April 29, 1958 C. L. MENG 2,832,572

WAVE ENERGY COUPLING DEVICE FOR ULTRASONIC ENERGY

Filed Dec. 1, 1955 2 Sheets-Sheet 1

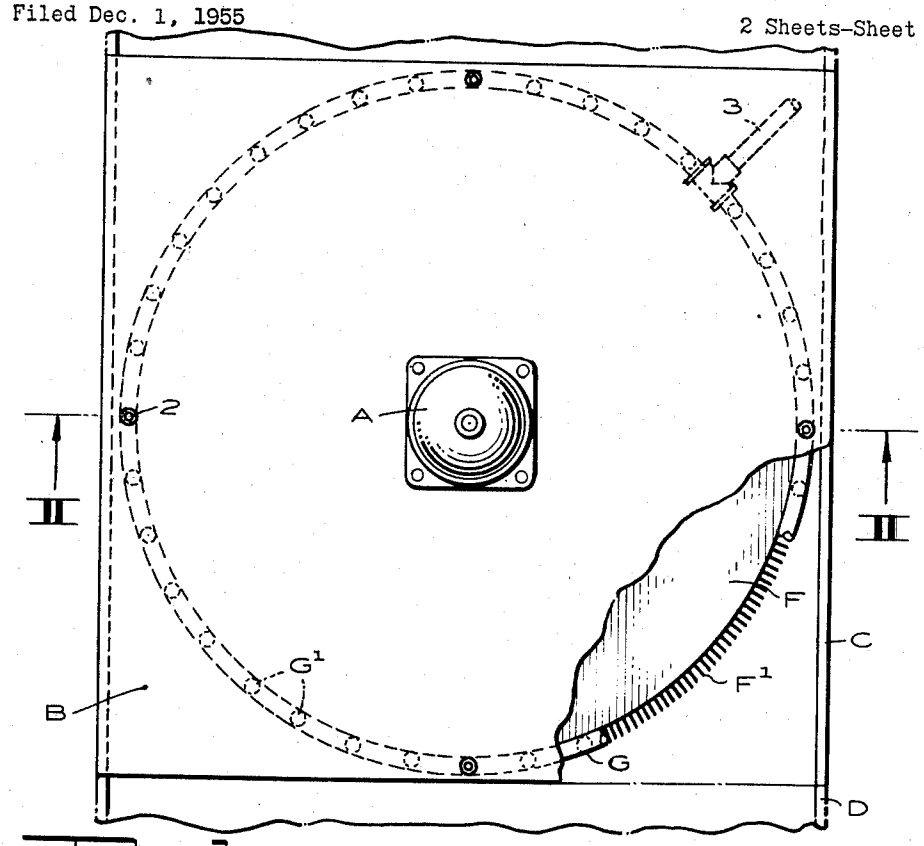

Fig. 1

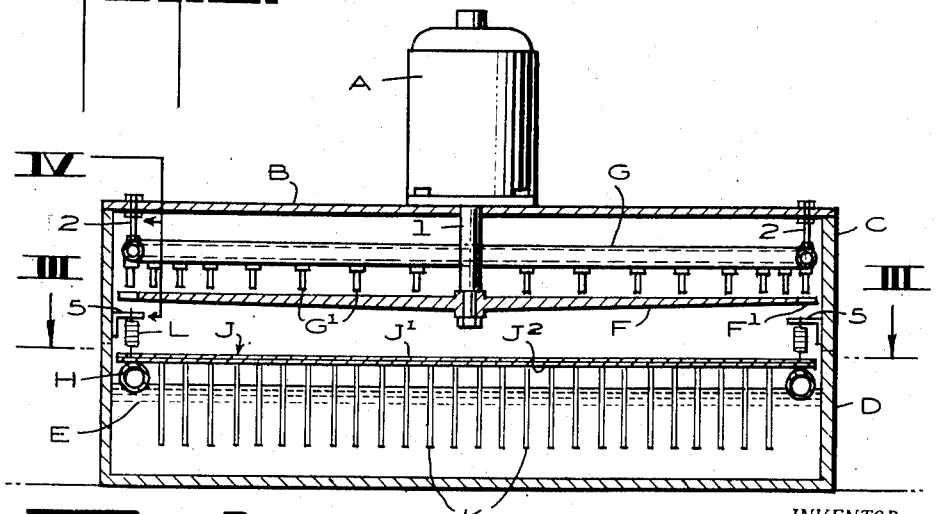

Fig. 2

