United States Patent

[11] 3,633,877

[72] Inventor **Albert G. Bodine**
7877 Woodley Ave., Van Nuys, Calif. 91406

[21] Appl. No. **856,958**
[22] Filed **Sept. 11, 1969**
[45] Patented **Jan. 11, 1972**

[54] **INDUCTIVE CAVITATOR**
2 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **259/72,** 259/DIG. 42, 259/DIG. 44
[51] **Int. Cl.** **B01f 11/00**
[50] **Field of Search** ..... 259/72, 12, 29, 54, DIG. 15, DIG. 42, DIG. 44, DIG. 41, DIG. 43; 68/3 SS; 134/1

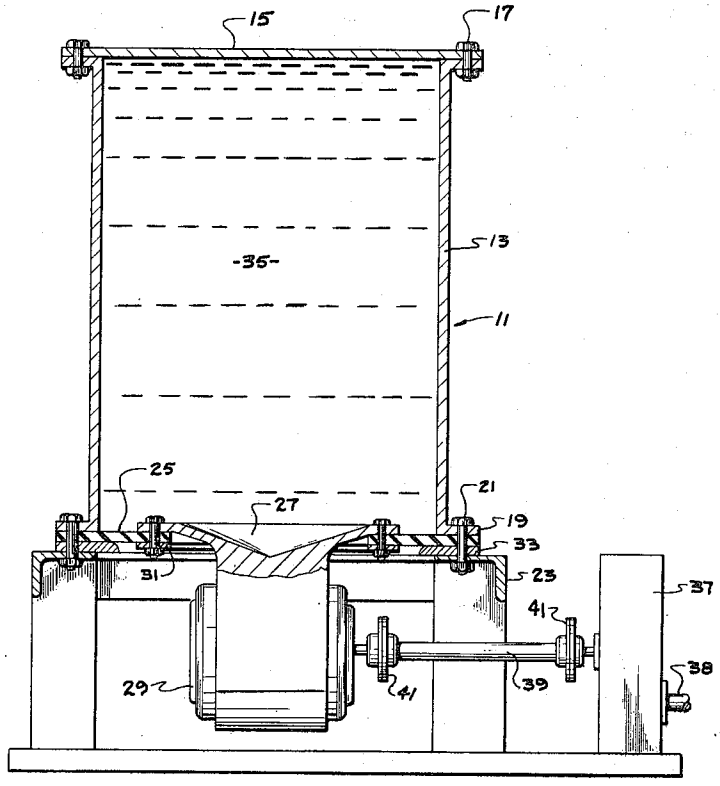
[56] **References Cited**

UNITED STATES PATENTS

2,498,990	2/1950	Fryklund	259/72
2,616,820	11/1952	Bourgeaux	68/3 SS
2,815,193	12/1957	Brown	259/72
2,824,437	2/1958	Reisch	68/3 SS UX
3,198,489	8/1965	Finch	259/DIG. 15
3,320,992	5/1967	Bodine	259/DIG. 15
3,417,966	12/1968	Bodine	259/72 X

Primary Examiner—Edward L. Roberts
Assistant Examiner—Alan I. Cantor
Attorney—Sokolski & Wohlgemuth

ABSTRACT: A tank for containing a liquid whose bottom portion is partially comprised of a housing for an inductive oscillator having a pair of rotors. The rotors move in opposite directions so as to provide an in-phase reaction normal to the base of the tank to establish cavitation in liquid disposed in the tank.



