

[54] ELASTOMERIC PISTON

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 666,398, Sept. 8, 1967, Pat. No. 3,544,073,

[52] U.S. Cl.259/72, 259/1, 74/61

[51] Int. Cl.B06b 1/16, B06b 1/20

[58] Field of Search259/72, 1, DIG. 4, DIG. 44;
74/61, 87; 173/49; 175/55; 134/184

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[57]

ABSTRACT

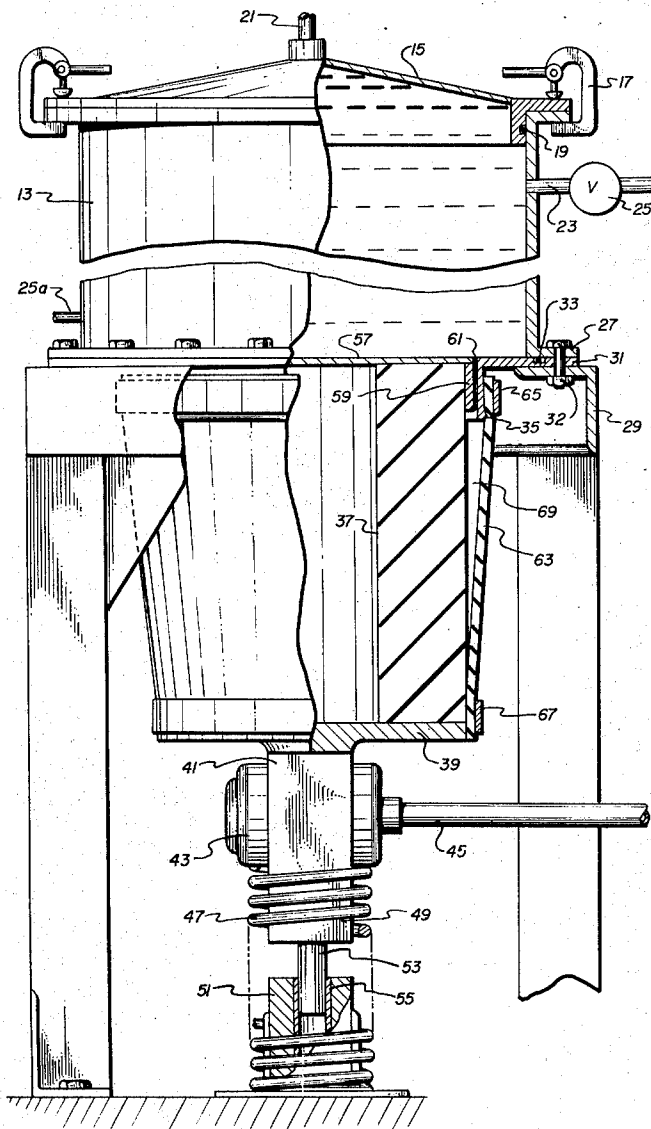
A device for radiating elastic pressure pulses into a liquid container which comprises a cylindrical body of elastomeric material, having connected to one end thereof an orbiting mass oscillator, with the opposite end covered by a plate being affixed thereto, this end being further exposed to and in contact with a body of water contained within a tank.