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2 Sheets-Sheet 2

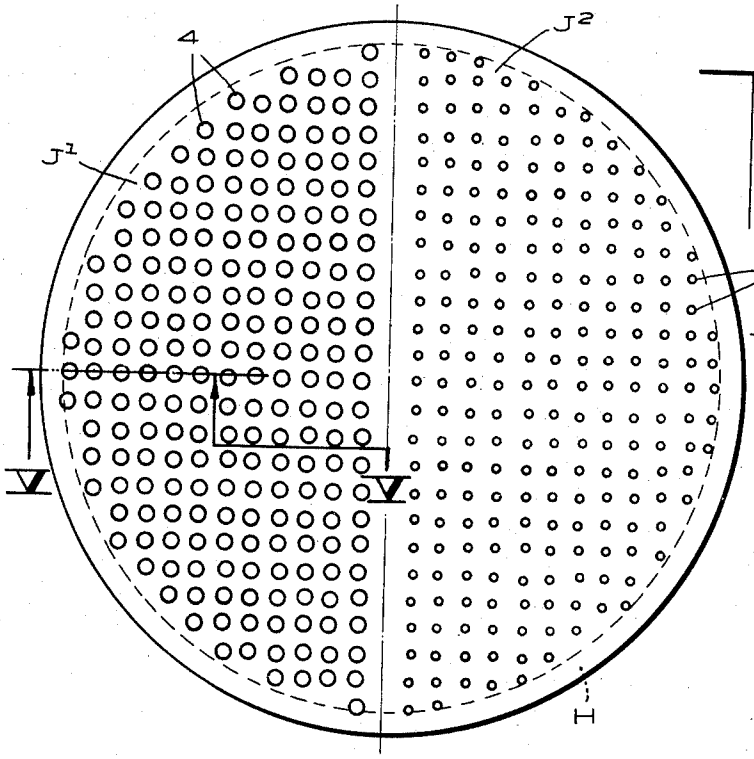

Fig. 3.

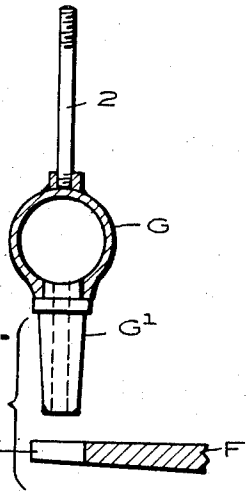

Fig. 4.

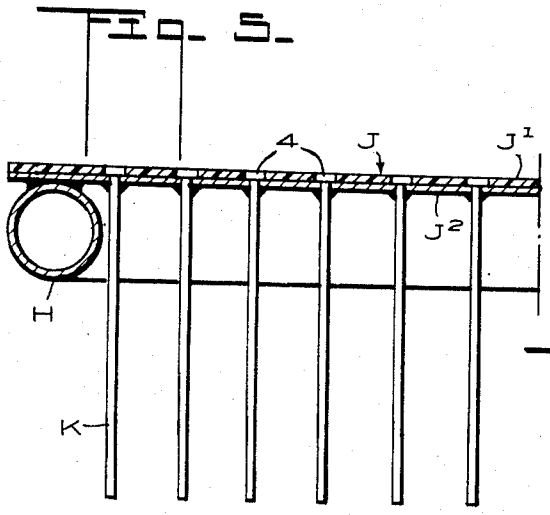

Fig. 5.

