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ULTRASONIC VIBRATION GENERATORS

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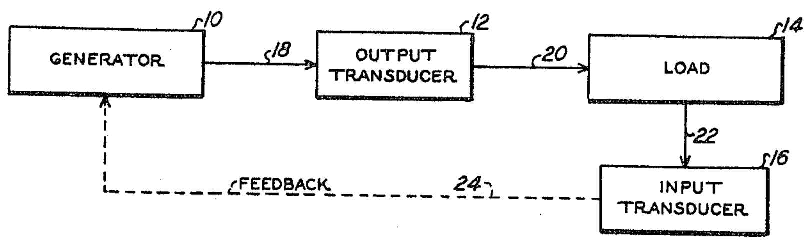

Fig. 1

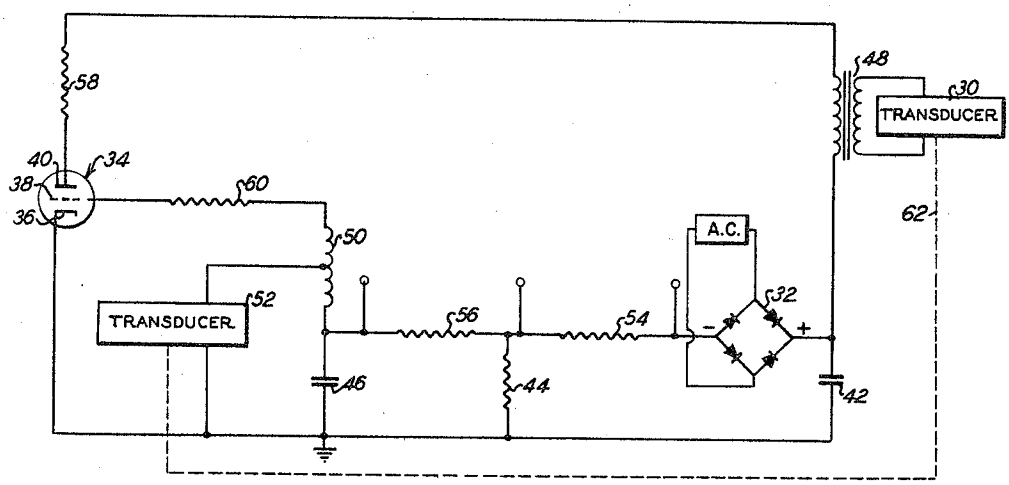

Fig. 2

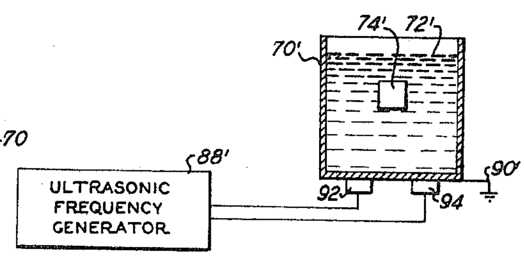

Fig. 4

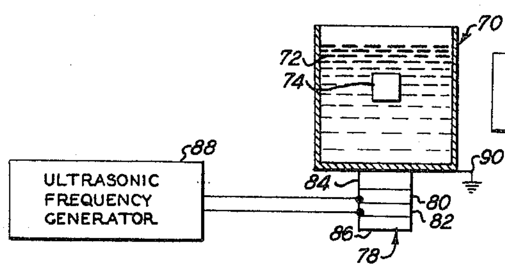

Fig. 3

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ULTRASONIC VIBRATION GENERATORS

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This application is a continuation of my application Serial No. 837,983, filed September 3, 1959, for Vibration Generators, now abandoned.

This invention relates to vibration apparatus and, more particularly, to apparatus used for generating ultrasonic frequencies and for controlling such generators.

A useful application of ultrasonic compressional wave energy has been made in the field of cleaning devices. In the conventional arrangement, an electromechanical transducer is placed in communication with the interior of a tank or container which is filled with a liquid which is usually a cleaning fluid. An electronic frequency generator or oscillator is arranged to generate a continuous ultrasonic frequency wave which is applied to excite the transducer. In turn, the transducer develops compression waves at ultrasonic frequencies in the cleaning fluid.

These waves are in the form of a conical, divergent beam directed away from the transducer. An object or article may be cleaned by being placed in the cleaning fluid within the zone of the beam.

It is the usual practice to place the transducer at the bottom of the tank so that the beam will be directed upwardly, and the objects to be cleaned are suspended, as by a tray or basket, above the transducer and within the zone of the beam. Sometimes several transducers are used.

