 DEVICE FOR GENERATING ACOUSTIC WAVES IN A LIQUID MEDIUM

The following statement is a full description of this invention, including the best method of performing it known to

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This invention relates to a device for generating an acoustic wave in a liquid medium. Such a device can be used in particular for seismic prospecting.

The state of the art in the field of seismic prospecting may be illustrated, for example, by U.S. patent No. 3,545,563 which describes the emission of acoustic waves in water and discloses a device essentially comprising two plates provided with means for moving them apart from each other very abruptly, thereby generating a void space, so that water, when abruptly filling said space, produces an implosion resulting in the formation of an acoustic wave. The plates are moved apart from one another by explosions of combustible mixture in an explosion chamber, while the plates are brought together again by means of air under a very high pressure.

According to the present invention, there is provided a device for generating an acoustic wave in a liquid medium, comprising a hollow enclosure including at least one first element, at least one second element communicating with the first element or elements through at least one constricted part, an opening in the or each first element at the end of the or each first element remote from said constricted part or parts, and means operable to close the communication between the first and second elements, the device being such that in use of the device a pressurised gas can be introduced into the first element or elements to expel liquid medium therefrom and a fluid pressure level substantially lower than that in the first element or elements can be created in the second element or elements, with said communication closed,
subsequent re-opening of said communication allowing
the pressurised gas in the first element or elements
to pass into the second element or elements so that
liquid medium outside the enclosure rushes into the
or each first element, the impact of the inrushing
liquid medium against the or each constricted part
producing the acoustic wave.

Embodiments of a device according to the present
invention will now be described by way of example with
reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic view in longitudinal
cross-section of a first embodiment of the device, with
its valves in the position for suction from the second
element;

Figure 2 is a diagrammatic view in longitudinal
cross-section of the first embodiment of the device,
with its valves in the position for the discharge of
water from the two elements;

Figure 3 is a diagrammatic view in longitudinal
cross-section of a second embodiment of the device,

to each constricted part
producing the acoustic wave.

Figure 5 is a diagrammatic view in longitudinal
cross-section of a fourth embodiment of the device,
comprising two symmetrical enclosures each provided with
a membrane; 41,891/72

Figure 6 is a diagrammatic view in longitudinal cross-section of a fifth embodiment of the device, in which the element comprising a membrane is further provided internally with a perforated rigid member used as an abutment for the membrane; and

Figure 7 is a diagrammatic view in longitudinal cross-section of a sixth embodiment of the device, comprising a jack for creating in the second element a pressure substantially lower than that prevailing in the first element.

Referring to Figures 1 and 2, the generating device comprises two tubular elements 1 and 2 interconnected through a narrow passage or constricted part 3. This device may be formed of a strong material, preferably transparent to the acoustic waves. It can be made of steel. A two-positioned valve 4 is operable to establish a communication between or fluid-tightly separate elements 1 and 2. The tubular element 1 is open at the end thereof remote from the constricted part 3, whereas the tubular element 2 is closed at the end thereof remote from the constricted part 3.

The element 2 is connected to a circuit for introducing a pressurised gas into said element 2 and for discharging the same and creating a vacuum therein. This circuit comprises a compressor 5 connected through two valves, 6 and 7 respectively, to two pipes 8 and 9 each opening into the tubular element 2.
The valve 6 has a position of discharge to the atmosphere (Figure 1) and a position of discharge into the element 2 (Figure 2).

The valve 7 has a position of suction from the atmosphere (Figure 2) and a position of suction from element 2 (Figure 1).

The device is immersed and connected, through a cable 10, to a surface installation 11 on which the compressor 5 and valves 6 and 7 are disposed.

The valve 4 illustrated in Figure 1, is a spherical valve whose body comprises a channel 4a interconnecting the tubular elements 1 and 2 when its longitudinal axis is in the direction of the longitudinal axis of the constricted part 3. Gaskets 12 ensure sealing between the channel 4a and the elements 1 and 2 when the valve 4 is in the closed position of Figure 1.

