

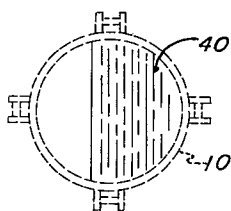
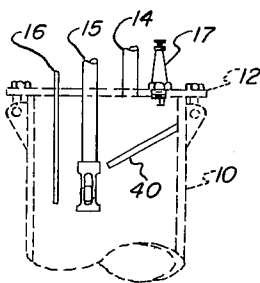
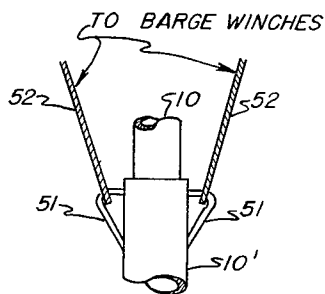
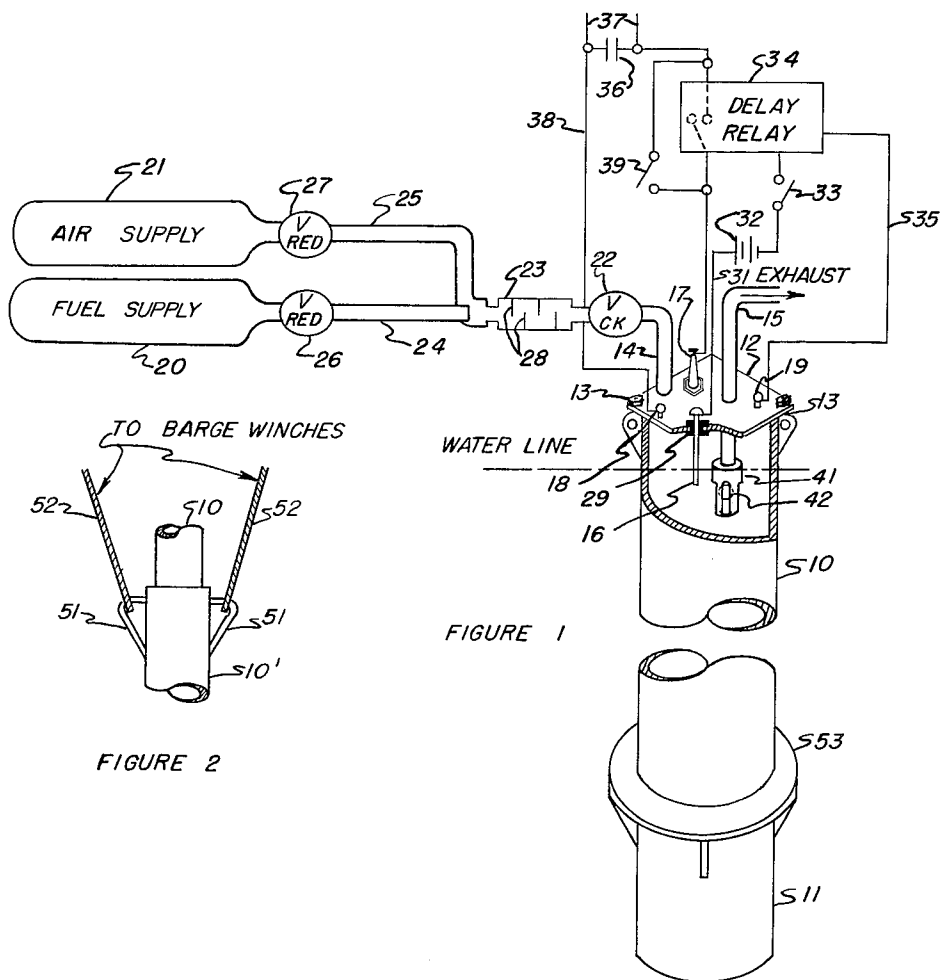
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H. A. LUBNOW

3,048,816

LOW FREQUENCY UNDERWATER SOUND GENERATION

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HAROLD A. LUBNOW
INVENTOR

BY *George Sipkin*
Edith H. Carter
ATTORNEYS

1

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LOW FREQUENCY UNDERWATER SOUND GENERATION

Harold A. Lubnow, 1918 Dewitt, Panama City, Fla.
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5 Claims. (Cl. 340-12)

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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 prime sources of compressional wave energy and more particularly to a novel system for the underwater generation of high intensity, low frequency sound by the combustion of explosive mixtures in an explosion chamber open to the water at its bottom.

