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Knudsen

[11] **3,724,590**

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[54] **BUBBLE PULSE SUPPRESSION WITH ACOUSTIC SOURCE OPTIMIZATION**

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[52] **U.S. Cl.** .... **181/.5 XC**

[51] **Int. Cl.** **G01v 1/10,** G01v 1/28

[58] **Field of Search** ...181/.5 A, .5 XC, .5 H; 340/12, 340/17

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[57] **ABSTRACT**

The acoustic wave associated with an underwater gas bubble pulse is optimized by permitting the gas bubble to expand as freely as possible during its initial expansion. After the initial expansion, or primary pulsation, the energy of the oscillatory system in the form potential energy is prevented from being transformed into the kinetic energy of water rushing in to fill a collapsing cavity. The potential energy of the oscillatory system is dissipated gradually to permit the device used to be made ready for the generation of a subsequent gas bubble. The method of the present invention is embodied, for example, in a structure having a surface which is covered with strips of a flexible material whose acoustic properties are close to the acoustic properties of water, e.g. a material for which rho-c, the product of the density of the material times the speed at which sound travels in the material, is close to the rho-c of water. The material is attached to the structure at selected points on the surface thereof. When a gas bubble is generated as a result of the creation of an acoustic wave, the acoustic wave is transmitted through the material and into the surrounding water without significant reflection or alteration. As the bubble expands, the water forced ahead of the expanding bubble is allowed to flow through the structure by the flexing of the covering material at the locations at which the material is not attached to the mesh structure. When the gas bubble has reached its maximum radius and the water surrounding the perimeter of the bubble begins to rush in to fill the cavity of the bubble, the covering material which has flexed to allow the water to flow out of the structure is forced into place around the exterior of the structure by the pressure of the water filling the bubble cavity. The covering material prevents water from rapidly filling the cavity so that the oscillation of the bubble is essentially stopped. The surface of the material may contain perforations to permit water to gradually return into the cavity to provide a reasonably short recycling period of the acoustic wave generation device.

12 Claims, 5 Drawing Figures

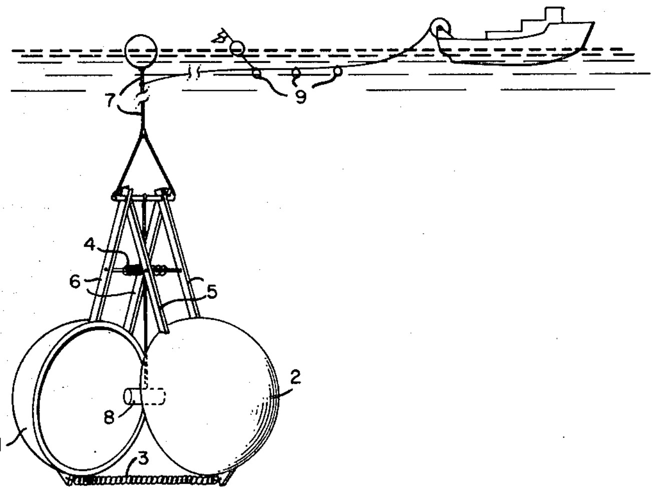
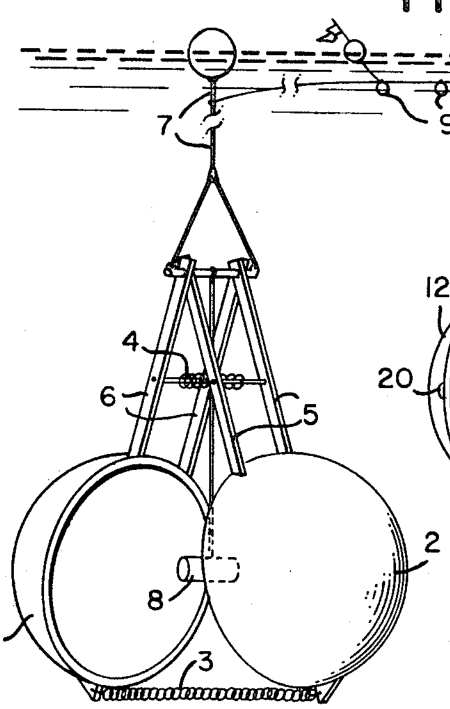