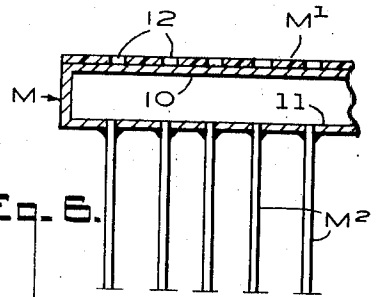

Fig. 6.

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WAVE ENERGY COUPLING DEVICE FOR ULTRASONIC ENERGY

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Application December 1, 1955, Serial No. 550,283

6 Claims. (Cl. 259—1)

An object of my invention is to provide a coupling device for ultrasonic energy and it consists in the constructions, operations and advantages hereinafter described and claimed.

The purpose of my invention is to provide a method of coupling ultrasonic energy to or introducing it into matter which it is desired to treat. Ultrasonic waves are of the nature of sound waves in that their energy is reflected and deflected as they strike solid or liquid surfaces. Since effective ultrasonic treatment of any nature requires absorption of the wave energy, it becomes necessary to reduce this reflection as much as possible.

In acoustical design, the reflection of audible sound (echoes) is reduced in a room by making the wall and ceiling surfaces rough and uneven. This contributes to clear or pure sound which retains the same characteristics it had when transmitted by the source to the adjoining media. Such sound is not changed by the interference of reflected sound energy. Rough and elastic surfaces assist in the absorption of ultrasonic energy. Conversely, smooth and solid surfaces reflect the greater part of this energy. Because of greater elasticity, liquids absorb wave energy to a slightly greater extent than solids. These principles are made use of in the design of the coupling device described herein.

By coupling is meant the transfer of wave energy which is being transmitted through one medium, to waves which are then transmitted through another medium. In the device which I will describe, the longitudinal waves travel downward through air from the fin-air jet interruption to the upper diaphragm surface. When they strike the diaphragm, which due to its buoyancy on a fluid body is free to vibrate, they will force a resonant vibration upon it. It in turn through its parts which are in contact with the liquid, transmits this vibrational energy or micro-agitation to the molecules of the liquid, causing these molecules to assume wave motion in many directions. These latter waves may be called bulk waves, due to their irregular directions of propagation through the medium. Thus the resonator diaphragm acts as a coupling agency, coupling the energy of the longitudinal air transmitted waves to the energy which generates the bulk waves in the liquid.

The ultrasonic coupling device disclosed in the present case makes use of the ultrasonic wave generator set forth in my Patent No. 2,715,384, issued August 16, 1955, or a similar device. My present ultrasonic energy coupling device can be used for the treatment of liquids for such purposes as sterilization, homogenization, emulsion and the like.

A further object of my invention is to provide a device of the type described which is simple in construction and is durable and efficient for the purpose intended.

Other objects and advantages will appear as the specification proceeds. The novel features will be set forth in the claims hereunto appended.

Drawings

My invention is illustrated in the accompanying drawings, forming a part of this application, and in which:

Figure 1 is a top plan view of the device with a portion being broken away to disclose the disc and peripheral fins of the resonator diaphragm assembly;

Figure 2 is a transverse section taken along the line II—II of Figure 1;

Figure 3 is a horizontal section taken substantially along the line III—III of Figure 2 and shows a top plan view of one half the upper disc with its perforations, and one half the lower disc with its agitator rods;

Figure 4 is an enlarged vertical section taken along the line IV of Figure 2, and shows the ring-shaped conduit and nozzle and a portion of the disc and one fin of the resonator diaphragm assembly;

Figure 5 is an enlarged transverse section through a portion of Figure 3 as indicated by the line V—V; and

Figure 6 is a modified form of the resonator diaphragm assembly.

Description

While I have shown only the preferred forms of my invention, it should be understood that various changes, or modifications, may be made within the scope of the annexed claims, without departing from the spirit thereof.

