Feb. 2, 1971 L. G. COPLEY 3,560,913

ACOUSTIC PULSE FOCUSING MEANS

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Fig. 1

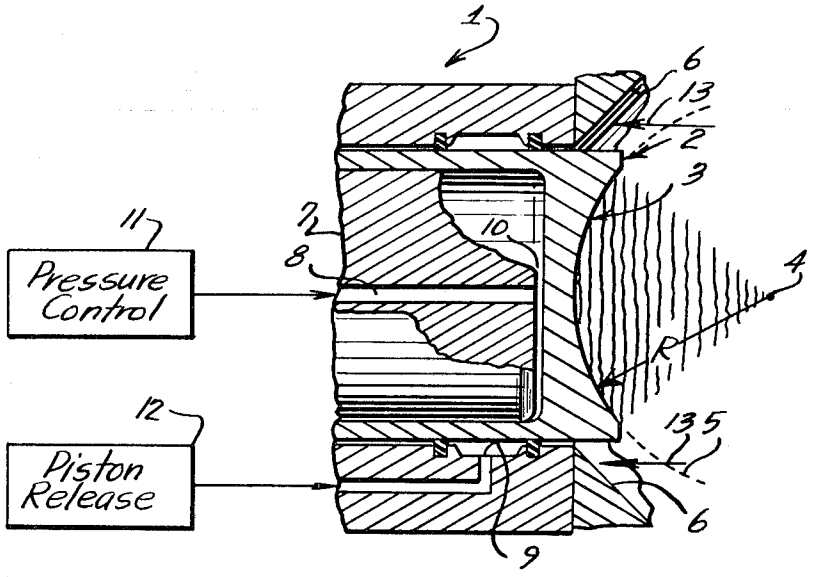
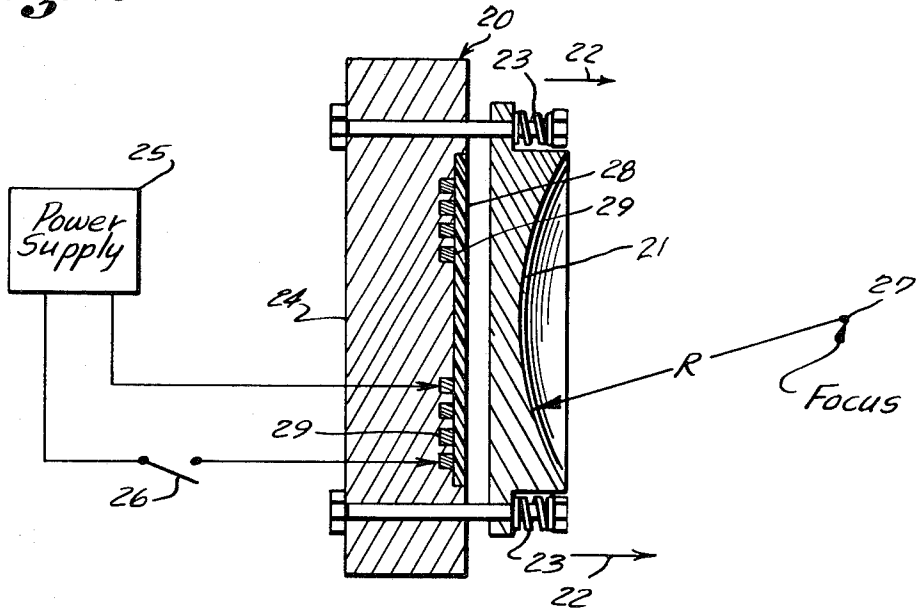


Fig. 2



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ACOUSTIC PULSE FOCUSING MEANS

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ABSTRACT OF THE DISCLOSURE

An acoustic impulse generator is provided with a concave piston head for focusing the pulse generated by the head to a point ahead of the generating surface.