FIG. 1



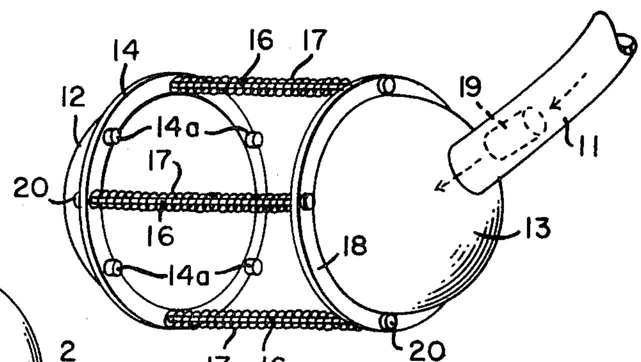


FIG. 2

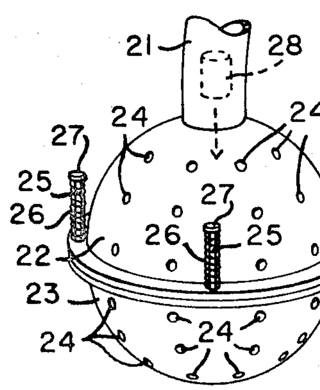
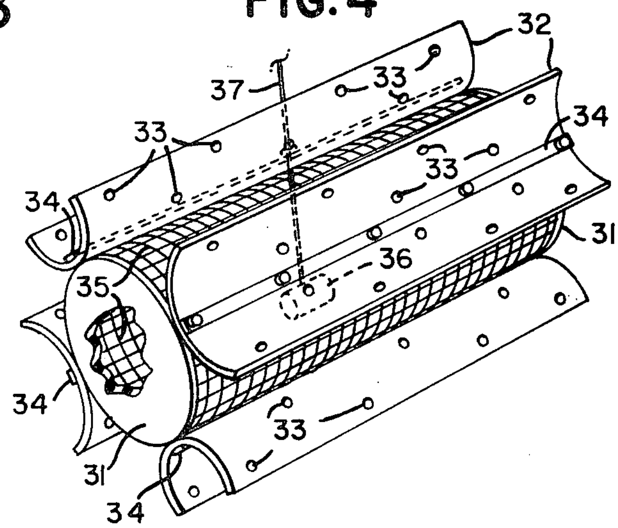


FIG. 3

FIG. 4



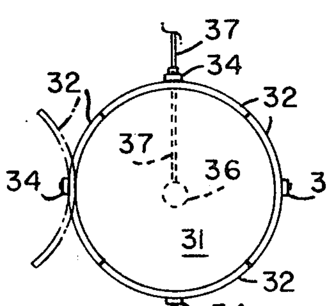


FIG. 4a

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BUBBLE PULSE SUPPRESSION WITH ACOUSTIC SOURCE OPTIMIZATION

BACKGROUND OF THE INVENTION

My invention relates to the optimization of an underwater seismic source used in offshore prospecting and more particularly, to a method and apparatus for maximizing the amplitude of the acoustic wave generated by a seismic source while at the same time suppressing secondary pulsations associated with the gas bubble formed by the source.

In seismic prospecting an acoustic disturbance having appropriate frequency and amplitude characteristics is initiated at a known location or locations at a known time and the resulting disturbance is recorded as a function of time at a number of locations. The acoustic wave generated by the seismic source travels through and reflects from and refracts along geologic strata in the subsurface. A man skilled in the seismic prospecting art is able to use the recorded acoustic disturbance to infer the position and attitude of geologic structures. Such information is of great value in mineral prospecting, in geophysical research and in prospecting for oil.

In offshore prospecting a series of recording geophones is trailed behind a search ship. Seismic sources are typically activated under water and the resulting acoustic disturbances are recorded by the geophones. Originally, explosive charges or gas gun-bursts were activated at shallow depths so that the associated gas bubble would be vented at the surface. As a result of the venting a single acoustic wave or pressure pulse would be radiated. Recently, the practice has been to locate seismic sources at greater depths to obtain stronger seismic signals. At these greater depths there is no venting of the associated bubble to the surface and an oscillatory system is created. If no steps are taken to control or manipulate the gas bubble it will expand to its maximum radius and then oscillate until the gas in the bubble is absorbed by the surrounding water or until the bubble breaks up into inumerable smaller bubbles or until the bubble works its way to the surface. This oscillation generates secondary acoustic waves which produce signals detectable by the geophones. These secondary signals will mask the true character of the subsurface and are highly undesirable.

