

[54] **ULTRASONIC MULTI-FREQUENCY SYSTEM**

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[58] Field of Search **181/5 R; 310/8.0, 310/8.1; 318/114, 116, 118**

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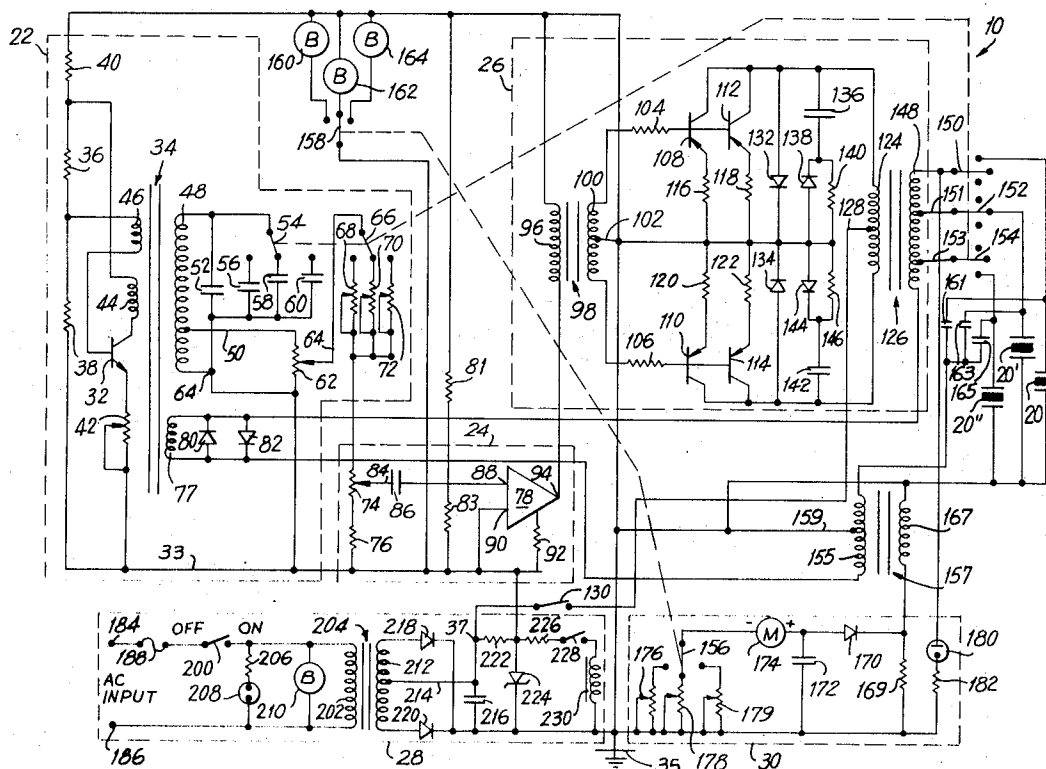
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ABSTRACT

The system includes converter means for transforming regular current; i.e., 60 cycles per second, to electrical current at different frequencies in the sonic and/or ultrasonic range for driving individual motors each connected to the converter means for being energized at a different frequency.

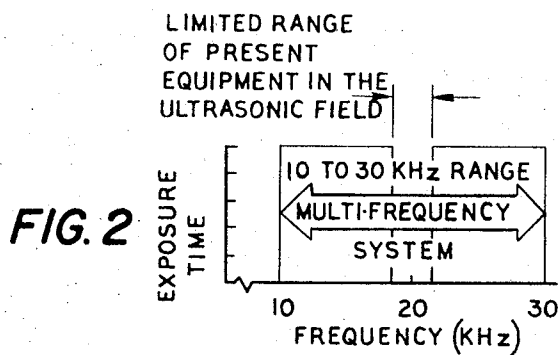
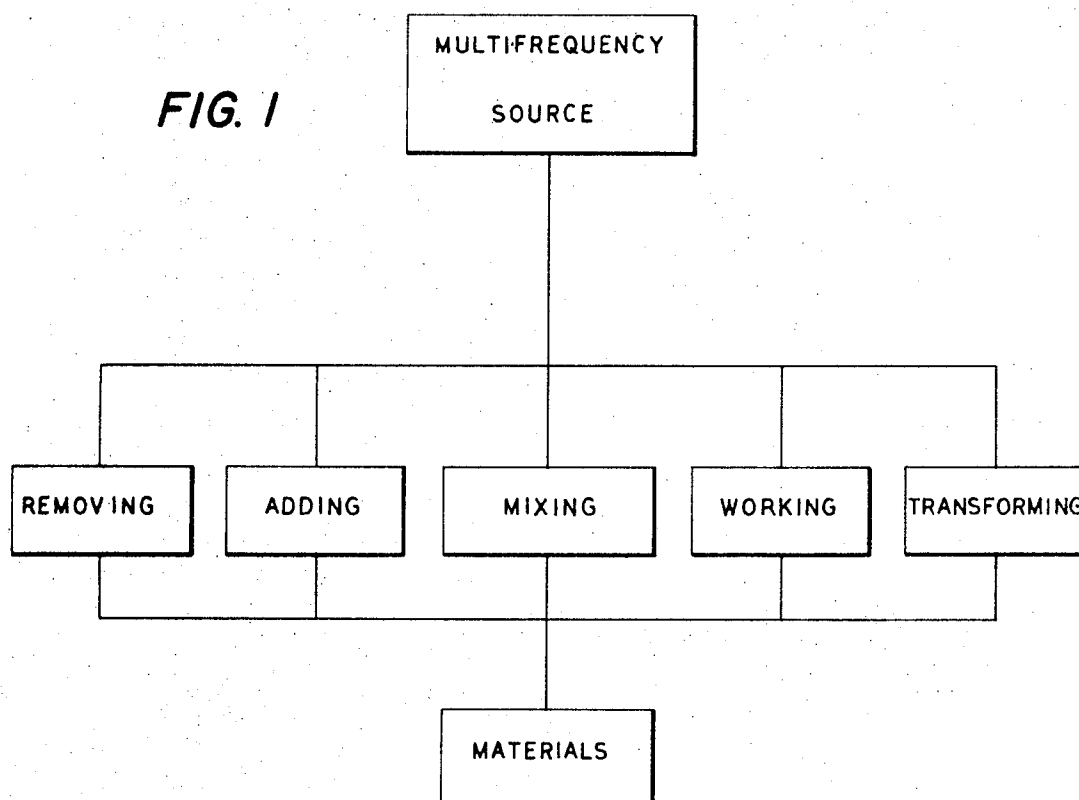
10 Claims, 5 Drawing Figures