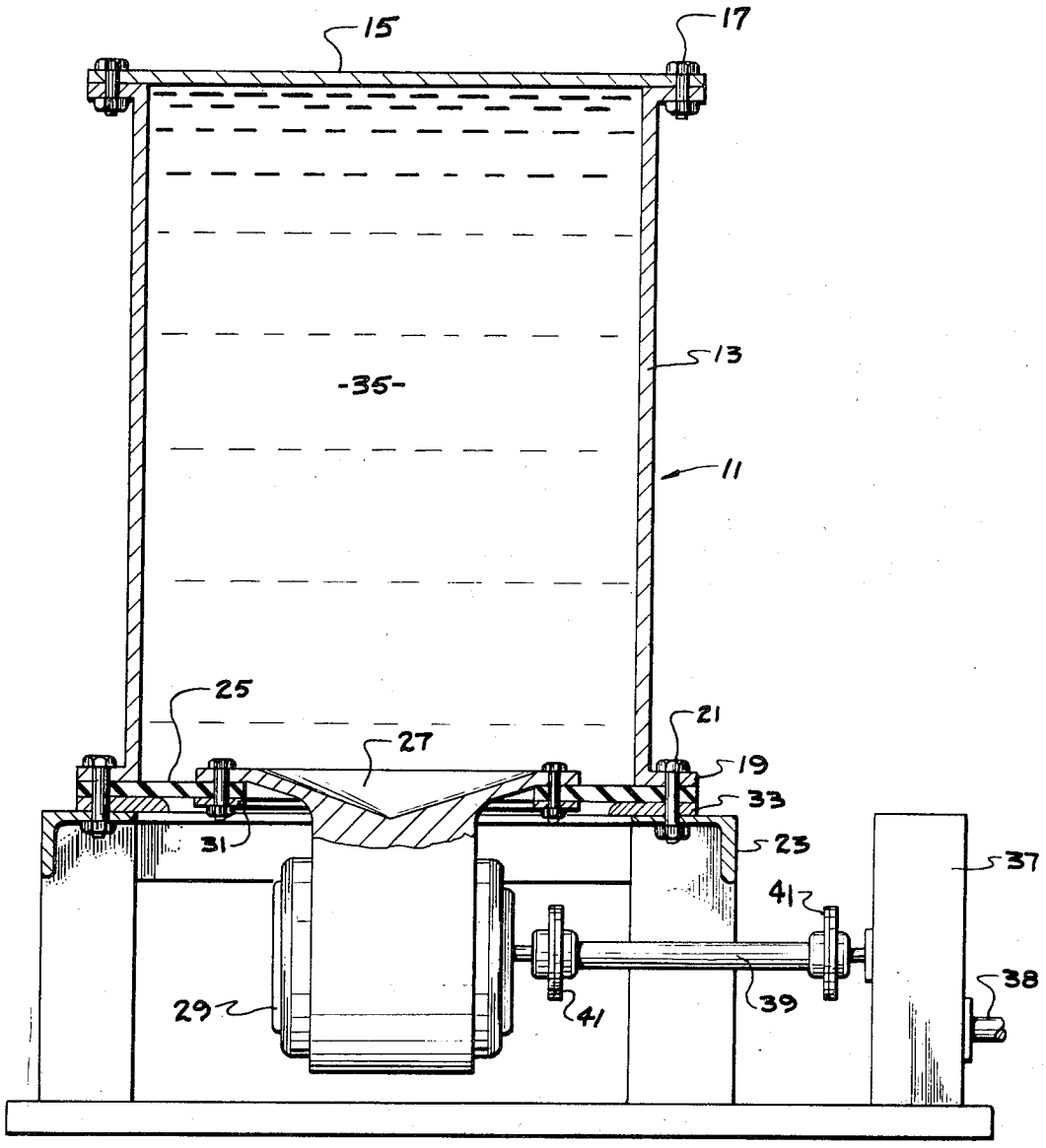


FIG. 1

INVENTOR.
ALBERT G. BODINE
BY
SOKOLSKI & WOHLGEMUTH
ATTORNEYS

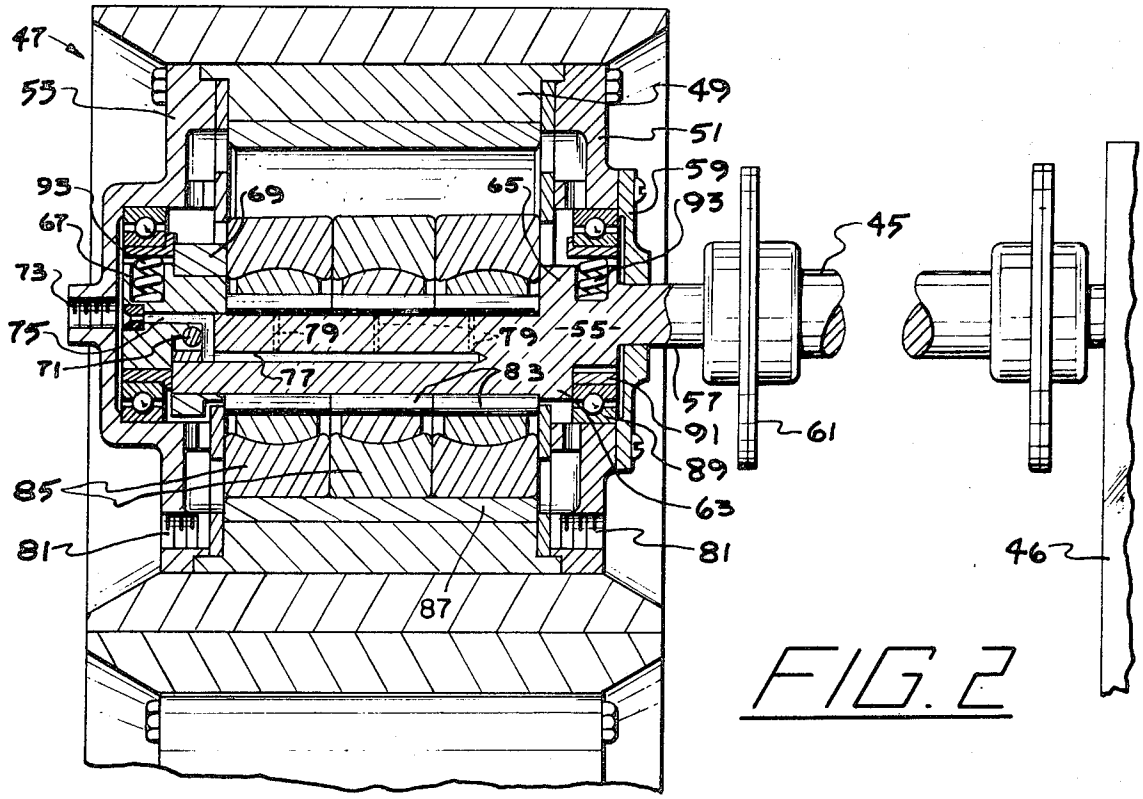


FIG. 2

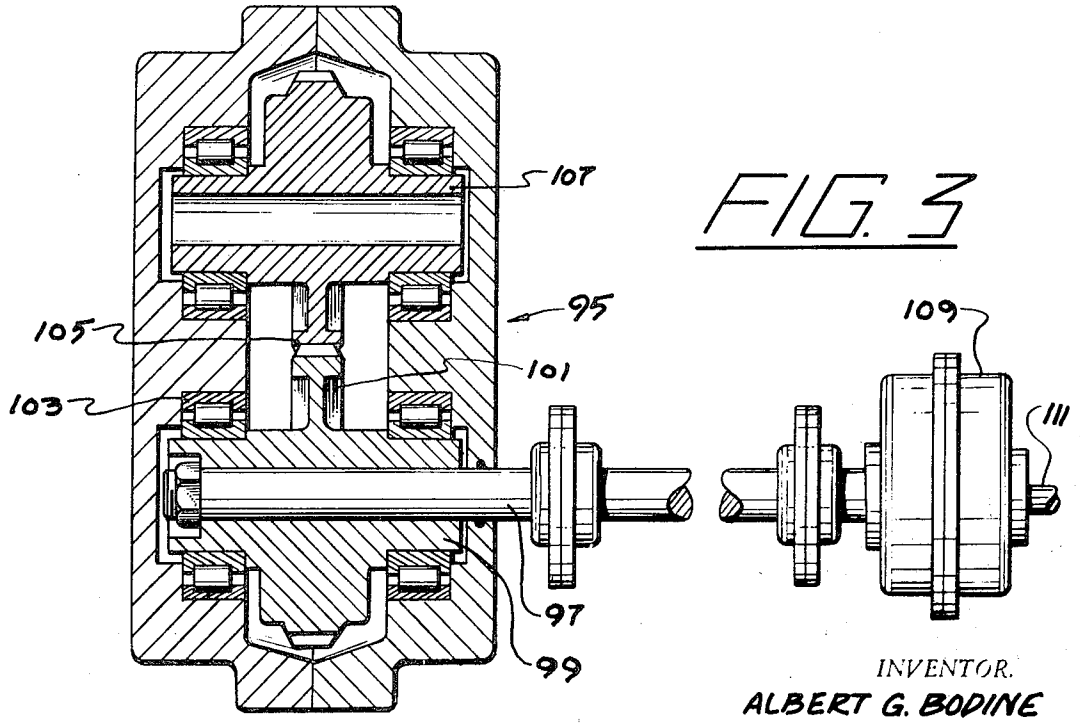


FIG. 3

INVENTOR.
ALBERT G. BODINE

BY

SOKOLSKI & WOHLGEMUTH
ATTORNEYS

INDUCTIVE CAVITATOR

There has been disclosed in prior applications to the same inventor various inductive oscillators working in a liquid media to clean parts or the like in the liquid. In the prior disclosures, an elastic member such as a rubber tubular element is disposed between an oscillator and a radiating piston which delivers the energy to the liquid. By the use of such an elastic member, particularly when the system is operating at elastic resonance, it is possible to accomplish a maximization of delivery of power to the liquid. However, these prior systems utilizing such elastic members have some disadvantages.

One disadvantage of the prior systems is that the elastic member allows the piston surface to rock or tilt periodically in its vibratory movement. The piston not only moves back and forth as it applies compressional waves to the liquid, but also develops a rocking or tipping movement which is superimposed over the main vibratory movement. This