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

This invention relates to acoustic generators and, more specifically, to an improvement in the shape of the piston face of an impulse generator which provides focusing of the pulses generated to a point ahead of the generating surface. The basic function of these impulse generators is to produce a high intensity pulse by means of rapid acceleration or deceleration of a piston-like structure to obtain a shock wave which propagates with a directional characteristic. A typical acoustic pulse generator is the hydroacoustic generator described in patent application No. 3,277,437 to J. V. Bouyoucos filed Apr. 5, 1965. This patent describes a hollow tubular piston that is partially exposed to seawater and whose internal surface provides a close fit to a shock-mounted anvil. The basic operation of the generator involves drawing the piston towards the anvil, thus also drawing in water surrounding the outer face of the piston. When the piston is stopped by the anvil, a shock wave having an almost infinitely short wavelength is produced in the indrawn fluid medium. While the shape of the piston disclosed in this patent is substantially flat, producing a short intense pulse in the surrounding liquid medium, the shape and propagation characteristics vary with the shape of the outer face of the piston and the surrounding baffle.

The pulse produced by a flat piston decreases in amplitude inversely as the distance from the generator. A more intense area of pulsed energy may be created in a well-defined focal region by providing the piston head with a concave, spherical surface. Pulses generated by this spherical surface will be concentrated at the center of this sphere because the travel time of shock waves generated at any point on the spherical surface to the center will be constant. This area of highly concentrated acoustic energy may be used in acoustic material testing where isolated areas of the material are to be tested as well as in broad band sonar systems designed, for example, to survey those portions of the ocean floor which are not illuminated by sunlight and which cannot be illuminated by artificially-produced light.

An acoustic pulse generator provided with the above concave piston produces a more highly refined focal region than do continuous wave acoustic generators. In the latter case, the degree of focusing increases as the frequency increases. With the concave piston pulse generator, the degree of focusing increases with increasing piston size and with decreasing rise time for the acceleration or deceleration pulse of the piston. It is currently feasible to produce a high degree of focusing with available impulse generators such as the aforementioned hydroacoustic generator.

One of the ways the time intervals between the generating surface and the focal point are made equal is by shaping the concave surface to resemble a sphere. This produces a point of energy removed from the generator by a focal length determined by the radius of the sphere. For acoustic ocean bottom sonar, this radius would be made quite large so that the distance between the sonar transducer and the object sought would be at a maximum while maintaining some degree of focusing. When this device is used for flaw detection, the focal length would be made relatively short to obtain maximum intensity and resolution over the small area to be tested.

It will be appreciated that there are alternate ways of producing high-intensity focused pulses utilizing the principle that the generating surface be equidistant from the focal point. Such devices include generators which draw an elastic or flexible membrane in towards a stationary concave anvil. The concavity of the generating surface may also be obtained by electromechanical or electromagnetic means as well as by materials which selectively deform when excited, so long as the surface is spherical at the time the pulse is produced.

It will be further appreciated that the embodiments shown indicate both implosive and explosive generating means. In the explosive case, the generating surface is quickly accelerated rather than being rapidly decelerated.

It is therefore an object of this invention to provide means for shaping the pulse generated by a shock wave producing generator.

It is a further object of this invention to provide a concave surface for the face of the piston in an acoustic pulse generator.

It is a further object of this invention to provide that the shape of the concave generating surface of an acoustic generator be substantially spherical.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description thereof when considered in conjunction with the accompanying drawings in which like numerals represent like parts throughout and wherein:

FIG. 1 is a cross-sectional view of one type of implosive pulse generator with a concave piston head; and

FIG. 2 is a cross-sectional view of one type of explosive pulse generator having a magnetically-actuated concave piston head.

Referring to FIG. 1, a cross-sectional view of one type of acoustic pulse generator is shown with a concave, spherical piston head. In this embodiment, a hydroacoustic generator **1** is shown including a hollow piston **2** coacting with an anvil **7**. Piston **2** has a concave head **3** which, when accelerated in the direction shown by arrow **13** and then rapidly decelerated, produces a shock wave in the fluid medium at its forward face. This shock wave propagates away from the piston towards center **4** of circle **5**. Circle **5** is defined as that circle which has a section of the piston head **3** as a segment thereof. It is a property of the piston head configuration that any portion of a shock wave formed at any point along the piston head will arrive simultaneously with any other point on the piston head since all points on the piston face are equidistant from the center **4**.

