energy were directed toward the target. A warhead having such capability is an aimable warhead.

Aiming is difficult because of the inability to determine, until a few milliseconds before the warhead is detonated, on which side of the target the missile and warhead will pass. Thus, in a period of a few milliseconds, the warhead must be aimed at the target and detonated. In this short time it is difficult to aim the warhead by changing its attitude, because the inertia of the warhead makes it difficult to physically rotate it into the proper position sufficiently fast to hit the target.

A system is disclosed herein for an aimable warhead in the form of an explosive "fisheye" cylindrical or spherical lens. With detonators spaced about its surface, the warhead can be simultaneously aimed and fired in any direction by firing a detonator on the opposite side. When a detonator opposite the direction of aim is fired, detonation waves progressing through the warhead will detonate all the explosive in the warhead in such a way as to focus the detonation waves on the side of the lens in the direction of aim. Equations are derived herein for the required detonation velocity as a function of radius normal to a cylinder axis or through the center of a sphere; explosives are selected with the proper detonation velocities desired.

It is an object of the invention; therefore, to form a warhead in the form of an explosive fisheye spherical or cylindrical lens.

Another object of the invention is to provide an efficient cylindrical warhead, aimable in any radial direction about its cylindrical surface.

A further object of the invention is to provide an explosive cylindrical warhead in which the explosive, when detonated along any line on one side of warhead parallel to the cylinder axis, develops a shock wave focused on a line at the other side of said cylinder for propelling a concentration of warhead fragments in the direction of aim.

Other objects and many of the attendant advantages of this invention will become readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 shows a typical fisheye lens warhead with a plurality of detonators spaced about its surface.

FIG. 2 is a series of cross-sectional views of a fisheye lens warhead, as in FIG. 1, showing progression of detonation wave through the warhead, from a point of detonation on one side, detonating the explosive in such a way as to focus the detonation waves on a point on the opposite side of the lens.

FIG. 3 illustrates the differential relationship for bending of the direction of propagation of a shock wave passing through a cylinder.

FIG. 4 illustrates the propagation direction of a shock wave in a fisheye lens.

The system discussed here is for a cylindrically symmetric warhead which can be aimed in a given radial direction about the cylinder axis without turning the warhead itself. The warhead **10** is constructed in the form of an explosive lens, analogous to Maxwell's "fisheye." (J. C. Maxwell, *Cambridge and Dublin Math Jour.*, Vol. 8, 1854, p. 188.) The cylindrical warhead **10** has a plurality of linear arrays of exploding bridge-wire-type detonators **12** (or plane-wave generators) mounted along lines about the surface of the explosive lens and parallel to the cylindrical axis. The warhead is simultaneously aimed and fired in a given direction by detonating any one of the detonator arrays or the like on the opposite side. The construction of the lens is such that the detonation waves, starting on an array line, fire all the explosive in the warhead in such a way that the detonation is focused on a line on the opposite side of the lens. Fire control system **18** determines the direction of aim, when and which detonator **12** to fire.

The fisheye lens warhead is constructed from a number of coaxial cylindrical shells **14** in which the detonation velocity v of each shell is given by the equation

$$v = [1 + (r/r_o)^2 * 9 \; /2 v_o \tag{1}$$

where r is the radius of the shell, r_o the radius of the lens, and v_o the detonation velocity at the lens surface. Equation (1), which is hereinafter derived, shows that the velocity increases slowly with r when r is small. Thus the central part of the lens can be uniform, as shown in FIG. 1. If there are five shells of explosive, for example, and the outer shell has a detonation velocity of 8,000 meters/sec, the detonation velocities might have the values shown in Table 1.

Table 1. Detonation Velocity as a Function of Radius

$$v_o = 8000/0.95$$

r	r_{av}	v, m/sec
0 to 0.5 r_o	0.25 r_o	4460
0.5 to 0.7 r_o	0.60 r_o	5720
0.7 to 0.8 r_o	0.75 r_o	6550
0.8 to 0.9 r_o	0.85 r_o	7250
0.9 to 1.0 r_o	0.95 r_o	8000

The detonation velocity of 4,460 meters/sec, in the first row of Table 1, is lower than the detonation velocity of most explosives used in warheads. Although detonation velocities of 4,000 meters/sec and less can be obtained from low-density explosives, the detonation pressures produced by these explosives are also low. Baritol, a mixture of barium nitrate and TNT, is a better choice for the cylindrical core. Detonation velocities of Baritol mixtures can be 4,500 meters/sec or less, depending on the composition. Since the density of

these explosives is high, the detonation pressure they produce is also high.