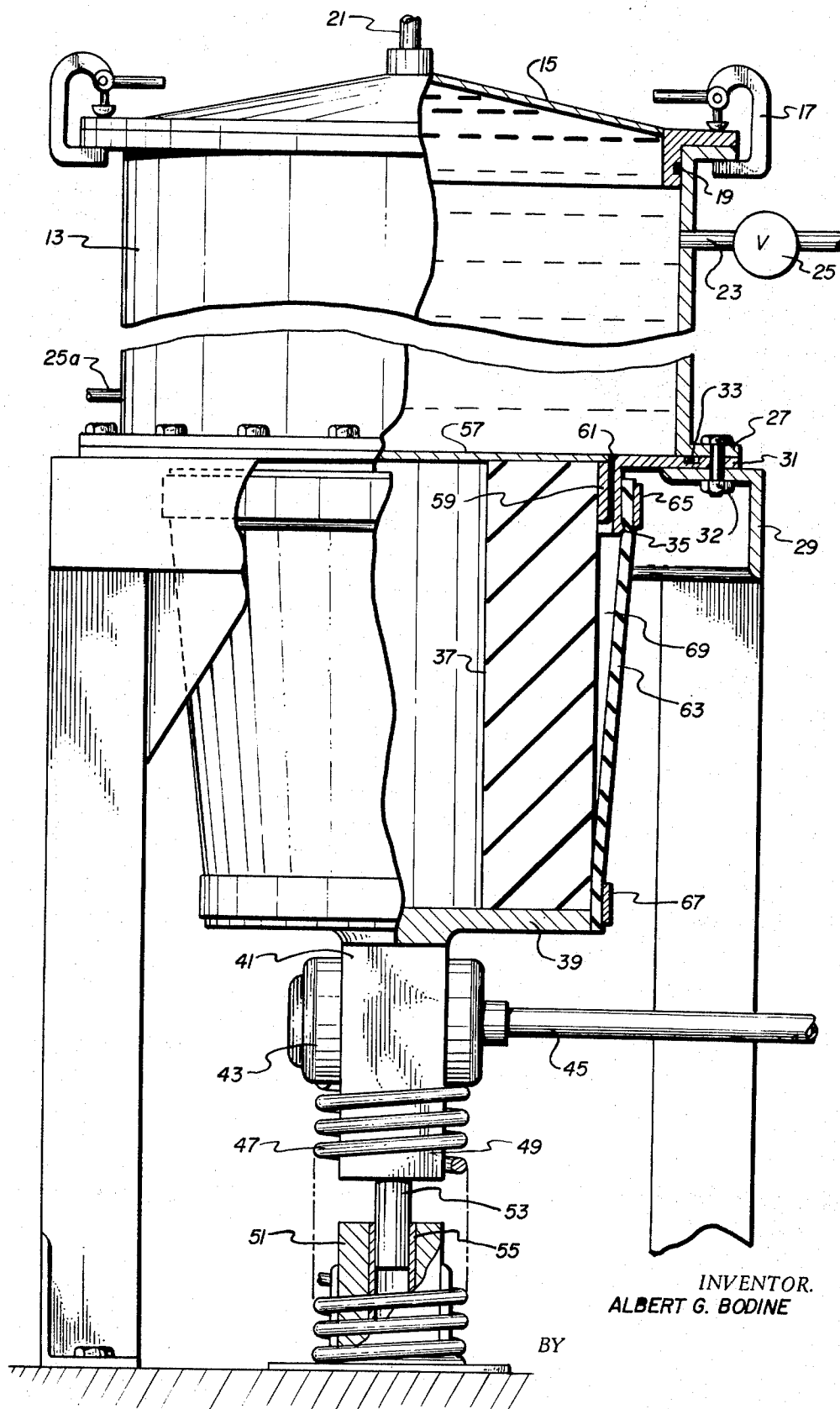
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4 Claims, 1 Drawing Figure





ELASTOMERIC PISTON

This is a continuation-in-part of application, Ser. No. 666,398 filed Sept. 8, 1967, now U.S. Pat. No. 3,544,073.

In previously filed patent application, Ser. No. 666,398 filed Sept. 8, 1967, by the same inventor, there is disclosed a device which is comprised of an elastomeric resonator coupled to an orbiting mass oscillator. The elastomeric resonator is disclosed as being a cylindrical element having one end connected to the oscillator. The cylindrical elastomeric resonator is disposed within a tank of water or other suitable fluid. Articles or fluids to be cleaned or washed or otherwise sonically treated are then submerged in the tank, the particular action benefitting from the sonic energy generated therein.

It has been subsequently found that elastomeric resonators are inclined to resonate in a great number of complex modes. As a result various surfaces of the resonator will vibrate out of phase in relation to other surfaces. Often, when a major portion of the elastomeric resonator is in contact with liquid, the resonator might choose a mode wherein the out of phase motion of adjacent surfaces will cause a canceling effect so that pressure impulses are neutralized. It is pointed out that this does not happen in all cases. However, many resonators of the elastomeric type will tend to seek this di-pole mode of operation since this results in the least amount of work being delivered to the liquid. In other words, the end effect is that such a resonator would have a strong tendency to actually seek a mode where it has least coupling to the liquid.

Thus an object of this invention is to provide a novel elastomeric resonator combination involving maximum coupling of the resonator to the liquid body.

The above and other objects of the invention are accomplished by the herein device, comprising a vessel for containing liquid medium which could be utilized such as to clean parts or provide treatment of the liquid itself. An elastomeric resonator in the form of a cylinder is provided adjacent to the vessel. One end of the elastomeric resonator is disposed contiguous with a surface of the vessel, while the opposite outer end of the resonator is coupled to an orbiting mass oscillator to effect vibration of the resonator. The end of the resonator contiguous with the surface is provided with a cap, preferably of metal construction, which provides a mass on this end of the resonator as well as sealing the interior of the cylinder from the liquid in the vessel. The resonator is preferably enclosed in a cylinder extending from the vessel. A small clearance is provided between the cap on the end of the resonator element and the contiguous wall of the vessel. Essentially the liquid in the vessel is exposed only to the action of the end surface of the resonator element having the metal cap thereon.