In practice the generation of acoustic pulses at great depths has possessed inherent advantages which have outweighed the difficulty due to the associated gas bubble oscillations so that exploration geophysicists have been willing to endure the complications introduced by secondary pulsations. In addition to obtaining a larger seismic amplitude from a given charge size or gas burst certain normal modes of wave propagation which make reflections seismology interpretation difficult or impossible in some water-covered areas are suppressed.

Gas bubble sources currently include explosive charges, gas gun bursts, the mixing the gases such as propane and oxygen to cause explosions, the generation of gas bubbles by electric discharges, mechanical separators, and fully inclosed mechanical boomers. Any of these sources may be employed in conjunction with the method and apparatus of the present invention since it is concerned with the optimal transmission of the acoustic wave after it is generated while subsequently suppressing secondary pulsations.

In open water when a gas bubble is generated approximately one-half of the energy of the source is radiated away in the form of a shock or acoustic wave. Approximately one-half of the total energy of the source remains in the form of the internal energy of the bubble gases and kinetic energy of the outwardly flowing water. When the bubble reaches its maximum radius this retained energy is present primarily in the form of the potential energy of the bubble cavity. Without interference, the bubble will contract and the energy of oscillation is converted back into the kinetic energy of the water which is rushing in to fill the collapsing cavity. Similarly, at the instant of minimum bubble radius, the energy of oscillation is contained in the form of the internal energy of the gases. Unless structural barriers are placed in the path of the oscillating bubble it will continue to oscillate until the energy of oscillation is dissipated by natural processes such as turbulence and the radiation of energy in the secondary pressure pulses. And as the bubble oscillates acoustic waves are generated whenever the water experiences maximum outward acceleration.

In order to prevent the interference with the seismic disturbances recorded from the primary pulsation it is necessary to prevent the secondary pulsation. Secondary pulsation can be suppressed in several ways. The classical technique is to generate the gas bubble at a shallow depth so that the bubble is vented to the surface. An additional possibility is to cut off the recording means after a pre-determined period of time so that secondary pulsations are not recorded. This procedure has the unfortunate effect of limiting the reflection range (either laterally or in depth) of the seismic signals being detected so that only near fields are being investigated. In a previous patent, U.S. Pat. No. 2,877,859 I disclosed a method for suppressing secondary pulsations. It consisted of substantially surrounding a gas bubble source with a rigid container having perforations on the surface thereof so that the expanding gas bubble would have to do work to force water through the perforations of the container. The work done by the expanding gas bubble dissipates its internal energy so that secondary pulsations have lower amplitutes. An unfortunate limitation inherent in this disclosure is that the acoustic wave is damped by the presence of the surrounding rigid container. The acoustic wave is damped because it is capable of traveling freely only through the perforations and because, according to an approximation based on Bernoulli's equation, the amplitude of the acoustic wave is proportional to the acceleration of the bubble volume and the presence of the rigid container reduces this acceleration. Thus, the presence of the rigid container per se physically limits the amplitude of the acoustic wave. Additionally, it has been found that rigid containers which substantially surround seismic sources are subject to deterioration due to the significant differential pressures that are experienced across their surfaces as the gas bubble associated with the source expands.

It is, therefore, an object of this invention to provide a method and apparatus for suppressing secondary pulsations which create a minimal impediment to the initial expansion of a gas bubble pulse.

It is a further object of this invention to provide a method and apparatus for suppressing secondary pulsations which do not subject the apparatus to extraordinary pressure differentials.

It is a still further object of this invention to provide a method and apparatus for obtaining an optimum acoustic wave from an underwater seismic source while suppressing secondary pulsations in the gas bubble associated with the seismic source.