In tests of thin cylindrical fisheye explosive lens' 6 inches in diameter and three-fourths inch thick each lens was constructed from coaxial rings of the explosives listed in Table 2. The first four rings were cast and composition C_4 was pressed into place. The first, third, and fourth detonation velocities are averages for 1.0 inch diameter charges of

Table 2. Detonation Velocity of Explosives Used

Radius, in inches	Explosive	Detonation velocity, m/sec
0 to 1.50	67% $Ba(NO_3)_2$, 33% TNT	4890
1.50 to 2.10	33% $Ba(NO_3)_2$, 67% TNT	5720
2.10 to 2.40	TNT	6520
2.40 to 2.70	Composition B	7250
2.70 to 3.00	Composition C_4	7900

the explosives as measured by streak camera and by pin switch oscilloscope methods. The second detonation velocity is a linear interpolation from the measured values for 50 percent $Ba(NO_3)2$ and 50 percent TNT, and for 100 percent TNT. The detonation velocity of Composition C_4 is a handbook value. A comparison of Tables 1 and 2 shows that the detonation velocity of the inner ring deviated from the desired value by about 10 percent. However, this deviation did not prevent the lens from functioning. The warheads tested detonated as theory indicated they should. Detonation started at the point of initiation A (top left in FIG. 2). By the time the detonation wave had passed halfway through the disc, the detonation front was almost plane; the detonation wave then converged, or focused, to a point B on the opposite side of the explosive lens (bottom right FIG. 2). Intense jets, which formed at this point, progressed away from the point of focus. FIG. 2 was drawn from a series of pictures taken by a Beckman & Whitley camera; another series of pictures showed the formation of the jets as they move away from the point on the lens where the detonation waves converge. From the camera speed, which was 5.8 μsec per frame, it was found that the jets have a velocity of about 3,500 meters/sec.

Tests proved conclusively that: the explosive lenses constructed in accordance with the invention perform effectively; (these warhead lenses produce jets that cause intensive damage at distances where an isotropic charge of the same size would have little effect; and the direction of the jets is a function of the point of initiation of the lens.

Equations for the explosive fisheye lens are derived here without any reference to optics.

The explosive fisheye lens is in the form of an inhomogeneous cylinder **10.** If the explosive is detonated by a detonator **12** along a line parallel to the axis of the cylinder on the surface of the cylinder and the shock wave is to focus on a line at the other side of the cylinder, the propagation velocity of the shock wave must be larger on the outside of the cylinder, for this shock wave must travel farther in the same amount of time than a shock wave traveling through the center of the cylinder. Since the propagation velocity is a function of only the radius of the cylinder, lines normal to the shock fronts, or parallel to the direction of propagation, must lie in planes which are normal to the cylinder axis. Such a plane is shown in FIG. 3 where O is the axis of the cylinder. Bending of the propagation direction will result from the propagation velocity being a function of radius. In FIG. 2 the propagation velocity at a point $r + \Delta r$ will be greater by a small increment than the propagation velocity at the point r. This difference in propagation velocity causes a curvature of the direction of propagation by an amount $\Delta\psi$.

From FIG. 2, by Taylor's expansion:

$$v' = v(r) + \Delta r(dv/dr) \tag{2}$$

By trigonometry

$$\tan \Delta\psi = (v' \Delta t - v\Delta t/\Delta r/\sin \phi) = \sin \Phi \, \Delta t(dv/dr) \tag{3}$$

As Δt and $\Delta r \rightarrow 0$, this becomes

$$d\psi = \sin \Phi \, dt(dv/dr) \tag{4}$$

where $d\psi$ is the element of bending of the propagation direction. Since (from FIG. 3) $dr/dt = v \cos \Phi$, equation (4) can be written as

$$d\psi = (dv/v) \tan \Phi \tag{5}$$

The change in **101** or $\Delta\Phi$ will be the difference between $\Delta\psi$ and the change in θ or $\Delta\theta$. From FIG. 3,

$$\tan \Delta\theta = (v \, \Delta t \sin \Phi/r) \tag{6}$$

As $\Delta t \rightarrow 0$, this becomes

$$d\theta = (v \sin \Phi dt/r) \tag{7}$$

and from equations (4) and (7)

$$d\Phi = \sin \Phi \, dt(dv/dr) - (v \sin \Phi \, dt/r) \tag{8}$$

Since $dr/dt = v \cos \Phi$, equation (8) can be written as

$$d\Phi = \tan \Phi(dv/v) - \tan \Phi(dr/r) \tag{9}$$

Division by tan Φ and integration give

$$r/v \sin \Phi = k \tag{10}$$

where k is the constant of integration.