rocking or tipping vibration of the piston results in portions of it moving in what is, in effect, an amplified motion. In other words, the main vibratory motion of the piston has added to it the tipping motion at various localized regions where the tipping movement is in phase with the main vibratory movement. Alternatively, at the opposite edge of the piston the tipping is necessarily subtractive and this, in effect, reduces the amount of movement of the piston at the opposite edge.

The aforegoing secondary superimposed tipping or rocking of the piston is due to the elastic freedom provided by an elastic member as shown in the various prior disclosures. As a result, the main motion of the piston resulting from the elastic member thus has superimposed upon it the tipping motion which results from the secondary elastic vibrations in the elastic member.

A further disadvantage of the aforementioned tipping effect is that one portion of the piston face moves with augmented motion relative to the basic vibration while the opposite region of the piston face, that is the region across the centerline, moves with reduced motion. This is because the tipping motion subtracts from the main vibration of each cycle. The result is that the effects in the liquid opposite the piston are no longer uniform.

It should be pointed out that in systems where cavitation is employed in the liquid that the cavitation is a borderline condition. Therefore, if there is a region where the pressure excursions are slightly greater than they are in an adjacent region, the region having greater excursions will be where the predominate action of cavitation takes place. This is a disadvantage in certain processes such as cleaning of metallic parts where certain regions in the parts-holding basket are subjected to greater action than other regions in the basket. This produces a nonuniform cleaning of a batch of parts.

Thus, an object of this invention is to provide a uniform energy density of sonic application throughout a liquid body.

Another object of this invention is to provide an inductive cavitation system which does not have any secondary rocking or tipping of a piston to cause nonuniform energy density.

Still another object of the invention is to provide a inductive cavitator system wherein secondary effects in the liquid body can be neutralized.

Still one further object of this invention is to provide an inductive cavitator system which permits precise control of the energy output to the liquid.

