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VARIABLE FREQUENCY MAGNETOSTRICTIVE TRANSDUCER

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FIG. 1

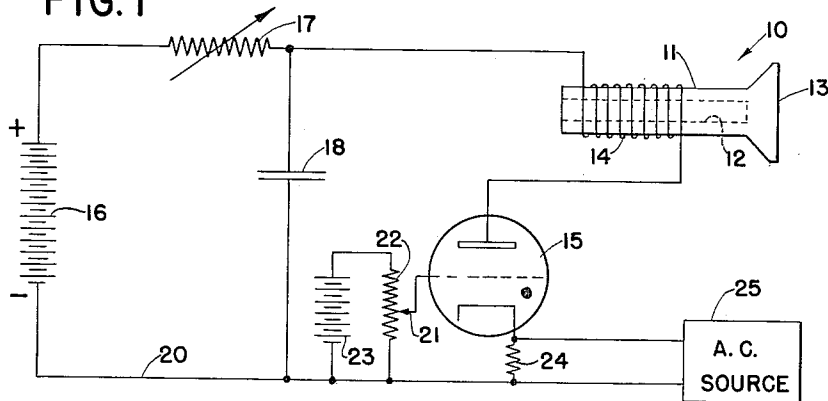


FIG. 2

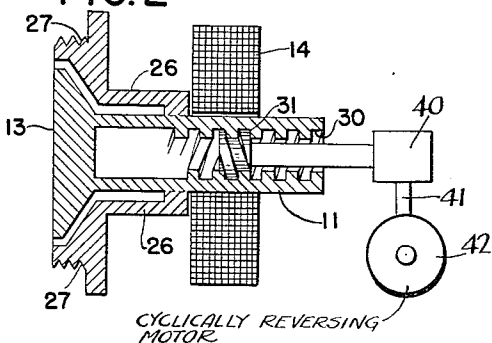


FIG. 3

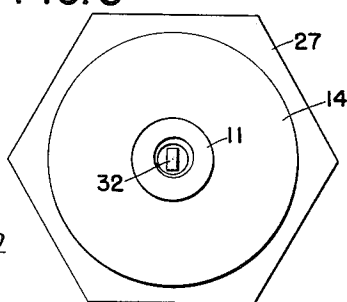


FIG. 4

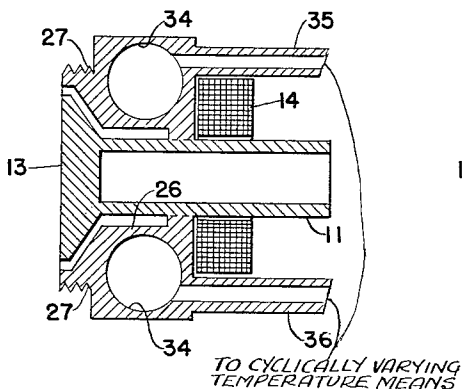
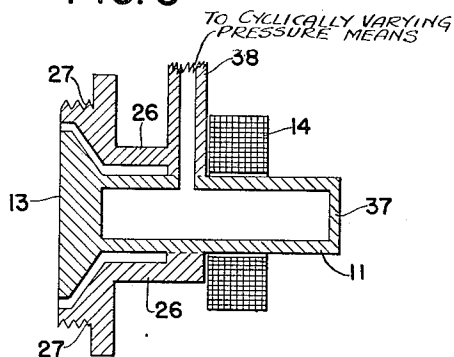


FIG. 5



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VARIABLE FREQUENCY MAGNETOSTRICTIVE
TRANSDUCER

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This invention relates to magnetostrictive devices and has particular reference to a shock excited transducer which is employed to generate trains of sound waves that are applied to liquids to keep solid matter in suspension. The invention also relates to means for varying the free period of a magnetostrictive transducer so that sound waves generated by an electrical shock pulse may have a variable and controllable frequency.