In carrying out my invention, I make use of the ultrasonic device disclosed in my Patent No. 2,715,384, above mentioned. The patented device includes a motor A, mounted on a platform B, that in turn is supported by a frame C. The frame C extends above a tank or trough D in which a liquid E or other substance, is disposed that is to be treated. If the substance to be treated is in batch form, then a tank D may be used. If the substance can be moved in a continuous manner, such as a flowing liquid, then a trough D would be used. The invention adapts itself to a batch or continuous process.

The motor A has a motor shaft 1 that extends downwardly through an opening in the platform B, and a disc F is carried by the lower end of the motor shaft. Above the disc F, I mount a ring-shaped conduit G, and Figure 2 illustrates how supporting bolts 2 connect the conduit G to the platform B so that the plane of the ring-shaped conduit G, will parallel the plane of the disc F. Nozzles G^1 extend downwardly from the ring-shaped conduit G, and they communicate with the interior of the ring.

The periphery of the disc F has a plurality of radially extending fins F^1 that are arranged concentric with the axis of the shaft 1. The circular row of nozzles G^1 are arranged concentrically with the shaft axis and the nozzle outlets are disposed just above the fins F^1. An air pipe 3 communicates with the ring-shaped conduit G, and delivers air under pressure to the conduit. The nozzles G^1 will direct the compressed air downwardly in streams that are caused to pulsate at ultrasonic frequency by the fins F^1 as they are moved transversely through the air streams. The disc F will be rotated at about 3600 R. P. M. and the diameter of the disc is about five feet two inches which will give it a peripheral speed of about 1000 feet per second. There are approximately 1700 fins arranged around the disc periphery and there are about thirty nozzles G^1, although far fewer are illustrated in Figure 1 for purposes of clarity. The fins are spaced apart and the streams of air in passing through the recesses provided between the fins, will be interrupted by the fins to create about 100,000 or more waves per second. When 1700 fins F^1 are mounted on a disc rotating 3600 R. P. M., the air stream from one nozzle G^1 will be interrupted 102,000 times per second. With thirty nozzles, the combined interruptions will be 3,060,000 per second.

The parts thus far described produce fin-air jet inter-

ruption at ultrasonic frequencies. It is readily understood that the frequency may be varied by making the diameter of the disc F larger or smaller while the fin spacing remains the same. Frequency variation may also be accomplished by varying the speed of the driving motor A. Recent improvements in the design of variable speed electric motors will be of great importance to the generation of ultrasonic energy by the device set forth in my Patent No. 2,715,384. The intensity of the wave energy may also be varied by changing the pressure of the air which is delivered by the conduit to the jets. These variations of frequency and intensity are of great value in the development of uses for ultrasonic energy.

The purpose of the present invention is to take this cylindrical air curtain pulsating at ultrasonic frequency and deliver the pulsations into the body of the matter being treated rather than direct the pulsating medium against the surface of the material to be treated. It is best now to refer to Figures 2 and 3 where I show a resonator diaphragm assembly J comprising a hollow ring H and a pair of discs J^1 and J^2 secured to each other. The upper disc J^1 is made of hard rubber or plastic and has perforations 4 therein, see Figure 5 and the left half of Figure 3; while the lower disc J^2 is made of thin metal with a plurality of agitator rods K, depending from this plate, see the right half of Figure 3, and also Figure 5.

Figure 5 illustrates the hollow ring H, the upper and lower discs J^1 and J^2, and the agitating rods K on a larger scale. The upper disc J^1 has a plurality of openings 4 therein. As many openings 4 as possible are provided in the upper disc J^1 so long as the layer is not weakened. I prefer that the openings 4 be less than 1/16" in diameter and that they be spaced from each other about 1/4" or less on a disc approximately five feet two inches in diameter. If a smaller upper disc J^1 is used, the openings 4 and the distances between them would be reduced proportionately. The upper disc is about 1/8" thick.

