Apparatus for generating a substantially oscillation-free seismic signal for use in underwater petroleum exploration, including a bag with walls that are flexible but substantially inelastic, and a pressured gas supply for rapidly expanding the bag to its fully expanded condition. The inelasticity of the bag permits the application of high pressure gas to rapidly expand it to full size, without requiring a venting mechanism to decrease the pressure as the bag approaches a predetermined size to avoid breaking of the bag.

5 Claims, 6 Drawing Figures
BACKGROUND OF THE INVENTION

This invention relates to seismic signal sources. The exploration for underwater petroleum deposits can involve seismic mapping that is conducted by generating an underwater shock wave or other seismic signal, and recording the reflections of the acoustic wave. A clean high amplitude pulse which is free of oscillations that can mimic reflections of sound waves, is highly desirable in many situations. One way to produce an underwater pulse is to rapidly expand a rubber enclosure by pumping high pressure air therein. However, rapid expansion requires a much larger pressure within the enclosure than in the surrounding water, and such pressure difference can cause bursting of the rubber enclosure and therefore prevent its reuse. Such bursting can be avoided by venting the pressured gas as the enclosure reaches its full expansion configuration. However, such venting is hard to control, and typically results in the enclosure rapidly decreasing in size which results in the generation of bubbles that soon burst and produce secondary oscillations. A reusable underwater seismic signal apparatus which could produce a rapid expansion of the container without rapid decreases in the container size, would be of considerable value in underwater seismic mapping.

SUMMARY OF THE INVENTION

In accordance with one embodiment of the present invention, an apparatus for generating underwater seismic signals is provided which can produce relatively oscillation-free signals. The apparatus includes a flexible bag and means for rapidly supplying gas to the bag to expand it. The bag has walls that are flexible but substantially inelastic, so that the bag will not expand more than a predetermined amount and therefore will not break in spite of a considerable pressure difference between gas in the bag and water outside the bag. The bag walls can comprise an inner layer of rubber material for sealing in the gas, and an outer layer of a flexible but substantially inelastic material such as a metal or Kavlar cloth. The bag can have a substantially spherical shape when expanded to provide large strength, and the sphere can be folded into a cruciform cross-section when contracted. In order to further strengthen a bag against breakage when in its fully expanded condition, a frame can be positioned about the bag, which is substantially open and expandable to engage the bag when it is fully inflated so as to prevent further outward movement of areas of the bag.

The novel features of the invention are set forth with particularity in the appended claims. The invention will be best understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation view of an underwater seismic source, showing it in use in a body of water. FIG. 2 is a view taken on the line 2—2 of FIG. 1. FIG. 3 is a view taken on the line 3—3 of FIG. 1. FIG. 4 is a graph showing the type of seismic signal which can be generated by the apparatus of FIG. 1. FIG. 5 is a plan view of the flexible bag of FIG. 1, but showing it folded into another configuration. FIG. 6 is a perspective view of a frame which can be utilized with the apparatus of FIG. 1.
the bag can be folded to the configuration shown in FIGS. 1 and 2, wherein the bag is folded in a cruciform shape with four arms. This can be accomplished in a variety of ways, as by utilizing elastic bands 28 within the bag that pull the folded portions together when the bag does not contain high pressure gas. Another folding technique illustrated in FIG. 3, produces six folds 30. These may be at opposite ends of a first line 31, but substantially no folds at opposite ends of a perpendicular second line 33. The expansion of the bag of FIG. 5, produces large pressure pulses in directions 32, 35 away from the centerline of the folded bag, with the pulse in the direction 35 passing towards the floor of the body of water.