Magnetostrictive transducers have been used to send sound waves through liquids to cause mixing, emulsification, and to aid in keeping solid particles in suspension. One difficulty in applying sound energy to liquids in a container resides in the fact that multiple reflections from the container walls cause standing waves and nodes or "dead spots" where the vibratory energy is practically zero. When dead spots occur at or near the inside surface of the container there is a tendency to deposit solid matter on the walls. An effort has been made to eliminate this effect by mounting several transducers in the walls of the container at different localities in the hope that the dead spots from one unit will not coincide with the dead spots from the other unit. However, multiple positions of transducers will not always insure an absence of dead spots particularly when there exist small cavities and pipes which are joined to the main container. These cavities form their own resonant chambers and if the frequency is constant considerable solid matter may be deposited at a location where its presence is least desirable. The present invention produces variable frequency sound energy for eliminating dead spots or energy nodes which have a permanent location within a closed container.

One of the objects of this invention is to provide an improved magnetostrictive transducer which avoids one or more of the disadvantages and limitations of prior art arrangements.

Another object of the invention is to provide a magnetostrictive transducer which can be operated efficiently by shock excitation and still be controlled to change its frequency.

Another object of the invention is to provide a simple, inexpensive transducer which takes up little space and which has facilities for varying its free period over a considerable range.

Another object of the invention is to cool the transducers by a stream of cold water or gas to maintain their temperatures within an efficient range and at the same time varying the free period to produce variable frequency sound energy.

Another object of the invention is to alter the free period of a magnetostrictive transducer by the application of gas pressure.

Another object of the invention is to alter the free period of a magnetostrictive transducer by changing the position of a small mass within the transducer assembly.

One feature of the invention includes a magnetostrictive transducer which is operated by shock excitation, the free period of which may be varied by altering one of the

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physical characteristics on which the free period depends.

Other features include cooling of the transducer elements by liquid circulation, changing the pressure within the magnetostrictive element, and loading the vibrating parts by a slidable weight.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description taken in connection with the accompanying drawings.

Fig. 1 is a schematic diagram of connections of a magnetostrictive transducer coupled to a circuit for periodic shock excitation.

Fig. 2 is a cross sectional view of a transducer having a movable mass for changing the free period.

Fig. 3 is an end view of the transducer shown in Fig. 2.

Fig. 4 is a cross sectional view of a magnetostrictive transducer having an annular cavity for the circulation of cooling liquid.

Fig. 5 is another cross sectional view of a magnetostrictive transducer having a closed cavity and arranged for variable gas pressures.

Referring now to Fig. 1, a magnetostrictive element 10 comprises a tubular rod 11 having an interior cavity 12. An enlarged face 13 is formed at one end of the rod for contact with the liquid. The element is energized by current through a coil 14 which is connected in the anode circuit of a gas-filled triode 15. Power is supplied by a battery 16, or other suitable source of potential connected in series with an adjustable resistor 17. A large capacitor 18 is connected between the low potential end of the resistor and the negative supply conductor 20.

The control electrode of triode 15 is connected to an adjustable tap 21 of a voltage divider 22 which is supplied with electric power by a small source of direct current power 23. This circuit is arranged to bias the control electrode so that conduction in the tube does not occur until the anode voltage has been increased to a predetermined value.

The cathode of triode 15 is connected to conductor 20 through a cathode resistor 24 which may be omitted for general cyclic operation. However, to increase the flexibility of operation, and to make possible a random firing rate, an auxiliary generator 25 is connected across resistor 24. This generator delivers an alternating current output, the frequency of which may be a multiple of the frequency supplied by the triode 15 or it may deliver a frequency which has no direct relationship with the triode frequency.

The operation of the above described circuit is as follows: When the source of potential is first connected, the capacitor 18 charges through resistor 17. During the time of charge no current flows through coil 14 because it is in series with the anode of triode 15 which is biased for non-conduction. When the anode voltage increases to a pre-determined value, the tube becomes conducting and the charge on capacitor 18 discharges through coil 14 and the anode-cathode circuit in triode 15. This discharge comprises a large current of short duration because the resistance of the circuit is quite low.