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

The FIGURE is a partially sectioned view of the devices of the invention.

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 , mechanical compliance C_m is equated with electrical capacitance C_e , 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, $F_0 \sin \omega t$, ω being equal to 2π times the frequency of vibration, that

$$Z_m = R_m + j\left(\omega M - \frac{1}{\omega C_m}\right) = \frac{F_0 \sin \omega t}{u} \quad (1)$$

Where ωM is equal to $(1/\omega C_m)$, a resonant condition exists, and the effective mechanical impedance Z_m is equal to the

mechanical resistance R_m , the reactive impedance components ωM and $(1/\omega C_m)$ cancelling each other out. Under such a resonant condition, velocity of vibration u is at a maximum, effective power factor is unity, and energy is most efficiently delivered to the object being vibrated. It is such a high-efficiency resonant condition in the elastic system being driven that is preferably utilized in the methods and devices of this invention to achieve the desired end results.

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. Thus, 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. Where a low-impedance load, such as water, is present, the acoustic impedance of the elastomer so closely matches that maximum transfer of the vibratory energy is achieved. The mismatch of impedance arises at the interface of the water and parts submerged therein wherein the desired action can occur.

Just as the sharpness of resonance of an electrical circuit is defined as the "Q" thereof, and is indicative of the ratio of energy stored to the energy used in each cycle, so also the Q of a mechanical resonant circuit has the same significance and is equal to the ratio between ωM and R_m . Thus, high efficiency and considerably cyclic motion can be achieved by designing the mechanical resonant circuit for high Q.

Of particular significance in the implementation of the methods and devices of this invention is the high acceleration of the components of the elastic resonant 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), several factors are to be noted. First, this equation represents the total effective resistance, mass and compliance 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.

It is also to be noted that orbiting mass oscillators are utilized in the devices of the invention that automatically adjust their output frequencies to maintain resonance with changes in the characteristics of the load. Thus, in situations where we are dealing with parts which are placed in a bath during the operation of the device which will change that load, the system automatically is maintained in optimum resonant operation by virtue of the "lock in" characteristics of applicant's orbiting mass oscillators. The vibrational outputs from such orbiting mass oscillators are generated along a controlled predetermined coherent path to provide maximum output along a desired axis or axes. The orbiting mass oscillator automatically changes not only its frequency but its phase angle and therefore its power factor with changes in the resistive impedance load to assure optimum efficiency of operation at all times. Such orbiting mass oscillators are capable of efficiently generating high-level vibrational outputs.

By utilizing as a resonator element an elastomeric material such as rubber, a much greater feedback to the oscillator is accomplished than when the resonator is of a high-impedance material such as, for example, a steel column. This feedback results, since the elastomer, because of its inherently low impedance, provides a greater cyclic stroke for a given frequency at the point where the oscillator is connected. Previously, other low-impedance resonator elements such as air springs have been affixed to an oscillator. However, these elements have lumped constant impedance characteristics. On the other hand, the elastomeric material is a distributed constant

system. A distributed constant system has the advantage of being able to accomplish an acoustic lever effect where, for example, a high velocity or amplitude vibration at the coupling to the oscillator can be converted to a low velocity with a high force at the end of the resonator exposed to the load element.

Further, as indicated, one of the advantages of an orbiting mass oscillator is its lock-in characteristics, with the automatic adjustment of operating frequencies to accommodate for sudden changes in environmental reactive impedance. This feedback is best accomplished by a low-impedance resonator, such as the elastomeric element disclosed which has a large-amplitude vibration to better accomplish the feedback. Additionally, in this same vein, the automatic accommodation for changes in environmental resistive impedance caused by a work load is better fed back to the oscillator through a low-impedance resonator since there is greater activity where the resonator is coupled.

Turning now to the FIGURE, there is seen a cylindrical tank 13 open at both ends. The top of the tank 13 has a cover 15 affixed thereto by clamps 17. O-ring seal 19 may be provided to leakage of the liquid in the tank between the cover and the tank walls at the clamp area. The cover 15 may additionally be provided with a riser pipe 21 which will accommodate fluctuations of the liquid in the tank during the vibratory action. Intersecting the tank 13 is an inlet line 23 through which the liquid can be directed and controlled by a valve 25. Drainage is accomplished by removing a plug from nipple 25a.

The bottom of the tank 13 is provided with a radial flange 27 which allows the tank to be secured to a stand 29 by bolts 32. Intermediate the radial flange 27 and the stand 29 is disposed a separate flange element 31, having an O-ring 33 imbedded therein, serving to prevent leakage of liquid from the tank 13. Flange 31 has a downward extending inward neck portion 35, which surrounds the upper end of the elastomeric resonator element 37.