In a complete installation, a vacuum pump 34 can be provided to aid in evacuation of the bag as it is slowly collapsed. In a typical operation, control cables 36, 38 leading from a ship 40 will extend down to the pressure source 14 to operate it and the valve 16, and also to the vacuum pump 34. Where compressed air or the like is utilized, it is also possible to pump air from a ship down through hoses to a reservoir to repeatedly fill it. Where the pressure source 14 supplies compressed air or the like to the bag to fill it, the air supplied to the bag will be cooler than the surrounding water, and therefore after expansion of the bag, the air will slowly heat and expand to slightly increase the pressure in the bag. Of course, during this time some of the air may be vented. Where a solid propellant or other gas generating apparatus is utilized, the gas in the bag may be better than the surrounding water, and therefore the gas will cool and decrease in pressure after the bag is expanded. However, the rate of pressure decrease would be relatively slow and would not ordinarily be a problem. A pressure pulse as illustrated by the graph 42 of FIG. 4 can be produced by the expandable bag, with the pulse having a rapid rise time and a relatively slow decrease without appreciable oscillations.

FIG. 6 illustrates a cage or frame 44 that can be utilized to surround the bag 12 so as to aid in preventing expansion past a predetermined maximum size so as to prevent bursting of the bag. The cage 44 can be constructed of high strength wire of a material such as steel or a high strength plastic. The frame is primarily open, with the wire of the frame constituting a very small percentage of the total area of the sphere formed by the frame, so that water rapidly displaced by the rapidly expanding bag is not greatly retarded by the frame. It may be noted that such a frame can also be utilized with an elastic bag to prevent its expansion to more than a predetermined size.

Thus, the invention provides an apparatus for generating an underwater seismic signal which is relatively oscillation-free. The apparatus can include a relatively inelastic bag and a pressure source for rapidly expanding the bag to its full size by applying gas to the bag which is at a higher pressure than that of the surrounding water. In a typical application, a bag of maximum diameter of a few feet may be utilized which contains gas at a pressure of a few hundred psi. Where only a single use of the bag is sufficient, a pyrotechnic device such as solid rocket propellant can be provided within the collapsed bag, together with an igniter, to create gas that quickly expands the bag.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art, and consequently, it is intended that the claims be interpreted to cover such modifications and equivalents.

1. A method for generating an underwater seismic signal, comprising:
   surrounding a folded flexible bag by a substantially inelastic and open frame;
   rapidly inflating said bag and rapidly expanding it until it presses on said frame; and
   collapsing said bag at a rate much slower than the rate at which it was inflated;
   said step of expanding including moving opposite sides of said bag rapidly towards opposite sides of said frame, wherein the center point of said bag will undergo substantially no displacement as a result of said expansion.

2. A method for generating an underwater seismic signal, comprising:
   collapsing a flexible but inelastic bag to a cruciform cross-section;
   rapidly inflating said cruciformly collapsed bag with gas to its fully expanded condition; and
   venting gas from said bag only after the bag has reached its fully expanded condition, and then
   venting the gas at a rate much lower than the rate of inflation.

3. Apparatus for generating an underwater seismic signal, comprising:
   a flexible bag; and
   means for rapidly supplying gas to said bag to expand it;
   said bag having walls that are flexible so that the bag can be collapsed to a small volume, but substantially inelastic so that the bag will not expand to more than a predetermined size;
   said bag having a cruciform cross-section when collapsed, and said bag being substantially spherical when expanded to said predetermined size to effectively resist breakage when rapidly inflated.

4. Apparatus for generating an underwater seismic signal, comprising:
   a flexible bag which can be contracted to a small volume and then expanded to a predetermined size without breaking;
   a substantially open cage surrounding said bag and of said predetermined size to engage the bag when it is expanded; and
   means for rapidly supplying a pressure medium to said bag to expand it;
   said bag when collapsed having opposite sides which can expand apart from one another, and said cage extending around a majority of the surface area of the expanded bag, to permit bag expansion in opposite directions without obstruction to the outflow of water by the expanding bag.

5. A method for generating an underwater seismic signal, comprising:
   maintaining a bag in a collapsed state wherein it has at least one fold at opposite ends of a first line but substantially no folds at opposite ends of a second line perpendicular to the first, each line passing through the center of the bag;
   rapidly inflating said bag with gas while allowing the bag portions along said second line to rapidly move apart wherein the center of said bag will undergo substantially no displacement as a result of said movement.