The current pulse through coil 14 energizes the magnetostrictive element 10 and causes it to oscillate or "ring". Since there is little damping, the number of free oscillations sent out may be as high as 150 before the natural decay reduces the amplitude to one-third of the original value. After the first current pulse, the anode voltage is reduced by the voltage drop across resistor 17 and the triode 15 loses its conductivity. Then capacitor 18 starts charging up again and the whole cycle of events is repeated.

The frequency of pulse-occurrence may be adjusted within limits by changing the value of resistor 17 and by changing the value of the bias voltage applied to the con-

control electrode. The above operation has been described under the assumption that no voltage is being delivered by the generator 25. When generator 25 is in operation a cyclic voltage is applied to the cathode which is equivalent to a cyclic variation applied to the control electrode. This additional voltage supply has the effect of changing the operating frequency of the triode circuit. If the added alternating voltage is fixed multiple of the triode frequency the effect may be an increase or a decrease of the triode frequency, depending upon the phase relationships. If the applied wave from generator 25 has no direct multiple or sub-multiple relationship the result will be a random discharge time, sometimes shorter than the triode period and sometimes longer, but never having a predictable time sequence.

Figs. 2 and 3 show one design of a magnetostrictive element which contains a movable weight and can be tuned to give a variable ringing frequency which can be varied over a wide range. The active element comprises a flat face 13 which is placed in contact with the liquid to be agitated, a hollow tubular portion 11, and a coil 14. The active element may be made of nickel or one of the nickel alloys which has a large magnetostrictive constant. The tubular portion 11 is held at a point near its center by a supporting tube 26 and this tube, in turn, is supported by a flanged screw 27, suitable for connecting through an opening in a container. Tube 11 and its tubular support 26 are joined at a node and may be welded together. The supporting tube 26 and the flanged screw 27 are preferably made of steel or some other material which has a low magnetostrictive constant.

On the inside of element 11 a square shaped thread 30 is formed which extends from the outer end to a point near the node support. A weight 31, having a similar thread is screwed into the element and is used to vary the free period of the element. A flat bar 32 is coupled to the weight 31 and is used to adjust its position by an external control which includes a gear box 40, a shaft 41, and a cyclically reversing motor 42. When the weight is screwed in to the element and is near or at the node position it has little effect on the free period of oscillation. As it is turned to a position near the open end, the free period is increased (frequency is lowered) and a continuous control of frequency values is available over a wide range of values. In operation the weight is turned slowly, in and out, to perform a cyclic change of frequency which may take ten or fifteen minutes to complete.

The alternate design shown in Fig. 4 is made for boilers and keeps the scale particles in the boiler water in suspension. The screw 27 is secured to the side of the boiler and face 13 is in direct contact with the hot water. Nickel and its alloys lose their magnetostrictive properties when heated to a temperature above 600 degrees F., hence a cooling system is always advantageous. An annular cavity 34 is formed within the supporting structure and an input pipe 35 employed to conduct a cooling liquid into the cavity and then discharge it through outlet pipe 36.

By turning the cooling liquid on and off or by varying the temperature of the liquid, the temperature of the vibrating element may be varied through a considerable range. The free period of the element 11 is varied accordingly.

The alternate design shown in Fig. 5 has similar elements as those described above but the end of the hollow tube 11 is closed by a plug 37 and a single inlet pipe 38 is provided for passage to the cavity. When in operation, gas is pumped into the cavity to increase the pressure in the cavity to several atmospheres, then the gas is slowly allowed to escape and then the pressure cycle is repeated. The change of pressure alters the free period of oscillation since the elastic component is greatly increased by the application of gas pressure while the mass is increased very little.

Combinations of any two or all three of the described methods can be used to obtain a greater degree of flexibility and control of the free period.

While there have been described and illustrated specific embodiments of the invention, it will be obvious that various changes and modifications may be made therein without departing from the field of the invention which should be limited only by the scope of the appended claims.

I claim:

1. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a bar of metal surrounded by a coil of wire, circuit means for supplying an electrical pulse to the coil, and means for continuously varying the free period of oscillation of the metal bar, said means comprising a change of one of the physical characteristics of said bar on which the free period depends.

2. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a bar of metal surrounded by a coil of wire, circuit means for supplying an electrical pulse to the coil, and means for continuously varying the free period of oscillation of the metal bar, said means comprising the cyclic variation over a pre-determined range of one of the physical characteristics of said bar on which the free period depends.

3. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a bar of metal surrounded by a coil of wire, circuit means for supplying an electrical pulse to the coil, and means for continuously varying the free period of oscillation of the metal bar, said means comprising a slidable weight movable to positions in contact with the bar which alter the free period in a cyclic manner.

4. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a tubular bar of metal surrounded by a coil of wire, circuit means for supplying an electrical pulse to the coil, means for continuously varying the free period of oscillation of the metal bar, said means comprising a slidable weight within the tubular bar and in contact with the sides thereof, and means for moving the weight to positions which alter the free period in a cyclic manner.

5. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a tubular bar of metal surrounded by a coil of wire, circuit means for supplying an electrical pulse to the coil, means for continuously varying the free period of oscillation of the metal bar, said means comprising a screw thread on the inside of the tubular bar, a weight having a screw thread cut on its exterior, means for turning the weight to position it at points within the bar where the free period of oscillation is changed.

6. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a tubular bar of metal surrounded by a coil of wire, circuit means for supplying an electrical pulse to the coil, means for continuously varying the free period of oscillation of the metal bar, said means comprising a slidable weight within the tubular bar and in contact with the sides thereof, and means for moving the weight from a node to an anti-node in a cyclic manner.

7. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a bar of metal surrounded by a coil of wire, circuit means for supplying an electrical pulse to the coil, and means for continuously varying the temperature of the bar over a pre-determined range to vary the free period of oscillation of the bar.

8. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a bar of metal surrounded by a coil of wire, circuit means for supplying an electrical pulse to the coil, and means for continuously varying the temperature of the bar over a pre-determined range to vary the free period of oscillation of the bar.

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tion of the bar, said means comprising circulating a liquid coolant around a portion of the bar.

9. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a bar of metal supported at a node by a supporting structure, a coil of wire surrounding the bar, circuit means for supplying an electrical pulse to the coil, and means for continuously varying the temperature of the bar over a pre-determined range of temperature values to cause a cyclic change in the free period of oscillation of the bar, said means comprising circulating a liquid coolant in contact with the supporting structure.

10. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a bar of metal supported at a node by a supporting structure, said structure containing one or more annular cavities for the circulation of a liquid, a coil of wire surrounding the bar, circuit means for supplying an electrical pulse to the coil, and means for continuously varying the temperature of the bar over a pre-determined range of temperature values to cause a cyclic change in the free period of oscillation of the bar, said means comprising circulating a liquid having a variable temperature through the annular cavities in the supporting structure.

11. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a tubular bar of metal having an interior cavity surrounded by a coil of wire, circuit means for supplying an electrical

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pulse to the coil, and means for continuously varying the free period of oscillation of the metal bar, said means comprising subjecting the interior cavity to a cyclic variation of gas pressure.

12. A magnetostrictive transducer for converting electrical energy into mechanical vibrations comprising, a hollow bar of metal surrounded by a coil of wire, circuit means for supplying an electrical pulse to the coil, a pipe connecting with the hollow portion of the bar, and means for continuously varying the free period of oscillation of the metal bar, said means comprising the application of gas under varying degrees of pressure to the pipe and said hollow portion.

References Cited in the file of this patent

UNITED STATES PATENTS

1,380,869	Fay	June 7, 1921
1,738,565	Claypool	Dec. 16, 1929
2,014,412	Pierce	Sept. 17, 1935
2,071,260	Holden	Feb. 16, 1937
2,317,166	Abrams	Apr. 20, 1943
2,401,943	Leigh et al.	June 11, 1946
2,419,373	Schrumm	Apr. 22, 1947
2,422,425	Lane	June 17, 1947
2,452,211	Rosenthal	Oct. 26, 1948
2,453,595	Rosenthal	Nov. 9, 1948
2,496,557	Norderskjold et al.	Feb. 7, 1950