In the operation of the generator, piston **2** is first moved into a cocked position away from anvil **7** by a high pressure fluid introduced through channel **8** by control **11** and is clamped in its cocked position by a hydraulic clamping means **9** and control **12**. The hydroacoustic generator is fired by evacuating chamber **10** and releasing clamping means **9**. The pressure head, P_h, or ambient sea pressure drives piston **2** towards anvil **7**. The almost instantaneous stoppage of piston **2** is communicated to the fluid which results in an instantaneous pressure rise at

the face 3 of piston 2 which communicates with the fluid medium or sea. A pressure disturbance is produced having a spacial extent equal to the rise time of the velocity step multiplied by the speed of sound in the medium. When piston 2 and anvil 3 come into contact, the fluid at piston face 3 is at an elevated high pressure and has zero particle velocity. This produces a shock wave which will propagate away from the piston face. The horn shown at 6 is provided to focus any stray acoustic energy towards the focus 4.

While this type of generator operates on the principle of implosion, it will be appreciated that any acoustic impulse generator having a driven member which coacts with the fluid medium may utilize a concave surface so as to focus the shock wave.

One such generator is shown diagrammatically in FIG. 2. This generator is an electromagnetically-actuated impulse generator which works on the aforementioned explosive principle. Generator 20 is shown having a concave piston head 21. This head is moved in the direction of arrow 22 against spring loads 23 by the electromagnet shown diagrammatically at 24 when power supply 25 is connected thereto by any suitable switching means 26. This movement is caused by eddy current repulsion in which a current is induced in a piston head made of conducting nonmagnetic material. This induced current opposes the magnetic field of the electromagnet and forces the head away from a smooth glass or plastic surface 28 which covers coils 29. It will be appreciated that the instantaneous forward acceleration of the piston creates a pressure rise similar to that of the imploding generator so as to form a shock wave at the face of piston 21. This shock wave is focused at 27 which is a point in the surrounding medium at a distance R from the surface of the concave piston. After the pulse is generated, the piston is returned to a position adjacent the electromagnet by springs 23.

As may be seen by the examples shown in FIGS. 1 and 2, any actuating means which imparts an instantaneous acceleration or deceleration to a concave piston may be used to generate a highly focused shock wave. In addition, concave piston heads having shapes which approximate a sphere may be used to produce energy confined to a refined focal region.

teachings. It is therefore to be understood that within 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. In a hydroacoustic generator of the type in which a rigid member having a free surface exposed to a fluid medium strikes an anvil and thereby produces a single intense transient positive pulse having substantially no negative rarefactive component in said fluid medium, the improvement comprising:

a portion of said rigid member being spherically concave to provide said free surface with a curvature that directs all of the energy produced by said generator to a point in said fluid medium which is the geometric center of said surface when said rigid member strikes said anvil such that all of the energy in said transient positive pulse arrives at said point at substantially the same time and is focused thereat.

2. In a hydroacoustic generator which produces a single intense acoustic pulse in a fluid medium of the type comprising:

a housing including a cylindrical cavity having an open end exposed to said fluid medium;

a piston slidably disposed within said cavity for defining a chamber having a given volume when said piston is disposed in said given open end of said cavity;

a shock-mounted anvil interposed between said piston and said housing in said cavity;

fluid pumping means connected to said cavity for sliding said piston outwardly to said open end of said cavity;

hydraulic means connected to said pumping means for clamping said piston in said open end of said cavity;

means for evacuating said chamber below the ambient pressure of said fluid medium; and

control means coupled to said hydraulic clamping means for releasing said piston such that when said piston is released it strikes said anvil and produces a transient positive pulse with substantially no negative rarefactive component in said fluid medium, the improvement comprising:

the portion of said piston exposed to said fluid medium being concave and in the form of a hemisphere to provide said exposed portion with a curvature that directs all the energy produced by said generator to a point in said fluid medium which is the geometric center of said hemisphere when said piston strikes said anvil such that all of the energy in said transient positive pulse arrives at said point at substantially the same time and is focused thereat.

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