SUMMARY OF THE INVENTION

The method and apparatus of my invention allows a gas bubble to expand as freely as possible during the initial expansion, i.e. during the primary pulsation, so that the acoustic wave approaches the intensity it would have if the gas bubble were generated in open water. When the gas bubble reaches its maximum radius the energy of oscillation is trapped in the form of the potential energy of the expanded cavity by preventing the water surrounding the expanded cavity from rushing in to fill a collapsing cavity. Numerous devices can be constructed to prevent the rapid collapse of the cavity. For example, a wire mesh structure at least partially covered with a material whose acoustic properties are nearly like those of water can be used. The material is attached to the wire mesh structure at selected points. When the gas bubble is generated within the wire mesh structure the outwardly expanding water forces the material covering the structure to flex away from the surface so that the water can flow outwardly. When the bubble has reached its maximum radius and begins to contract the form-fitted material will be pushed in to again cover the surface of the mesh structure. Thus, the cavity will not rapidly collapse. In order to prepare the structure for subsequent use perforations can be included on the surface of the material so that water will gradually fill the mesh structure. The size of the mesh structure should be from about one-half to about twice the expected maximum radius for the gas bubble to permit the potential energy trapping principle to operate. The potential energy trapping principle operates if the bubble is prevented from collapsing for a period on the order of a second which is long as compared to the natural period of oscillation of the bubble which is on the order of a tenth of a second.

BRIEF DESCRIPTION OF THE DRAWINGS

To facilitate the understanding of the method and apparatus of my invention reference may now be had to the drawings which are hereby incorporated in and made a part of this specification and in which:

FIG. **1** illustrates a pair of hemispherical shells which are attached by supports to a common point and are separated by a spring means under normal hydrostatic conditions. When a gas bubble is generated approximately mid-way between the hemispherical shells the initial expansion of the bubble proceeds freely in all directions except in the directions of the hemispherical shells. When the bubble has fully expanded and begins to contract the pressure on the exterior of the shells will force them together so that no rapid collapse of the bubble is possible.

FIG. **2** illustrates a pair of hemispherical shells which are normally separated by spring means wound around rods connecting opposing flanges on the respective hemispherical shells. An elongated tube connected to the surface enters one of the hemispherical shells to permit the introduction of an explosive charge or of a burst of gas. The expanding bubble can force water out the open area around the hemispherical shells. When the maximum radius of the bubble is reached the pressure on the outside of the hemispherical shells will cause them to come together.

FIG. **3** illustrates a pair of perforated hemispherical shells which are normally positioned together to form a sphere. An elongated tube extending the surface of the water permits the introduction of an explosive charge or of a gas burst. When a gas bubble is generated within the pair of hemispherical shells, the shells will separate and the springs wound around rods connecting opposing flanges of the hemispherical shells will be compressed. The shells will separate a distance equal to the length of the rods connecting the opposing flanges. A significant portion of the acoustic pulse will escape from the open area between the hemispherical shells. After the maximum radius of the bubble is reached the shells will come together to prevent a rapid collapse of the cavity. Perforations on the surfaces of the hemispherical shells will permit water to gradually re-enter the cavity to recycle the apparatus for subsequent use.

FIG. **4** illustrates a wire mesh cylinder whose sides and ends are covered with material whose acoustic properties nearly match the acoustic properties of water. The material along the sides is divided into individual strips each of which is attached to the mesh cylinder along its central portion. When a seismic source is activated within the wire mesh structure the acoustic wave travels through the covering material and the outwardly flowing water surrounding the associated gas bubble is allowed to leave the wire mesh structure by the flexing of the material away from the wire mesh surface. After the bubble has fully expanded and the pressure surrounding the bubble exceeds the pressure within the bubble the material covering the wire mesh structure will move back to cover the surface so that the bubble will not rapidly collapse. Perforations in the flexible material permits water to gradually re-enter the cylinder to ready it for subsequent use.

FIG. **4*a*** is an end view of the covered wire mesh cylinder of FIG. **4** showing the covering material in conformance with the shape of the cylinder. A phantom strip of the material is shown to differentiate the flexed position from the conformed position.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. **1** it can be seen that hemispherical shells **1** and **2** will normally be spaced apart by action of springs **3** and **4**. Supports **5** which are attached to hemispherical shell **2** and supports **6** which are attached to hemispherical shell **1** are connected together at a common point which is supported by cable **7** extending to the surface of a body of water. Supports **5** and **6** are of equal length so that when springs **3** and **4** are compressed hemispherical shells **1** and **2** will form a complete sphere. In the preferred embodiment spring **3** will have a maximum extension which will be determined by a link chain or rod inserted within the spring. The chain or rod will prevent spring **3** from breaking upon the initial outward expansion of the bubble and will prevent the hemispheres from swinging so far apart that they are not pushed together by the contracting bubble.