The bottom end of the elastomeric cylindrical element 37 is affixed to a metal 39 by adhesive or the like. The plate 39 in turn is affixed to a housing 41 of an orbiting mass oscillator 43. The orbiting mass oscillator can be of the type, for example, shown in U.S. Pat. No. 3,402,612 to the same inventor, and is driven by shaft 45 from a motor not shown. The orbiting mass oscillator is seated on a spring 47 which surrounds its upper end a downward extending portion 49 of the oscillator housing.

A separate housing 51 is provided adjacent the bottom portion of the spring 47 that serves to contain a downward extending guide rod 53 which is free to move vertically within a bushing element 55. This permits the downward vibratory motion of the oscillator to be absorbed essentially by spring 47. It is pointed out that the arrangement of the spring to the oscillator is of no great moment to the herein invention in that other suitable arrangements are possible within the scope of the disclosed invention. This is but one means of supporting the oscillator relative to the elastomeric resonator 37 such that no vibratory energy is dissipated to the surrounding environment; and also so as to assure simple longitudinal vibration.

Affixed to the upper end of the resonator 37 and covering it is a metal plate 57 which can be glued or vulcanized to the resonator element. This plate 57 can be of steel, or preferably of non-corrosive material such as stainless steel. As shown in the drawing, the metal element 57 is in the form of a cap and covers a portion of the side walls of the outer diameter of the resonator 35 at portion 59 adjacent the neck portion 37 of the flange. A very small clearance 61 is provided between portion 59 of the element 57 and the flange neck portion 35 to allow

the resonator 37 to vibrate freely without dissipating energy into the vessel. A typical clearance 61 could be 0.20 inch.

Extending from the neck portion 35 of flange 31 downwardly is a cylindrical boot 63, of preferably elastomeric material such as rubber. The boot is secured to the outer periphery of the neck portion 35 by a band clamp element 65, and is additionally secured to plate 39 adjacent the oscillator 43 by a similar clamp 67 to provide a water tight seal therebetween. Thus a small chamber 69 is formed between the outer periphery of the resonator 37 and the inner wall of the cylindrical boot element 63, which will be filled with the liquid from the tank 13 that passes through the small gap 61 prior to operation of the oscillator.

In the operation of the device, parts or fluids to be treated are first admitted to the vessel 13 after a cover 15 has been removed. The cover is then replaced and clamped by clamp 17 and the liquid medium is admitted to completely fill the tank. The tank is completely filled so that all reflections or boundaries within the tank are of high impedance, maximizing the cyclic pressure in the tank. The orbiting mass oscillator 43 is then started, causing the resonator 37 to vibrate. The metal plate 57 on the resonator contiguous with the bottom of the tank 13 causes the end of the resonator to be stiff and thus prevents it from breaking into various di-poling modes. The remaining portion of the resonator 37 is not confined, so that various forms of vibration can take place therein. Under these conditions the orbiting mass oscillator will seek the best possible vibratory mode for maximum energy input to the tank. The main body of the resonator is effectively isolated from the liquid in the tank 13 by having the close fit between it and the neck portion 35 of the flange 31 at gap 61, and a small area 69 between the resonator 37 and the surrounding cylinder 63. Because of the small gap 61, the liquid layer therein has a very high acoustic impedance at resonant frequency. This high impedance thus blocks pressure impulses set up within the area 69 from being effectively transmitted to the main body of liquid in vessel 13. Thus the effective coupling of the resonator 37 to the body of liquid in vessel 13 is through the metal surface 57 at the end of the resonator.

Under the foregoing conditions the orbiting mass oscillator 43 will seek the best possible vibratory mode for maximum energy import to the low-impedance liquid media in the vessel 13.

I claim:

1. In combination:

a vessel for containing a liquid,

a cylindrical elastomeric resonator column having only one end thereof with a plate affixed thereto and disposed for acoustically coupling to contents within said vessel, the remaining portion of said resonator disposed outside of said vessel, and
an orbiting mass oscillator affixed to the other end of said resonator column.

2. The combination of claim 1 wherein said vessel has a bottom surface provided with an opening therein,
and wherein said one end of said resonator column is disposed within said opening.

3. The combination of claim 2 further comprising:

a flexible sleeve extending from said vessel and surrounding said resonator.

4. The combination of claim 2 wherein said opening has a diameter slightly larger than the one end of said resonator so as to provide a small circumferential gap between said bottom surface and said one end, said gap having a width sufficient to cause any liquid therein to have a high acoustic impedance.

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