We will consider propagation curves starting at a point P on the surface of the cylinder of radius $r = 1$ and passing through the cylinder to a second point on the opposite side, as shown in FIG. 4. The propagation velocity at the surface of the cylinder is assumed to have a value of unity. The propagation velocity inside the cylinder is less than 1.0. A particular propagation curve from P will make an angle α at P with a line passing through the center of the cylinder. From equation (10), since the propagation velocity equals 1.0 at the surface of the cylinder where $r = 1.0$,

$$\sin \alpha = k \tag{11}$$

At $\theta = \pi/2$, $\Phi = \pi/2$: and therefore equation (10) reduces to

$$r/v^* = k \tag{12}$$

where v^* is the propagation velocity at $\theta = \pi/2$. From equations (5) and (10), by eliminating Φ, we can derive the equation for the bending of the direction of propagation,

$$d\psi = (k\, dn/n\ \sqrt{n^2r^2 - k^2}) \tag{13}$$

where $n = 1/v$.

The total angle of bending is 2α and, from equation (11), $\alpha = \sin^{-1} k$. At $\theta = \pi/2$, half the bending has taken place and $v = v^*$. Thus, from equations (11) and (13), the total bending is given by

$$2\int_1^{n^*} \frac{k\,dn}{n\sqrt{n^2r^2 - k^2}} = 2\sin^{-1} k \tag{14}$$

where $n^* = 1/v^*$.

It can now be shown that equation (14) is satisfied by

$$n = (2/1 + r^2) \tag{15}$$

When equation (14) is divided by 2 and equation (15) is substituted into the left side of equation (14), it can be integrated to give

$$\sin^{-1}(n^* - k^2/n^*\ \sqrt{1 - k^2}) - \sin^{-1}\ \sqrt{1 - k^2} \tag{16}$$

From equations (12) and (15), with $n^* = 1/v^*$,

$$n^* = 1 + \sqrt{1 - k^2} \tag{17}$$

and

$$(n^* - k^2/n^*\ \sqrt{1 - k^2}) = 1 \tag{18}$$

so that (16) becomes

$$\pi/2 - \sin^{-1}\sqrt{1 - k^2} \tag{19}$$

Taking the sin of (19) gives

$$\sin\,[(\pi/2) - \sin^{-1}\sqrt{1 - k^2}] = \cos\,(\sin^{-1}\sqrt{1 - k^2}) = k \tag{20}$$

Thus the integral of equation (14) reduces to $\sin^{-1}k$, which shows that equation (15) is a solution of the integral equation (14). Equation (15), it can be noted, is the basis for equation (1).

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An aimable explosive warhead operable to be aimed without physical rotation of the warhead and fired in any given radial direction about the axis thereof, comprising:

a. an explosive "fisheye" lens warhead in the form of an inhomogeneous cylinder,

b. said explosive fisheye lens having an outer cylindrical warhead fragmentation casing,

c. said cylindrical casing being filled with explosives, said explosives consisting of a plurality of concentric cylindrical explosive shells about a cylindrical explosive core,

d. a plurality of linear detonator arrays mounted and equally spaced about the cylindrical surface of said warhead casing in parallel alignment with the cylinder axis of said explosive fisheye lens,

e. fire control means for selectively firing any of said detonator arrays upon command,

f. said explosive fisheye lens warhead operable to be aimed in any radial direction by said fire control means by selectively firing a detonator on the opposite side of the warhead from the desired direction of aim,

g. said fisheye lens warhead upon detonation of any one of said detonator arrays operable to cause detonation waves to progress from the line of detonation through the entire warhead detonating all the explosive therein such that the detonation waves are focused on a line on the opposite side of the fisheye lens from the detonation line in the direction of aim directing intense jets of warhead fragments in the direction of aim.

2. A warhead as in claim **1** wherein said explosive shells and core are each of different explosive composition.

3. A warhead as in claim **1** wherein the adjacent explosive shells and core are each of different density.

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