An explosive charge or other gas bubble source such as a compressed air gun is located in the approximate center of the region between the hemispherical shells 1 and 2. When the gas bubble is generated the acoustic pulse will radiate outwardly and generally be unimpeded except for the energy which proceeds in the direction of the hemispherical shells. The movement of water surrounding the expanding bubble would cause hemispherical shells 1 and 2 to rapidly move apart if they were located close to the bubble source. The initial spacing between the shells is determined by balancing two criteria. The shells should be far enough apart to permit the acoustic wave to radiate away with minimal impedance. On the other hand the shells should not be so far apart that no differential pressure is experienced on the exterior of the shells as the gas bubbles reaches its maximum radius and begins to contract, i.e. so for apart that the shells are not "caught up" by the contracting gas bubble. In practice this spacing will vary from one-eighth to one and one-half the maximum radius of the expanded gas bubble. When the shells come together the volume of the enclosed sphere should range from one-half to twice the volume of the expanded gas bubble for the potential energy of the bubble to be effectively trapped.

In a variation of the embodiment of FIG. 1 a rigid rod is run through the center of spring 4 so that hemispherical shells 1 and 2 cannot be pushed apart beyond a predetermined desirable spacing. When the expanding bubble reaches its maximum radius the pressure surrounding the bubble will cause a pressure to be exerted on the exterior of hemispherical shells 1 and 2. As a result of this pressure the hemispherical shells will move together so that the cavity will not collapse beyond the size of the volume of the sphere formed by hemispherical shells 1 and 2. Water will gradually seep in along the circumferential edges of the two hemispheres until the force on the exteriors of the hemispherical shells is equal to the force exerted by springs 3 and 4 plus the force of the internal water pressure at which time spring 3 and 4 will cause hemispherical shells 1 and 2 to open to their normal position.

The mechanical reaction time of the apparatus depicted in FIG. 1 is significant but is small enough so that the rapid continuous generation of seismic disturbances is possible. Also, substantial single pulse acoustic waves may be generated by the device of this figure. Any noise generated by the operation of the device, such as that occasioned by the collision of hemispherical shells 1 and 2 will be very minor compared to the acoustical wave generated by the seismic source and associated expanding gas bubble.

For the repetitive generation of single pulse acoustic waves it is necessary to introduce an explosive charge or a burst of gas into the region where generation is desired. For this purpose, in many embodiments a tube or shaft extends from the surface to the region in which the bubble is generated. Shaft 11, shown in FIG. 2, is capable of introducing a slug of air or explosive charge 19 into the region between hemispherical shells 12 and 13. The gas bubble so generated is able to expand outwardly into the open space between hemispherical shells 12 and 13.

It is evident that flange 14 on hemispherical shell 12 and flange 18 on hemispherical shell 13 provide a means for connecting the two shells in spaced apart opposition. Rods 16 extend through holes drilled in flanges 18 and 19. End means 20 on rods 16 prevent the rods from slipping out of the holes in the flanges. Springs 17 are wound around rods 16 to hole hemispherical shells 12 and 13 apart under normal hydrostatic conditions. The gas bubbles generated within the region between hemispherical shells 12 and 13 will quickly reach the maximum radius. At this point the water surrounding the bubble will begin to flow in to fill the collapsing cavity and, in the process, will exert pressure on the external surfaces of hemispherical shells 12 and 13. The effect of this pressure will be to compress springs 17 so that hemispherical shells 12 and 13 are pressed together. Impact absorbers 14*a* soften the impact of the colliding shells so they do not degrade too rapidly. Water will gradually seep in at the junction of flanges 14 and 18 until the interior of hemispherical shells 12 and 13 is filled with water. The presence of impact absorbers 14*a* separates the flanges and permits water to seep in more rapidly. At some point before the interior is filled with water the tension in spring 17 will force hemispherical shells 12 and 13 apart. When the pressure in hemispherical shells 12 and 13 approaches the tension in the springs the slow opening of the gap between the hemispherical shells will cause a rapid influx of water. The operation of the device of FIG. 2 permits a rapid outward expansion of the primary pulsation or the gas bubble while preventing significant oscillation of the bubble so that secondary pulsations do not generate acoustic waves which interfere with the geophone signals detected from the primary pulsation.