The cleaning action is caused by the low-intensity standing compression waves produced by the transducer within the cleaning fluid. The differential pressures between the nodes and anti-nodes of the waves produce a violent circulation of the cleaning fluid. It is well-known that in any given frequency range, maximum activity of the cleaning fluid will occur when the operating frequency of the transducer is such that the height of the liquid in the tank is an exact number of one-half wave lengths produced by the transducer. It is desirable, therefore, that the transducer be tuned to vibrate at the frequency which will produce an exact number of one-half wave lengths in the liquid and, at the same time, be in the region of the transducer resonance.

A major disadvantage of the conventional type of ultrasonic frequency device is that the generator system must be adjusted by hand in order to tune the transducer to the desired frequency so that maximum agitation can be produced. Several variable factors determine the most efficient frequency, and all must be considered simultaneously, otherwise the transducer will operate at an incorrect frequency and low efficiency will result. Certain of the factors which affect the frequency which should be applied to the transducer are, for example, the level of the liquid in the tank, the load placed in the tank, the heating of the transducer, etc.

In previous types of ultrasonic frequency devices, it is necessary to adjust continuously the frequency by hand in order to compensate for such variable factors so as to maintain the transducer vibrating at the frequency which will give optimum results. The manual procedure required to keep the transducer vibrating at the desired frequency is not only cumbersome and inefficient, but it is almost impossible to keep the transducer tuned to exactly the correct frequency due to the fact that the variable factors may be continuously changing. The manual adjustment of the transducer will usually lag the frequency at which the transducer should be driven for optimum results.

Reference is made to ultrasonic cleaning devices for purposes of example only. Other useful applications of ultrasonic wave energy have been made, such as in ultrasonic drilling, ultrasonic heating of materials, etc. Certain of these other applications of ultrasonic wave energy employ electromechanical transducers which must develop high wave amplitudes. Transducers of this type will give the maximum amplitude and, consequently, the highest efficiency when they are driven at a frequency very close to their natural resonance.

Conventional systems for driving such transducers demand an oscillator or generator of high frequency stability, and this usually requires a master oscillator-power amplifier system. If a self-excited oscillator is used, it is imperative that a high Q tank circuit is employed, and this arrangement gives high circulating currents and results in the need for expensive coils and capacitors as well as an appreciable power wastage in the tank circuit. In these conventional type systems, it is necessary to use such devices as variable capacitors, etc. in order to adjust the system for a change in the resonant frequency of the transducer. None of the conventional systems lend themselves to automatic compensation should a change of resonant frequency of the transducer occur. These changes, under certain conditions, may be quite appreciable, and consequently it is a serious drawback in the conventional systems that the frequency generated must be adjusted continuously by hand in order that maximum wave amplitude may be produced.

Accordingly, it is one object of this invention to provide a method for automatically controlling or maintaining the frequencies impressed upon an electromechanical transducer.

Another object of this invention is to provide a transducer arrangement by which compression waves produced by the arrangement are adjusted automatically to give maximum results.

Another object of this invention is to provide a vibration system in which the frequency is controlled by means of an integral feedback arrangement.

Another object of this invention is to provide a self-monitored ultrasonic frequency vibrating system.

These objects, as well as others which will become apparent to those skilled in the art, may be accomplished by providing an electronic generator or oscillator for driving an electromechanical output transducer at ultrasonic frequencies, which transducer may be used to produce compression waves for a variety of applicants and a second or input transducer which is mechanical-electrical, for producing signals which are fed back to the frequency generator so as to maintain oscillation of the output transducer at the most effective frequency. The second or input transducer is acted upon by the compression waves produced by the output transducer. These waves are reflected back to the input transducer after they have been applied to whatever application the vibrations are used for. When the output transducer is oscillating at its most effective frequency, the reflected waves will be at a maximum, resulting in maximum voltage being generated by the input transducer and fed back to the frequency generator. In this manner, the frequency generator is controlled or monitored directly in response to the changes in frequency which may be impressed on the second or input transducer, and the frequency impressed on the output transducer will be adjusted accordingly.

Although specific reference is made to ultrasonic frequencies, it should be readily understood that the principles and apparatus disclosed in connection with this invention may be adapted to sonic frequencies.

The details of this invention and the mode of its operation will become apparent from the following description given by way of an example of an embodiment.

In the drawings:

FIG. 1 is a block diagram illustrating the basic concept of the invention;

FIG. 2 is a schematic diagram illustrating in detail the system for carrying out the invention;

FIG. 3 is a diagrammatic representation of a specific application of the invention; and

FIG. 4 is a modification of the arrangement illustrated in FIG. 3.