This device is operated as follows:

The valve 4 being open, the valve 6 in the position of discharge towards the element 2 and the valve 7 in the position of suction from the atmosphere (Figure 2), the compressor 5 introduces air through the valve 6 and the pipe 8 into the tubular element 2 until the air also occupies the interior of the element 1, by expelling the water through the opening thereof. The valve 4 is then closed.

After the valve 6 has been moved to a position of opening to free air and the valve 7 has been moved to a position of suction from element 2 (Figure 1), through the valve 7 and the pipe 9 the compressor 5 sucks the air contained in the tubular element 2 therefrom and...
substantially creates vacuum therein.

At this moment, the valve 4 is opened. The air contained under pressure in the tubular element 1 expands into the element 2, and water outside the device rushes into the element 1. The movement of this mass of water is abruptly braked by the constricted part 3, which results in a shock which creates an acoustic wave which can be used for seismic prospecting.

The valve 4 and the circuit for compressed air supply and discharge, are controlled from the surface installation 11, although the control circuit is not shown.

The operation can be thus repeated at will, while the surface installation moves along a selected path of movement and carries out "shots" at a high rate, for example, every ten seconds.

Figure 3 illustrates the same device as Figure 1 but further provided with an adjustable clack valve 13. This clack valve is provided with a return spring 14 which is so calibrated that the clack valve 13 is not displaced by air rushing into the element 2 but will be displaced by water reaching the constricted part 3. Calibration of this spring 14 is easy since the flow of water exerts on the clack valve 13 a force considerably higher than that exerted by the air. The clack valve 13 thus closes the constricted part 3 when it is pushed by water.

The acoustic energy obtained by this device is far higher than that obtained by the device without clack valve.

Other suitable kinds of valve may be used for closing
It is also possible for the pipe 8 for the introduction of compressed air, or a branch on said pipe, to open directly into the element 1.

In the embodiment of the device of which a part is diagrammatically shown in Figure 4, the open part of the element 1 may be provided with a flexible membrane 15. The constricted part 3 between elements 1 and 2 may be formed, for example, by a wall 17 provided with an orifice 18 which can be intermittently closed by a clack valve 16 which is mechanically or electromagnetically controlled, or by a throttle valve. When a state of depression is created in the element 1, with the clack valve 16 in its position of allowing communication between the elements 1 and 2, the water rushes into the cavity of the element 1 and the membrane 15 is pressed against the wall 17 separating the elements 1 and 2. In order to prevent the membrane 15 being sucked through the orifice 18 left open by the clack valve 16, the membrane 15 is provided with a rigid member 19 at a place corresponding to that of the orifice 18.

The mass of water is abruptly stopped, thus resulting in the creation of an acoustic wave, according to the same principle as above indicated. By using this embodiment penetration of water into the element 2 is avoided.

In order to increase the energy of the emission source, two devices as described above with reference to Figure 4 can be coupled together, in the manner shown in Figure 5. This device has two elements 1 placed on
respective sides of a common element 2.

In the embodiment of the device illustrated in Figure 6, the element 1, provided with a membrane 15, is also provided in its interior with a wall 20 which is perforated with holes of small diameter. During the period of depression in the element 1, the membrane 15 is pressed against this wall 20 without substantial deformation into the orifices, due to their great number and small size. In such a case, the rigid member 19 is no longer necessary.

In the embodiment illustrated in Figure 7, the device comprises a cylinder 21 fixed to the tubular element 2 and extending the same in a direction away from the constricted part 3. Two pistons 22 and 23 slide respectively in the element 2 and in the cylinder 21 and are rigidly secured to each other through a rod 24 passing across a terminal wall 31 common to the element 2 and the cylinder 21. The two pistons 22 and 23 are each provided at their periphery with sealing joints 29 and 30. Sealing between the element 2 and the cylinder 21 is ensured by means of a joint 32. Two pipes 25 and 26 open on respective sides of the piston 30 and are connected to a circuit (not shown) for supplying pressurized fluid, oil for example. The device comprises a valve 4 identical to that of the embodiment of figure 1. It further comprises a pipe 28, fed with compressed gas (air for example) which opens in a portion of the element 1 which is the closest to the constricted part 3. The element 2 communicates with the external medium in the vicinity of the wall 31 through orifices 27 provided in the wall of the element 2.
This device is operated as follows:

The valve 4 being open, fluid under pressure is introduced through the pipe 26 and pushes the piston 3 towards the wall 31. The piston 22 which is fixed to the piston 23 expels into the element 1 the major part of the water contained in the element 2. The valve 4 is then closed and gas is injected through the pipe 28 in order to discharge from the element 1 the major part of the water contained therein. Pressurized fluid is thereafter injected through pipe 25. The back motion of the piston 23 drives the piston 22 up to the wall 31. A very high depression is generated in the part of the element 2 located between the constricted part 3 and the piston 22, due to the motion of the latter. The abrupt introduction of water produced by the opening of valve 4, and its braking by the constricted part 3, generates an acoustic wave in the manner hereabove described.

It is also possible to have the pipe 28 opening into the element 2 in the vicinity of the constricted part 3. In this case, when the piston 22 is, at the end of its stroke, in the vicinity of the constricted part 3, the valve 4 being open, fluid is injected through pipe 28. The water is expelled from the residual volume of the element 2, delimited by the piston 22 and the constricted part 3, and also from the element 1.

Other embodiments may of course be contemplated without departing from the scope of the invention as defined by the appended claims. The system formed by the cylinder 21 and the two integral pistons 22 and 23, may for example be adapted to any other of the described embodiments.
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A device for generating an acoustic wave in a liquid medium, comprising a hollow enclosure including at least one first element, at least one second element communicating with the first element or elements through at least one constricted part, an opening in the or each first element at the end of the or each first element remote from said constricted part or parts, and means operable to close the communication between the first and second elements, the device being such that in use of the device a pressurised gas can be introduced into the first element or elements to expel liquid medium therefrom and a fluid pressure level substantially lower than that in the first element or elements can be created in the second element or elements, with said communication closed, subsequent reopening of said communication allowing the pressurised gas in the first element or elements to pass into the second element or elements so that liquid medium outside the enclosure rushes into the or each first element, the impact of the inrushing liquid medium against the or each constricted part producing the acoustic wave.

2. A device according to claim 1, wherein the first and second elements are tubular.

3. A device according to claim 1 or claim 2 wherein the means operable to close the communication between the first and second elements comprises a two-position valve.
4. A device according to claim 1, claim 2 or claim 3 wherein the means operable to close the communication between the first and second elements includes a clack valve having a spring means so calibrated as to allow said pressurised gas to pass through the clack valve but to prevent said inrushing liquid medium from passing through the clack valve.

5. A device according to claim 1, claim 2 or claim 3 wherein said opening in the or each first element is provided with a flexible membrane for preventing liquid medium passing from the first element or elements to the second element or elements.

6. A device according to claim 5 wherein the membrane is provided with a rigid member which, when the membrane is in a position of abutment against the constricted part, closes the communication between the first and second elements.

7. A device according to claim 5 wherein the or each first element is provided in its interior with an apertured wall forming an abutment for the membrane.

8. A device according to any one of the preceding claims including a piston and means for slidably moving said piston within the or each second element, for establishing in the second element or elements a fluid pressure considerably lower than that prevailing in the first element or elements.

9. A device according to claim 8 wherein said means for slidably moving the piston comprises a cylinder body portion fixed to the or each second element and a piston which is slidable in said body portion and which is fixed to the first-mentioned piston.
10. A device for generating acoustic waves in a liquid medium, substantially as hereinbefore described with reference to Figures 1 and 2 or Figure 3 or Figure 4 or Figure 5 or Figure 6 of the accompanying drawings.

11. A device for generating acoustic waves in a liquid medium, substantially as hereinbefore described with reference to Figure 7 of the accompanying drawings.
FIG. 1

41.891 m²
FIG. 2