While the embodiments illustrated in FIGS. 2 and 3 utilize perfect hemispherical shells it is contemplated that other geometries can be employed as long as the separate portions are matched so that the potential energy of the cavity is trapped. The total volume of the containers should preferably be approximately the size of the expanded gas bubble and in any event should be between one-half and twice the size of the gas bubble at its maximum radius. The maximum radius of any expanded gas bubble may be determined from the intrinsic energy of the seismic source and the depth at which the source is activated and is given by

$$R_{mat} = .032\, E^{1/3} \;/(1+(d/33))^{1/3}$$

where

E = intrinsic energy of seismic source in foot pounds

d = depth at which source is activated in feet. For example, the maximum radius of a bubble produced by a seismic source with an intrinsic energy of 10^4 ft-lbs which is activated at a depth of 33 feet is 0.54 feet so the volume of the potential energy maintenance means, of whatever configuration, should range, as stated above, about the radius.

The shells of FIGS. 2 and 3 can be constructed of various materials. If a metal is used then there will be little transmission of the acoustic wave through the shells even though a significant acoustic wave will be radiated through the open water. To further optimize this acoustic wave the shells (or other geometries) can be fabricated from a composite of materials such that a large portion of the area of the shells has acoustic properties more nearly matching those of water. For example, rho-c rubber, rubber for which the product of its density times the speed that sound travels in it is nearly equal to the density of water times the speed of sound in water, can be bonded to a skeletal metal structure. The structure should be strong enough to withstand the hydrostatic pressure at the typical depths, say 32 feet, at which the seismic sources are activated. At such depths hydrostatic pressure will be on the order of 2 atmospheres. It should be remembered, however, that the amplitude of the acoustic wave is primarily determined by its radiation through the open water which is made possible by the initial separation of the shells or by the easy expansion of the initially closed shells.

In offshore seismic operations it is desirable in many instances to have a seismic source which can be operated in rapid succession. Such repetition is desirable since to achieve a desired number of seismograms per mile the more rapid the recycling the faster the ships can travel. In order to insure the rapid recycling of a device so that it will be available for the generation of a subsequent seismic disturbance it is necessary to allow the water which would ordinarily cascade into the collapsing cavity to return at a rate which rapidly fills the cavity but does not give rise to oscillation. It is possible to meet this requirement by requiring the water to do dissipative work as it returns into the cavity. For example, water which is forced to return through small perforations in a device will dissipate the energy of oscillation by creating turbulence which forms heat.

In FIG. 3, a pair of hemispherical shells **22** and **23** are shown to be normally positioned together to form a sphere. Flange **29** on hemispherical shell **23** and flange **30** on hemispherical shell **22** permit the two hemispherical shells to be attached together by means of rods **25** connected through holes drilled in flanges **29** and **30**. Heads **27** on rods **25** prevent hemispherical shells **22** and **23** from separating farther than the length of the rods. Spring **26** is wound around rods **25** so that the hemispherical shells are normally held together. When an explosive charge or a burst of gas is introduced into the interior of the two hemispherical shells by means of shaft **28** the instantaneous increase in pressure within the shells cause them to separate. As they separate, a gap is opened between the two hemispherical shells so that the acoustic wave can escape with minimal impedance. A by-product of this configuration is that the shells do not experience as great a pressure as a rigid container would experience. Thus, the degradation problem is less severe. It is true that the expanding bubble does work to open the two hemispherical shells so that some energy is dissipated but a significant portion of the original energy of the seismic source radiates as the acoustical wave or is present in the gas bubble as the potential energy of the expanding gases and the kinetic energy of the expanding water. When the expanding bubble reaches its maximum radius the inward pressure of the water which would normally cascade into the collapsing cavity pushes hemispherical shells **22** and **23** together again. The water under pressure which surrounds hemispherical shells **22** and **23** is able to enter the interior of the cavity by means of perforations **24** located on the surface of hemispherical shells **22** and **23**. The water which enters the collapsing cavity must do work to pass through perforations **24**; this work dissipates kinetic energy of the water which surrounds the collapsing cavity. The perforations also permit the cavity to fill relatively rapidly so that a subsequent charge **28** can be introduced into the now joined hemispherical shells **22** and **23**.