The sweeping of some acoustic mines requires high intensity sounds of subaudible frequencies down to as low as one cycle per second. Mechanical low frequency noise makers have had considerable use in minesweeping and are efficient within their limitations; however, present designs become excessively large and expensive if they are made capable of producing the intensities and frequencies required for the satisfactory sweeping of low frequency acoustic mines.

An object of the present invention is to produce underwater sound energy by causing successive explosions of a combustible vapor or powdered fuel to resonate a column of water.

Another object of the invention is to convert the energy of burning fuel into a cyclical movement of water without the use of rotating parts and with relatively little displacement of mechanical masses.

Still another object of the invention is the provision of an explosive type underwater sound generator in which the timing of the explosion is controlled by a resonating column of water so that operation at the resonant frequency is automatic.

In accordance with the invention a vessel or chamber in which explosions of a suitable fuel take place in rapid sequence is so proportioned that oscillations of the water column defined by the pipe may be sustained with the addition of a comparatively small additional amount of explosive energy during each operating cycle. This is, of course, another way of saying that advantage is taken of the well known effects of resonance.

It is another feature of the invention that the free surface within the pipe of the oscillating column of water serves the dual functions of timing the explosions and controlling the exhaust of spent gases.

The invention in its various aspects will be more fully understood from the following detailed description of the preferred embodiment thereof which read in connection with the accompanying drawing, in which

FIG. 1 is a perspective showing partly in section of a device utilizing a resonating column of water for converting sequential explosive energy into low frequency underwater sound;

FIG. 2 is a fragmentary showing of a construction which permits the length of the column of water while the device is operating; and

FIGS. 3 and 4 are phantom views in elevation and plan, respectively, showing a baffle arrangement for the combustion zone.

Referring now to the drawing, an embodiment of the invention is shown in FIG. 1 as comprising a section of pipe 10 open at its bottom end 11 and provided at its top end with a cover plate 12 removably secured thereto in any suitable manner as by toggle bolts 13. This cover plate 12 constitutes a support for an intake tube 14, an exhaust pipe 15, a conductor probe 16, a spark plug

2

17, and ground return terminals 18 and 19. The intake tube 14 is in communication with a fuel supply tank 20 and an air supply tank 21 through a spring loaded check valve 22, a labyrinthic passageway 23 and supply lines 24 and 25 leading to the respective fuel and air supply tanks 20 and 21. The supply tanks 20 and 21 are provided with suitable regulating valves 26 and 27, respectively, so that the desired combustible mixture may be supplied to the passageway 23 which is provided with baffle plates 28 to function as a mixing chamber. The use of the check valve 22 is not essential, but it does make less compliance for the pipe volume to expand into.

The conductor probe 16 carried by the cover plate 12 is insulated therefrom in any suitable manner as by a bushing 29 and is connected through a lead 31, a battery 32, a switch 33, the coil of a variable time delay relay 34, and through another lead 35 to the ground terminal 19, the arrangement being such that when a conducting fluid rises in the pipe 10 sufficiently to contact the conductor probe 16, a circuit is completed to energize the relay 34 to complete, after a selected time delay, the spark plug circuit now to be described.

A condenser 36 connected in charging relation across leads 37 from any suitable source of power (not shown) is connected in series through a lead 38 to the ground return terminal 18, the contacts of relay 34, and the spark plug 17, so that each time the relay 34 is actuated the spark plug is fired by the discharge of the condenser 36. The hand operated switch 33 included in a circuit disabling position is convenient for starting and stopping operation of the apparatus.

The exhaust pipe 15 extends through its supporting plate 12 downwardly into the pipe 10 and has its terminal portion provided with a buoyant check valve 41 of known construction such as a ball 42 suitably caged in alignment with its seat for closing the exhaust pipe 15 whenever water or other liquid rises high enough in the pipe section 10 to float the ball 42 against its seat, and opening under the force of gravity when the pressure inside approaches the ambient pressure as sensed through the exhaust pipe 15.