In FIG. 1, there is represented diagrammatically an electronic frequency generator or oscillator **10** for supplying vibrations at ultrasonic or sonic frequencies to an output electromechanical transducer **12**. In a well-known manner, the rapidly recurring voltages impressed upon the transducer **12** will causse the transducer to vibrate. These vibrations of the transducer **12** may be imparted to a load device **14** which in a practical application of the invention may be, for example, a tank containing a cleaning fluid, or a drill piece of an ultrasonic drilling apparatus, or the contact end of an ultrasonic heating apparatus.

Connected to the load device **14** is a mechanical-electrical input transducer **16** which receives vibrations from the load device **14** and converts these vibrations to voltage pulses which are fed back to the generator **10** for the purpose of monitoring the generator in response to the vibrations received by the input transducer **16**.

In the diagrammatic representation of FIG. 1, the line **18** represents an electrical link between the generator **10** and the output transducer **12**. The line **20** represents a mechanical link between the output transducer **12** and the load device **14**, and the line **22** represents a mechanical link between the load device **14** and the input transducer **16**. The links **20** and **22** are in the form of compression waves. The line **24** represents an electrical feedback link from the input transducer **16** to the generator **10**.

If the system of FIG. 1 is used, for example, in connection with a tank containing a cleaning fluid (load **14**), it is desirable that the frequency of the vibrations of the output transducer **12** produce a standing wave which corresponds to the height of the liquid in the tank, i.e., the height of the liquid should be an exact number of one-half wave lengths. This will produce maximum agitation of the liquid.

During such a condition, the wave energy created by the output transducer **12** will be maximum and, accordingly, the wave energy reflected to the input transducer **16** will be maximum and the voltage generated by the input transducer **16** and fed back to the generator **10** will be maximum. Should this condition change, because of a change in the level of the liquid, for example, the wave energy will not be maximum and the voltage generated by the input transducer **16** will be changed accordingly. The changed feedback voltage will then force the generator **10** to oscillate at a changed frequency which in turn is transmitted to the output transducer **12**. The new frequency impressed upon the output transducer **12** then represents the frequency at which maximum vibration and agitation of the liquid will take place. This controlling or monitoring of the generator **10** is completely automatic, without need for manual adjustment as in previous types of generator systems.

Control of the generator **10** may be made in response to wave amplitude in order to adapt the system for various other types of ultrasonnc frequency applications where high wave amplitude is desired, for example, in heating apparatus. It is necessary to consider the characteristics of the respective transducers for producing the desired controlling.

FIG. 2 shows a schematic diagram of a representative oscillating system for producing ultrasonic frequencies which can be monitored.

The system for causing ultrasonic frequencies to be impressed across an output tranducer **30** comprises a rectifier **32**, a triode **34** having cathode **36**, grid **38**, and plate **40**. A bypass capacitor **42** is supplied across the power supply. A resistor **44** provides the negative bias for the triode and also protects the rectifier **32** against high instantaneous currents should a short circuit occur in the capacitor **42**. A capacitor **46** across the bias network is a tuning capacitor used to resonate an output transformer **48** in the plate circuit. The output, or driver, transducer **30**, of course, is connected to the output transformer. An input grid transformer **50** has connected thereto an sensing and feedback transducer **52**. The voltage feedback for the grid is controlled by the transducer **52** and is dependent upon the voltage generated by the transducer **52** in accordance with the mechanical vibrations impressed thereupon.

A resistor **54** may be placed in the circuit so that the plate current may be read without breaking into the circuit, and a resistor **56** may be placed in the circuit so that the grid current may be read. Resistors 58 and **60** are anti-parasitic resistors.

In FIG. 3 there is illustrated a practical application of the system described above as it may be employed in an ultrasonic cleaning apparatus. There is provided a tank or container **70** containing a liquid **72** which may be a cleaning fluid. An article **74** which is to be cleaned is submerged in the liquid **72**. Such articles often are watch mechanisms, hypodermic needles, machined parts or similar articles which are not satisfactorily cleaned by ordinary washing methods because of their intricate contours.

A transducer assembly **78** is located beneath the tank **70** and in physical contact therewith. The transducer assembly **78** is of a composite type and comprises two adjacent, similar electrostrictive elements which may be of barium titanate, for example. It should be understood that magnetostrictive or piezoelectric elements may be employed as well. Passive matching sections **84** and **86** are provided at opposite sides of the elements **80** and **82**, respectively, and may be of steel or aluminum, for example. The members **80, 82, 84** and **86** are bonded together in the position illustrated in FIG. 3.