The above and other objects of this invention are accomplished by the herein device which comprises a suitable tank for containing liquid to clean parts and the like. The bottom of the tank has an opening therein. Disposed in the opening and filling and sealing it is an oscillator housing for a pair of rotors. Preferably the housing is acoustically isolated by rubber mounts or the like from the remaining bottom portion of the tank. The rotors are comprised of eccentric weights which move in an orbit so as to produce an oscillatory movement of the housing, thus exerting vibratory energy directly into the liquid in the tank. The two rotors move in opposite directions so as to cancel lateral vibratory effects while reinforcing the vibratory energy normal to the bottom of the tank, thus maximizing energy input. In one embodiment of the invention a pair of gears are meshed so as to turn in opposite directions. These gears are driven by a single shaft connected to one of the gears. Each gear has connected thereto an eccentric weight forming a portion of the mass of the gear. In another embodiment of the invention the oscillators are of a roller type where two separate crankshafts are individually driven through a gearbox. Weights in the form of large rollers surround the eccentric crankshaft of each rotor such that when the shaft rotates the rollers in effect achieve an orbital motion. Once again, the pair of oscillators in this embodiment rotate in opposite directions to achieve the aforegoing desired results.

It is believed that the invention will be better understood from the following detailed description and drawings in which,

FIG. 1 is a partially section pictorial view of the apparatus of this invention,

FIG. 2 is a partially section view of one embodiment of a roller-type oscillator, oscillators.

FIG. 3 is a partially section view of a second embodiment of a pair of geared oscillators.

It is helpful to the comprehension of this invention to make an analogy between a mechanical resonant circuit and an electrical resonant circuit. This type of analogy is well known to those skilled in the art and is described, for example, in Chapter 2 of "Sonics" by Hueter and Bolt, published in 1955 by John Wiley and Sons. In making such an analogy, force F is equated with electrical voltage E, velocity of vibration u is equated with electrical current i, mass M is equated with electrical inductance L, mechanical resistance (friction) R_m is equated with electrical resistance R, and mechanical impedance Z_m is equated with electrical impedance Z_e. Thus, it can be shown that if a member is elastically vibrated by a sinusoidal force, $F_o \sin \omega t$, ω being equal to 2π times the frequency of vibration, that

$$Z_m = R_m + j(\omega m) = (F_o \sin \omega t / u) \qquad (1)$$

It is to be noted by reference to equation (1) that velocity of vibration u is highest where impedance Z_m is lowest, and vice versa. Therefore, a high-impedance load will tend to vibrate at relatively low velocity, and vice versa. the square at an interface between high- and low-impedance elements, a high relative movement results by virtue of such impedance mismatch which, as in the equivalent electrical circuit, results in a high reflected wave.

Of particular significance in the implementation of the methods and devices of this invention is the high acceleration of the components of the system that can be achieved at sonic frequencies. It can be shown that the acceleration of a vibrating mass is a function of *the square* of the frequency of the drive signal times the amplitude of vibration. Under resonant conditions, the amplitude of vibration is at maximum and thus even at moderately high sonic frequencies very high accelerations are achieved.

In considering equation (1), two factors are to be noted. First, this equation represents the total effective resistance and mass in a vibrating circuit, and these parameters are generally distributed throughout the system rather than being lumped in any one component or portion thereof. Secondly, the vibrating system often includes surrounding components, a container holding the water and the water itself.

Turning now to FIG. 1 there is seen a tank **11** having a cylindrical wall **13** of metal or suitable material and a top **15** that can be rigidly affixed by bolts **17**. The bottom of the tank is open and has an outward radial flange **19**. Bolts **21** connect the flange to a support structure **23** for the tank. Connected between the flange **19** and support **23** and also secured by the bolts is a rubber diaphragm **25**. The diaphragm **25** serves to support an oscillator housing **27** for an oscillator **29**. The housing **27** is further secured to the rubber diaphragm **25** by a retainer ring **31**. The mounting ring **33** isolates the rubber diaphragm **25** from the support structure **23**. Thus, as can be seen the tank which contains a liquid **35** has the oscillator

housing 27 forming a portion of its bottom end. The housing 27 is free to vibrate since it is merely suspended by a rubber diaphragm 25. To allow for freedom of movement a motor 37 drives the oscillator 29 through a drive shaft 39. The drive shaft is provided with a pair of flexible couplings 41 such as standard universal joints. This allows the oscillator 29 and housing 27 to move freely in the vibratory mode relative to the fixed gearbox 37. A drive shaft 38 from a motor (not shown) drives the gears on box 37 and serves to rotate the drive shaft 39.