The timing of the ignition of the combustible mixture in the upper closed portion of the pipe 10 is controlled by the probe 16 and the delay time introduced by the relay 34. The probe 16 should depend from the closure plate 12 far enough so as to make certain it will be contacted by the water surface in the pipe 10 at the lowest height it is expected to operate the device, as for example, during amplitude modulation as hereinafter described. As shown in FIG. 1, the probe 16 depends to approximately the level of the check valve 41, which is the lowest high-water mark which will close this valve 41 to confine the force of the explosion to acting on the water in the pipe 10. If it is intended to operate the device only at maximum or any other constant amplitude, the probe 16 of proper length can be connected to the condenser lead 38 and the relay 34 shunted by closing a switch 39, the arrangement then being that the spark plug 17 is fired as soon as the water rises to contact with the probe 16, the lead 38 having been disconnected from the ground terminal 18.

To help protect the points of the spark plug 17 from splashing water an inclined baffle plate 40 may be secured in the combustion zone of the pipe 10 as shown in FIGS. 3 and 5. This baffle plate 40, due to its location as viewed in FIG. 3, also tends to assure that the burned gases will be scavenged from the vicinity of the spark plug 17.

The dimensional parameters involved will be more readily understood after reading the ensuing description of the operation of the device.

In order to make use of the device of FIG. 1 for its intended purpose it will be suitably mounted or supported by a vessel such as a barge (not shown) and lowered into the water until it is immersed to approximately the extent indicated in FIG. 1 by the broken line labeled water line. At this time the water inside the pipe 10 will have floated the buoyant ball 42 against its seat in the check valve 41 to prevent any further escape of gas from the pipe 10 to the atmosphere through the exhaust pipe 15. The water within the pipe 10 will continue to rise against the force of the entrapped gas being compressed until equilibrium is reached. The regulating valve 26 is opened to allow fuel from the supply tank 20 to flow into the pipe 10 to form with the air entrapped therein a combustible mixture for supporting the first explosion.

The regulating valve 27 is then opened to furnish the air necessary to form with the fuel a combustible mixture after the first explosion has been initiated. The device can now be placed in operation by closing the switch 33 which completes the coil circuit of the relay 34. Since the probe 16 is already in contact with the water in the pipe 10, when the relay 34 closes it contacts the condenser 36 discharges through the gap of the spark plug 17 to ignite the combustible mixture in the pipe 10. The resulting explosion, or more accurately, rapid burning of the combustible mixture produces hot gases which expand to displace downwardly the water in the pipe 10 until its force is expended, after which the momentum of the water column continues to move downwardly until its momentum energy is absorbed, at which time the reduced gas pressure within the pipe 10 allows the column of water to rise in the pipe 10, the exhaust valve 41 having opened when the gas pressure within the pipe 10 approached the ambient pressure present in the exhaust pipe 15. As the water continues to rise in the pipe 10, the burnt gases are forced out the exhaust pipe 15, and inasmuch as the fuel and air supply lines supply under pressure a combustible mixture in the intake tube 14, the spent gases in the extreme upper portion of the pipe 10, i.e., above the opening to the float valve 41 are scavenged by being replaced with the combustible mixture which is compressed after the rising water column closes the exhaust valve 41, thus placing the device in condition for another explosion which takes place a selected delay time after the rising column of water contacts the probe 16. By properly timing the succeeding explosions in the manner outlined above the water inside the pipe 10 can be made to resonate at its natural frequency, the period of which is primarily determined by the length of the pipe for any particular explosive force.

An operative embodiment of the device shown in FIG. 1 employing a sixteen foot segment of eight inch pipe 10 was found to have a resonant frequency of one cycle per second, an estimated displacement of three and one-half cubic feet, and an overall sound pressure level of about one hundred thirty-five decibels, which agrees with theory. Other dimensional parameters can be arrived at with a fair degree of accuracy for producing a desired output. For example, if it is desired to produce a sound pressure level of approximately one hundred sixty decibels at a frequency of two cycles per second, the physical size of the device could be approximately ten feet long and one and one-half feet in diameter. If losses due to friction, etc., are disregarded, these dimensions can be arrived at by considering that a particle of water six feet from the sound source would experience a force of 20,400 dynes per square centimeter if fifteen cubic feet of water are displaced at a rate of two cycles per second.

Maximum amplitude as well as maximum efficiency of operation is obtained by so adjusting the ignition system that the explosion is timed to take place just prior to the time the water column reaches its greatest height. Amplitude modulation of the sound output is at times desirable and it is possible to obtain a small amount of

amplitude modulation by varying the ignition timing either direction from the optimum, but preferably by delaying the ignition beyond that needed for maximum efficiency. This results in a smaller effective driving force which could also be obtained by varying the quantity of the combustible mixture ignited at each explosion.