An embodiment which permits rapid recycling with a minimal loss of acoustic wave energy is illustrated in FIG. 4. A wire mesh container, shown in FIG. **4** to be wire mesh cylinder **35**, is covered by a material **32** whose acoustical properties are close to the acoustical properties of water. The embodiment shown in FIG. **4** has the ends **31** of cylinder **35** constructed of a rigid material. The ends **31** can be covered with material **32** providing the material is reinforced to withstand the pressure along the axis of the cylinder. The sides of the cylinder are covered with strips of material **32** which are attached along the center portions **34** thereof to cylinder **35**. An explosive charge **36** or other seismic source is introduced in the center of the wire mesh container **35** by means **37**. Alternatively, the shaft means of FIGS. **2** and **3** may be used to introduce a gas burst or an explosive charge. When a gas bubble is generated within the mesh container **35** an outward pressure is exerted on the inside surface of the strips of material **32**. This pressure causes the portions of the strips of material **32** which are not attached to the mesh cylinder **35** to flex outwardly, as shown in FIG. **4**, thereby permitting the water to flow through the mesh structure. The acoustic wave is above to travel both through the mesh wire where it is open and through the acoustical material since its acoustic properties are nearly identical to those of water. This material has the property that the product of its density and the speed of sound within it is equal to the product of the density of water times the speed of propagation of sound in water. Certain types of rubber have this characteristic. Thus, the material surrounding the wire mesh structure serves as a neutral medium for the transmission of the acoustic wave.

When the expanding gas bubble has reached its maximum radius it will begin to collapse. At this point the external pressure on the strips of material **32** will force the edges to return to their original shape in conformance with the shape of the wire mesh. FIG. **4a** illustrates the conformance of strips **32** to the shape of the wire mesh cylinder. A phantom strip **32** differentiates the flexed position from the conformed position. As the water begins to press the exterior of the wire mesh cylinder **35** covered by strips **32** it will force its way into the interior by means of perforations **33** on the surface of strips of material **32**. As in the configuration of FIG. **3** the water will do work to re-enter the cavity so that the kinetic energy of the water will be slightly dissipated. No significant secondary pulse will be generated because the presence of material **32** slows the re-entry of the water so there is no rapid collapse of the bubble.

The embodiment of FIG. **4** provides a significant advantage over all other embodiments in that there is practically no impediment to the acoustical wave so that the strong seismic signal is obtained. Also, such a device can be cheaply constructed and would be relatively trouble free since there are few moving mechanical parts. Indeed, cylindrical boomers have been used as seismic sources for some time even though they generate secondary pulses. It is true, however, that the acoustic wave transmission feature of the embodiment of FIG. 4 can be incorporated in the embodiments discussed previously by constructing the potential energy trapping means at least partially from material whose acoustic properties are closs to those of water.

While specific embodiments have been presented in this specification to illustrate the operability of the method of my invention there are inumerable variations which fall within the scope and spirit of the invention. The principle, briefly stated, that can be implemented in many ways is to permit a gas bubble to expand as freely as possible so that the acoustic wave is transmitted away from the bubble to the ocean floor and thence to subsurface strata with minimal acoustic impedance. Two factors come into play. First, the absence of physical barriers permits the acoustic wave generated to travel at the speed of sound through the water without abnormal damping. Second, according to an approximation based upon Bernoulli's equation, the strength of an acoustical pulse which is generated by an expanding gas bubble is directly proportional to the second derivative of the volume of the expanding bubble with respect to time, i.e. is directly proportional to the rate of expansion of the bubble. Thus, if the bubble is allowed to expand as rapidly as possible, the strength of the acoustical wave which is generated will be greater. After the optimum acoustical wave is generated and the expanding gas bubble has reached its maximum radius of expansion the energy of oscillation exists primarily in the form of the potential energy of the expanded gas bubble. The water surrounding the expanded gas bubble should be prevented from rapidly collapsing into the cavity so the energy is not converted from potential energy to kinetic energy and thence into a secondary pulsation. The means of preventing a cascading effect are varied, several of which are shown in the apparatus enumerated herein. Numerous other embodiments are devisable and are intended to be included within the scope of this invention which is limited only by the scope and spirit of the appended claims.