In various past systems disclosed in pending applications and issued patents to the same inventor a resonant system was employed utilizing a mechanical oscillator which causes an elastic circuit to resonate. This in turn delivers this resonant elastic force to an acoustic piston surface which as indicated was coupled to a liquid body. However, it has been found that in some situations it is very desirable to closely control the amplitude of the pressure swing in the liquid. This is difficult to accomplish when employing a resonant system since a resonant system will tend to be somewhat indeterminant as regarding the pressure swing. This is because the resonance system changes its acoustic impedance output with changes in impedance in the liquid. In other words, in the resonant system the oscillators utilized would automatically adjust to changes in impedance and thus always maintain a resonant output.

The herein system utilizes a mechanical inductive-type oscillator which is one that employs the reaction force from continuing the cyclic path of a moving mass. It is found that the resulting process of the invention is very economical since large forces can be developed with reasonable cost of oscillator design. Further, the rotary orbital oscillators used in this invention result in a minimum weight for the oscillator housing so that maximized forces in motion can be delivered to the liquid body. Although various mechanical oscillators are possible for use in the instant invention most of them have an inherent limitation in that the oscillator will tend to be quite heavy. This wastes much of the force which would otherwise be delivered to the acoustic piston or in this case the housing for the oscillator. As a result, the herein oscillators to be described provide a very lightweight structure with a high force output.

Thus, the novel system of this invention is a nonresonant one. Because of this, the rotary motion of the oscillator must be polarized. In a resonant system the resonance itself will tend to polarize motion and thus permits a single rotor type oscillator to be utilized. In the absence, however, of resonance, it is necessary to otherwise polarize the motion so that the force is not delivered equally in all directions. With an acoustic piston it is of course necessary that the force be primarily in one direction. This is accomplished in the herein invention by using an inductive oscillator having a pair of oppositely orbiting masses which neutralize each other in the lateral direction but are additive in the direction of piston vibration, usually at right angles thereto.

Turning now to FIG. 2 there is seen in detail one of the rotary elements of an oscillator of this invention. In the device of FIG. 2 two such rotary elements are used. One only is shown in detail. Each element is separately driven by a drive shaft 45 connected to a gearbox 46. A single motor and drive shaft (not shown) is connected to the gearbox and serves to drive the rotors. An enclosed outer housing 47 surrounds both of the rotor elements utilized. The housing 47 with its piston surface in turn is connected to the base portion of the tank, through a compliant joint, in which the device is to be used so as to radiate into the liquid. Each of the rotary elements of the rotors comprise a cylindrical housing 49 having end plates 51 and 53. An eccentric crankshaft 55 is disposed within the housing 49 having an axle portion 57 extending outwardly from the housing through a cover plate 59 to a flexible coupling 61.

The crankshaft 55 is formed of two pieces, the first piece being the main crank portion 63 having an end 65 communicating with the axle end portion 57. The second piece of the crank 55 is end piece 67 which is affixed to the end of the crank opposite the axle end 57 by means of a split ring 69 and bolt 71.

An aperture 73 is provided in end plate 53 which communicates with a passage 75 formed in endpiece 67. Passage 75 communicates with an opening 77 formed longitudinally through the crank 55. A plurality of additional secondary passages 79 in turn lead from the main opening 77 through the crank to its outer surface. The purpose of the aforegoing openings through the crank is to allow a continual flow of lubricant during the operation of the device. The lubricant will exit the oscillator housing through apertures 81 provided in end plates 51 and 53.