The lower disc J^2 of metal is about 1/16" thick and is preferably bonded to the upper disc so that the two discs will constitute one unit. Figure 5 shows the agitator rods K with their upper ends welded or otherwise secured to the lower disc J^2. The agitator rods are about 1/32" in diameter and are preferably made of stainless steel. The agitator rods are of the same diameter throughout their length and are spaced about 1/4" apart in a disc having a diameter of 5' 2".

The two discs J^1 and J^2 are secured together and are mounted on the hollow ring H. The cross sectional diameter of the hollow ring is about 3 1/2", and the outer surface of the ring has a clearance from the adjacent surface of the vat or trough D, of about 1/8". The hollow ring H floats on the surface of the liquid E and the depth of the liquid is about 4" to 6". The agitator rods K are 4" or 5"' long and they will therefore penetrate a distance of 1/2" to 1 1/2" into the liquid. I do not wish to be confined to these exact measurements.

My device as described thus far consists of the resonator diaphragm assembly J that floats above the surface of the liquid E being treated, due to the buoyancy of the hollow ring H that supports the discs J^1 and J^2, adjacent to their peripheries. The discs are concentric to the hollow ring H. When treating liquids E of low specific gravity, additional support for the disc may be required beside that provided by the buoyant force of the displaced liquid on the hollow ring H. In Figure 2, I illustrate that the resonator diaphragm assembly may be additionally supported by sensitive helical springs L so arranged that the total supporting force due to buoyancy and suspension will permit free vibration of the assembly J. The lower ends of the coil springs L are connected to the upper disc J^1 while the upper ends are connected to brackets 5 which in turn are secured to the frame C.

From the foregoing description of the various parts of the device, the operation thereof may be readily understood. The tank or trough D contains the fluid to be treated and the agitator rods K will penetrate the liquid to the proper depth. The motor A is started and the disc F will be rotated at the desired speed. Compressed air or other desired gas will be fed into the ring-shaped conduit G and the nozzles G^1 will deliver the air in streams that will pass downwardly and be intercepted by the fins F^1 so that the air will be vibrating or pulsating at ultrasonic speed.

The cylinder of pulsating ultrasonic wave energy will strike the upper perforated disc J^1 of the resonator diaphragm assembly J. Due to the uneven upper surface of the upper disc J^1 caused by the multitude of openings 4, and due to the elastic support of the two discs J^1 and J^2 by the hollow ring H and the coiled springs L, the resonator diaphragm assembly will absorb a great part of the energy produced by the pulsating curtain of air striking it. The uneven top of the upper disc J^1 constitutes an absorbent cover for the resonator diaphragm assembly J, and absorbs the ultrasonic energy waves from the generator. The upper and lower discs will therefore vibrate in resonance at the ultrasonic wave frequency of the generator which comprises the air jets from the nozzles G^1 and the pulsating device which consists of the rapidly moving disc fins F^1 and the spaces between the fins. These vibrations and their accompanying energy are transmitted to the desired depths in the liquid E, by the agitator rods K, and to some extent by the hollow ring H itself that rests on the surface of the liquid.