I claim:

1. Apparatus for suppressing secondary pulsations while optimizing the acoustic wave from a primary gas bubble pulsation within a body of water, comprising, a pair of generally concave surfaces, said surfaces being matable along congruent edges to form an enclosure whose volume lies within the range from about one-half to about twice the volume of said gas bubble at its maximum expansion, at least one collapsable connecting means for connecting said concave surfaces, said collapsable connecting means separating said generally concave surfaces a fixed distance by holding said congruent edges in spaced apart opposition under conditions of normal hydrostatic pressure and when an outwardly directed pressure gradient exists across said surfaces, and collapsing to cause said generally concave surfaces to mate to form said enclosure when an inwardly directed pressure gradient exists across said concave surfaces, and a primary gas bubble pulsation source deliverable to the central zone between said concave surfaces.

2. The apparatus of claim **1** wherein said pair of generally concave surfaces is a pair of hemispherical shells having flanges on their circumferences and wherein said collapsable connecting means connects said hemispherical shells by contacting opposing locations on said spaced apart flanges.

3. The apparatus of claim **2** in which said primary gas bubble pulsation source is delivered to the central region between said hemispherical shells by means of an elongated shaft means extending from the surface of said body of water to the side of one of said hemispherical shells.

4. The apparatus of claim **3** wherein said collapsable connecting means is a rod inserted through holes on said opposing flanges, said rod having end means thereon to define a maximum separation for said hemispherical shells and having a spring wound thereon to cause said separation.

5. The apparatus of claim **1** wherein said pair of generally concave surfaces is a pair of hemispherical shells and said collapsable connecting means comprise a pair of support members, one of said support members being attached to the circumference of each shell, said support members being connected together rotatably at the other end thereof and at least one spring means interspaced between said hemispherical shells, said shells rotating together by means of said support members to form a sphere when an inwardly directed pressure gradient is experienced across said hemispherical shells.

6. Apparatus for suppressing secondary pulsations while optimizing the acoustic wave from a primary gas bubble pulsation within a body of water, comprising, a pair of generally concave surfaces, said surfaces being matable along congruent edges to form an enclosure whose volume lies within the range from about one-half to about twice the volume of said gas bubble at its maximum expansion, at least one expandable connecting means for connecting said concave surfaces, said expandable connecting means holding said concave surfaces in mated relation along said congruent edges under normal hydrostatic conditions and when an inwardly directed pressure gradient is experienced across said concave surfaces and allowing said concave surfaces to separate a fixed distance when an outwardly directed pressure gradient is experienced across said concave surfaces, and a gas bubble primary pulsation source deliverable to the region between said concave surfaces.

7. The apparatus of claim **6** wherein said pair of generally concave surfaces is a pair of hemispherical shells having flanged edges on the circumferences thereof and wherein said expandable connecting means is a rod inserted through holes on said opposing flanges, said rod having end means thereon to define a maximum separation and having a spring wound thereon to cause said mated relation under normal hydrostatic conditions.

8. The apparatus of claim **7** wherein the surfaces of said hemispherical shells are perforated to permit the gradual flow of water into the cavity of a contracting gas bubble after said hemispherical shells have come together.

9. An apparatus for suppressing secondary pulsations while optimizing the acoustic wave from a primary gas bubble pulsation within a body of water, comprising, a skeletal structure defining a cavity whose volume lies within the range from about one-half to about twice the volume of the gas bubble at its maximum expansion, the surface of said skeletal structure being substantially open, said surface being at least partially covered with a segmented material whose acoustical properties are close to the acoustical properties of water, said segments of said material being attached to said surface of said skeletal structure so that a significant portion of each segment will flex outwardly from said surface to allow water to pass through said surface when an outwardly directed pressure gradient is experienced across said surface and attached so that said segments will conform to said surface under normal hydrostatic conditions or when an inwardly directed pressure gradient is experienced across said surface, and a gas bubble primary pulsation source deliverable to the interior of said cavity.

10. The apparatus of claim **9** wherein said skeletal structure is a wire mesh cylinder having the ends thereof covered with rigid members.

11. The apparatus of claim **10** wherein said strips of said material contain perforations on the surface thereof to permit water to flow into the cylinder to fill the cavity formed by said primary pulsation.

12. The apparatus of claim **11** wherein said material is rubber.

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