Surrounding the crank 55 are three separate bearings 83. In turn driven by the bearings are three weighted rollers 85. As shown in the drawing, the rollers rotate on their outer diameter upon sleeve 87 formed of ball bearing steel or the like. In other words, as the crank 55 rotates, the rollers 85 are in continuous driving contact with the inner bearings 83 and carried by the outer sleeve 87 which, of course, additionally serves as a support bearing for the rollers.

In each end of the crank within the end plates 51 and 53 there is provided, bearings 89 which surround the crankshaft. The bearings 89 are supported from the crankshaft by a ring 91 which is separated from the crankshaft by a spring 93. The spring 93 is seated within an indentation provided in the crankshaft. It is to be noted that the crankshaft is not in tight contact with the bearings 89. Some freedom of movement is thus permitted so that there will be assurance during the operation of the device that the rollers 85 are maintained in contact with the outer bearing or sleeve 87. This contact will normally occur due to the centrifugal force developed during the operation of the device. However, when the device is initially started, it is important in order to prevent undesired oscillations from occuring, that the rollers are initially maintained in contact with the outer sleeve 87. This is assured by the action of the springs 93. Once the centrifugal force is sufficiently established the forces of the springs are overcome and the desired contact is maintained regardless of the spring pressure.

A further advantage of the invention particularly in the use of the paired rotors is that one can control the energy density in the liquid by the relative phase maintained through the gearbox 46. For example, if it is found that a certain region in the liquid tends to have a low energy density one can merely shift the gear setting in the gearbox one or two tooth differences in the standard gear phasing so as to make one of the rotors lead or lag the other rotor. This leading or lagging of the rotors will tend to neutralize any secondary effects in the liquid body which cause nonuniform energy density. Thus it can be appreciated that the inductive oscillator of this invention utilizing paired rotors can be positively adjusted to obtain a particular phased effect of the energy angle produced by the housing 47 relative to the body of liquid. This, of course, results in a very close control of the energy density in the liquid. Such a control is virtually impossible with any other form of oscillator which does not use paired rotors as disclosed in this invention.

Turning now to FIG. 3 there is seen a second embodiment of an oscillator of the invention. The oscillator disclosed in FIG. 3 comprises a housing 95. A single drive shaft 97 enters the housing 95 and is connected to a first eccentric weight 99. Eccentric weight 99 has radially formed about its midportion a gear 101. Bearings 103 serve to support the eccentric weight and gear within the cavity of the housing 95.

The gear 101 is intermeshed with the gear 105 of a second like rotor 107. Here again the phasing of the gears can be adjusted, to get a desired phasing of the piston vibration, as mentioned in connection with FIG. 2. As shown, the eccentric weight portions of the rotors swing around to neutralize each other in the horizontal component as shown particularly in FIG. 3, while reinforcing each other when they swing to either the top or the bottom of the housing 95 to reinforce the verti-

cal component. The shaft **97** is driven through a gearbox **109**. An axle **111** from a motor, not shown, in turn drives the gears in gearbox **109** and serves as a main driving force for the oscillator.

I claim:

1. In combination:

a vessel for containing a liquid having an opening in the bottom thereof,

an inductive oscillator having a pair of oppositely orbiting masses,

a housing for said oscillator having a portion thereof disposed within said opening in said vessel for directly delivering vibratory energy to the contents of said vessel, and

an elastomeric diaphragm for compliantly suspending said portion of said housing in said opening.

2. In a device for imparting sonic energy to a liquid for providing work functions in the liquid,

a tank for containing said liquid having an opening therein,

an elastomeric diaphragm attached to the edges of said opening,

an oscillator including a housing and a pair of masses mounted for orbital motion in said housing,

said oscillator housing being compliantly suspended in said diaphragm with the housing and diaphragm each partially covering said opening, the opening being completely sealed thereby, and

means for driving said masses in opposite directions to cause said housing to vibrate primarily along a single axis,

whereby said oscillator housing delivers vibratory energy directly to the liquid.

* * * * *