At this point I should like to describe the characteristic of sound known as resonance and show its relation to the principle underlying my invention. Two or more vibrating bodies are said to have resonant vibration when they are vibrating at the same frequency. The natural frequency of a body is the frequency at which it vibrates freely without significant interference from other vibrations. This natural frequency depends on its weight, shape, material, and position or attachment. A vibrating body may force its own vibrational frequency on surrounding bodies, in which case they are said to be vibrating in forced resonance. A common example of resonance in audible sound is that of a listener in a house in which all doors, windows, and other openings are closed. The walls are of brick or other rigid material and the roof is of tile or shingles heavy enough to reflect or absorb sound energy. Doors and windows are of normal construction. Sounds of fairly high intensity from the outside, such as ambulance sirens, loud talking, dogs barking and the like are readily heard and identified by the listener. The sound energy which travelled from the various sources and struck the solid walls or roof was either absorbed or reflected. At the same time the sound waves which struck the doors and window panes were able to induce or force their vibrational frequencies into these parts. The inner surfaces of these vibrating bodies generated sound waves in the air inside the house which were carried to the ear of the listener. Obviously there is some energy lost at each of these thin structural members due to their rigidity and framing. If we disregard this loss we may say that the outside sound waves, the thin member (door or window) and the inside sound waves have a resonant frequency. The same principle of resonance applies to ultrasonic energy waves. The resonator diaphragm assembly of my invention is for the purpose of transferring ultrasonic wave energy from air to liquid thus avoiding the interface reflection loss.

My resonator diaphragm assembly J with its agitator rods K that penetrate the liquid E, provide novel means for getting the ultrasonic vibrations beneath the reflecting surface of the liquid or other matter being treated. There is no true coupling effect if the vibrations are solely directed against the surface of the liquid because some of such vibrations will be reflected from the surface. The resonator diaphragm assembly J in my device when vibrated by the ultrasonic energy will transfer this energy

into the body of the liquid with little loss through reflection, because the agitator rods K penetrate the liquid. The openings 4 in the upper disc J^1 are closed by the lower disc J^2 and the uneven top surface of the upper disc will receive more vibrations than if the top surface were smooth.

The hollow ring H may be of any desired size and need not be of circular cross section. In fact the resonator diaphragm assembly J might be made a hollow metal disc M, see Figure 6, and thus do away with the hollow ring H. The top **10** of the hollow disc M could have the plastic perforated layer M^1 secured thereto and the agitator rods M^2 could extend downwardly from the bottom **11** of the hollow disc. The ultimate design for the resonator diaphragm assembly J or the hollow disc M is to provide one having the same natural frequency as the generated waves. The upper and lower discs J^1 and J^2, or the hollow disc M would then vibrate in natural resonance with the generator's vibrations. The plastic top layer M^1 would have perforations **12** therein.

I claim:

1. In a wave energy coupling device for ultrasonic energy: means for producing ultrasonic waves in an air stream; a member having a surface substantially non-reflecting to ultrasonic waves and being positioned to the ultrasonic air stream so as to receive and vibrate in unison with the ultrasonic waves; means containing a medium to be treated; said member carrying agitator rods that extend into said medium; whereby the ultrasonic waves are introduced into the interior of the medium with substantially no reflection of the waves from the surface of the medium.

2. The combination as set forth in claim 1: and in which the non-reflecting surface of the member has a plurality of recesses to make the surface rough and therefore substantially non-reflecting to ultrasonic waves.

3. The combination as set forth in claim 1: and in which buoyant means floats on the medium to be treated and supports the member in a position permitting the agitator rods to penetrate the medium.

4. The combination as set forth in claim 3: and in which coil springs provide an auxiliary-yielding support for said member in addition to the buoyant means.

5. In a wave energy coupling device for ultrasonic energy: means for producing ultrasonic waves in an air stream; a resonator diaphragm assembly having an upper and a lower disc in contact with each other; the upper disc having a plurality of openings therein providing a surface substantially non-reflecting to ultrasonic waves; a plurality of agitator rods depending from the lower disc; means containing a medium to be treated, the medium being penetrated by the rods; the upper disc being positioned in the ultrasonic air stream so as to receive and vibrate in unison with the ultrasonic waves; whereby the lower disc and rods will also vibrate in unison with the ultrasonic waves for transferring the energy of the waves into the interior of the material to be treated with substantially no loss of ultrasonic energy from surface reflection of the medium being treated.

6. The combination as set forth in claim 5: and in which buoyant means is connected to the discs and floats on the medium to be treated; whereby the discs are supported clear of the medium and determine the extent at which the agitator rods penetrate the medium.

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