The element **80** is electrically connected to an ultrasonic frequency generator **88** and is driven thereby at the frequency produced by the generator so as to create vibrations which are physically transmitted to the liquid **72** to cause a zone of compression waves therein. The high frequency of the waves results in violent agitation of the liquid through and around the article **74** which is in the zone of the waves. In this manner, the article may be cleaned in a few seconds.

The compression waves are reflected to the element **82** and impress physical vibrations upon the element which in turn generates voltages in a well-known manner which are proportional to the vibrations. The element **82** is electrically connected to the generator **88** so that these voltages are fed to the generator. A ground **90** is provided to complete the circuit.

It is desirable that the element **80** oscillate at a frequency which will create maximum wave energy and agitation in the liquid **72**. Maximum wave energy will result in maximum vibration energy being reflected upon the element **82** and a maximum voltage feedback impressed upon the generator **88**. Any wave energy less than maximum will result in less than maximum voltage feedback. If the generator **88** receives less than maximum voltage feedback, it is forced to oscillate at a changed frequency which will produce maximum wave energy, and this changed frequency is the frequency at which the element **80** will subsequently be driven.

Control of the generator **88** in this manner is instantaneous, and maximum agitation of the liquid throughout a cleaning cycle is achieved. There is no need for hand tuning of the generator as in conventional devices.

In FIG. 4 there is illustrated a modification of the arrangement of FIG. 3. Corresponding parts in FIG. 4 have been given the same reference numeral with the addition of a prime. A tank **70'** contains a liquid **72'**, and an article **74'** which is to be cleaned is submerged in the liquid **72'**.

An output transducer **92** (corresponding to the element **80** of FIG. 3) is in physical contact with the bottom of the tank **70'** and connected to a generator **88'** which drives the transducer **92** at an ultrasonic frequency. A separate input transducer **94** (corresponding to the element **82** in FIG. 3) is in physical contact with the bottom of the tank **70'** and receives vibrations from the liquid **72'** and converts the vibrations to voltage pulses which are fed to the generator **88'**. A ground **90'** completes the circuit.

It should be noted in the arrangement of FIG. 4, that the output driver transducer **92** and the sensing input transducer **94** are separate and spaced apart, and not assembled into a single unit as in the FIG. 3 arrangement. If desired, the individual transducers may be placed on the sides of the tank. Also, more than one output transducer or more than one input transducer may be employed.

It will be apparent to those skilled in the art that the control system for the generator has application in fields other than ultrasonic cleaning devices, wherever a frequency generator or oscillator is employed to generate pulses for driving a transducer. Furthermore, systems using sonic frequencies may employ the control system, i.e., where the frequencies or pulses generated by a generating system to drive an output transducer will be within the sonic range, or where the frequencies of the vibrations applied upon an input transducer will also be within the sonic range.

Although certain embodiments of this invention have been described in detail, it will be apparent to persons skilled in the art that modifications may be made. Consequently, it is intended that the foregoing description should be considered as exemplary only and that the scope of the invention should be determined from the following claims.

I claim:

1. A system for producing mechanical vibration comprising an open top tank having a bottom face and adapted to receive a cleaning liquid and articles immersed therein,

an electromechanical transducer mounted in driving relation to said face, mechanical-electrical transducer means mounted in coupled relation to said face to receive energy therefrom including reflected energy propagatable toward said face by liquid in said tank, amplifier means having an output circuit connected to the electromechanical transducer, an amplifier input circuit, and means regeneratively coupling the mechanical-electrical transducer to said input circuit operative to effect oscillation of the system and operable in dependency on said reflected energy to resonate the tank at a frequency producing an exact number of half wave lengths in liquid therein and thus maximize the reflected energy.

2. A system for producing mechanical vibration comprising an open top tank having a bottom face and adapted to receive a cleaning liquid and articles immersed therein, transducer means comprising a pair of conversion elements stacked between a pair of passive matching sections mounted in mechanical energy exchanging relation with said face, and electrical amplifying means connected in driving relation to one conversion element regeneratively responsive to reflected energy in the liquid propagated to the other conversion element to resonate liquid in said tank at a frequency producing an exact number of half wave lengths in the liquid and lying in the region of transducer resonance.

References Cited by the Examiner

UNITED STATES PATENTS

1,912,213	5/1933	Nicolson	331—162
1,962,154	6/1934	Pierce	331—157
2,430,013	11/1947	Hansell	340—10
2,536,025	1/1951	Blackburn	310—82

OTHER REFERENCES

Fox, F. E., and Rock, G. D. (Technical Paper), Quartz Plate With Coupled Liquid Column as a Variable Resonator, Proc. IRE, vol. 30, No. 1, January 1942, pp. 29–33.

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