In addition to amplitude modulation of the sound output it is also possible to construct the device to make possible some frequency modulation; one such arrangement being indicated in FIG. 2, where the segment of pipe 10 is comprised of two sections 10 and 10' assembled in telescoping relation with the lower segment 10' having the larger diameter as a matter of convenience. This segment 10' may be provided with suitable ears 51 to which supporting cables 52 may be secured. These cables 52 through the means of suitable winches provided on the supporting barge can raise or lower at the will of the operator the segment 10' to alter the effective length of the pipe confining the water column and thereby alter its natural frequency.

When the device of the invention is in operation there is a net lifting force, but most of this will be overcome by the relatively massive barge or other vessel on which the device is firmly mounted; however, by providing the pipe 10 with one or more baffles 53 this force, as well as oscillatory vibrations, will be considerably damped.

It is to be understood that the device is indifferent to the fuel employed as long as it provides a combustible mixture which will burn fast enough to be compatible with the frequency. Propane is a readily available and relatively inexpensive fuel which when mixed with air provides a combustible mixture which is highly satisfactory.

In the preferred embodiment of the invention described herein the intake and exhaust pipes, the spark plug, the timing electrode, and the ground return terminals are all mounted in the closure plate as a matter of convenience in manufacture and assembly. This construction offers the advantage of localizing damage in the event of a nearby explosion under water.

The output in water of the device of the invention is variously referred to herein as acoustic, sound, and infra-sonic compressional waves. It will be appreciated that "sound" in the range of one to ten cycles per second (the range for which the present device is best adapted) is infra-sonic, i.e., subaudible, and is in the twilight zone between what is generally referred to as sound and what is commonly referred to as pressure pulses whose frequency is ordinarily related in terms of duration, viz., a pulse duration of ten seconds, rather than one-tenth cycle per second.

After reading the present description many modifications will be evident to those skilled in the art and all such modifications are intended to be included within the scope of the appended claims.

What is claimed is:

1. Apparatus for generating underwater low frequency compressional waves which utilizes successive explosions of a combustible fuel to resonate a column of water, comprising when in use an elongated tubular housing open at its bottom and defining and containing a column of water within a body of water, a plate covering the top end of the tubular housing to form a combustion zone, a pressure operated intake valve communicating with the combustion zone for admitting fuel thereto, an exhaust pipe extending into the combustion zone and having its distal end provided with a water-buoyant check valve for determining the height the water column rises in the tubular housing, an electric circuit, probe means positioned to be contacted by the rising column of water for completing the electric circuit, and means controlled by the electric circuit for intermittently igniting fuel in the combustion zone in timed relation with the rise of the water in the tubular housing, whereby the column of water oscillates at its natural period.

5

2. Apparatus in accordance with claim 1 wherein the elongated tubular housing consists of at least two telescoped sections which can be moved axially relatively to each other, whereby the effective length of said housing may be varied to change the natural period of the column of water it defines.

3. Apparatus in accordance with claim 1 wherein the electric circuit includes a variable time delay relay adjustment of which alters the timing of the fuel ignition with respect to the instant the oscillating column of water reaches its greatest height.

4. A device for the underwater generation of low frequency infra-sonic compressional waves comprising in combination an elongated tubular housing closed at one end to form a combustion zone and open at the other end to permit easy ingress and egress of water, a pipe extending through the closed end of said housing and into the combustion zone for exhausting to the atmosphere gas displaced by water rising in said housing, a water-buoyant check valve means mounted on the end of the exhaust pipe and so arranged that water rising in said housing will float said means to closed position and thereafter compress the gas in the combustion zone, means for supplying a combustible mixture to the combustion zone, and means responsive to the rise of the water to a predeter-

6

mined height in said housing for igniting the combustible mixture.

5. An explosion powered generator of infra-sonic compressional waves in a liquid comprising when in use a tubular explosion chamber closed at one end and open at its other end and adapted to be supported in a vertical position with its open end downwardly directed in a body of water, means for periodically burning increments of fuel above the water in the explosion chamber, whereby water is forced out said open end, means for exhausting the spent gases including a valve which opens when the pressure in the explosion chamber approaches atmospheric pressure and closes when the water returns to a predetermined height within the explosion chamber, and means responsive to the rise of water in the explosion chamber for controlling the periodicity of said burning of fuel increments.

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