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FIG. 3

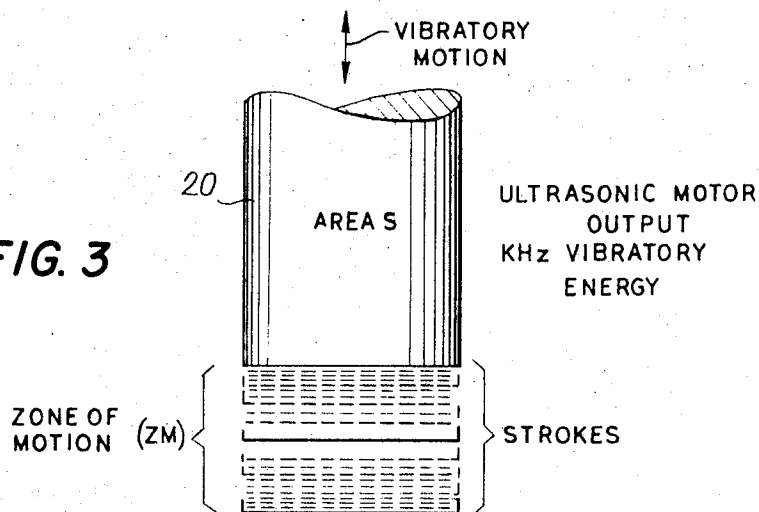
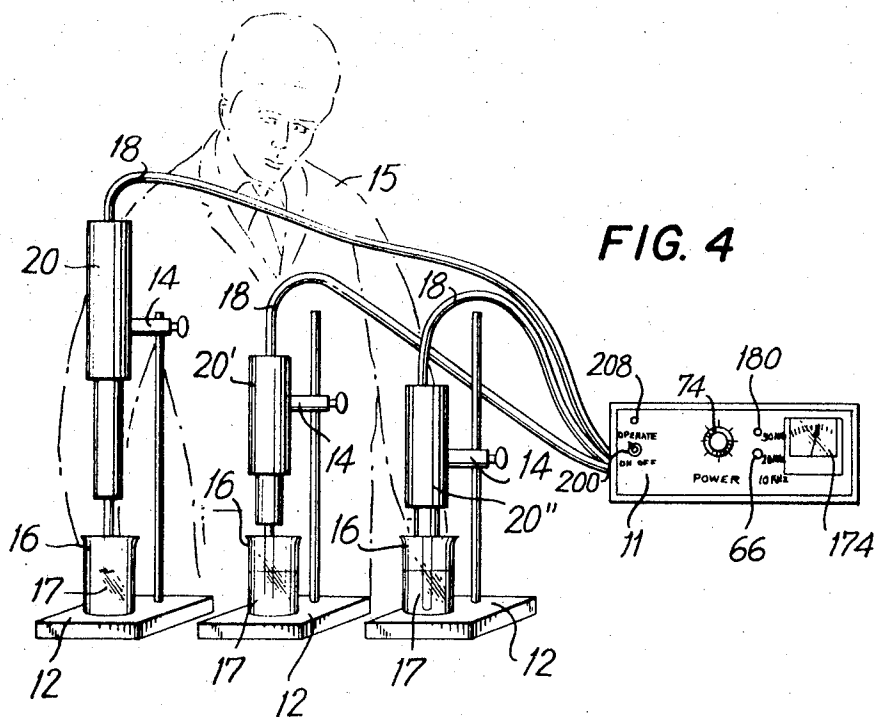


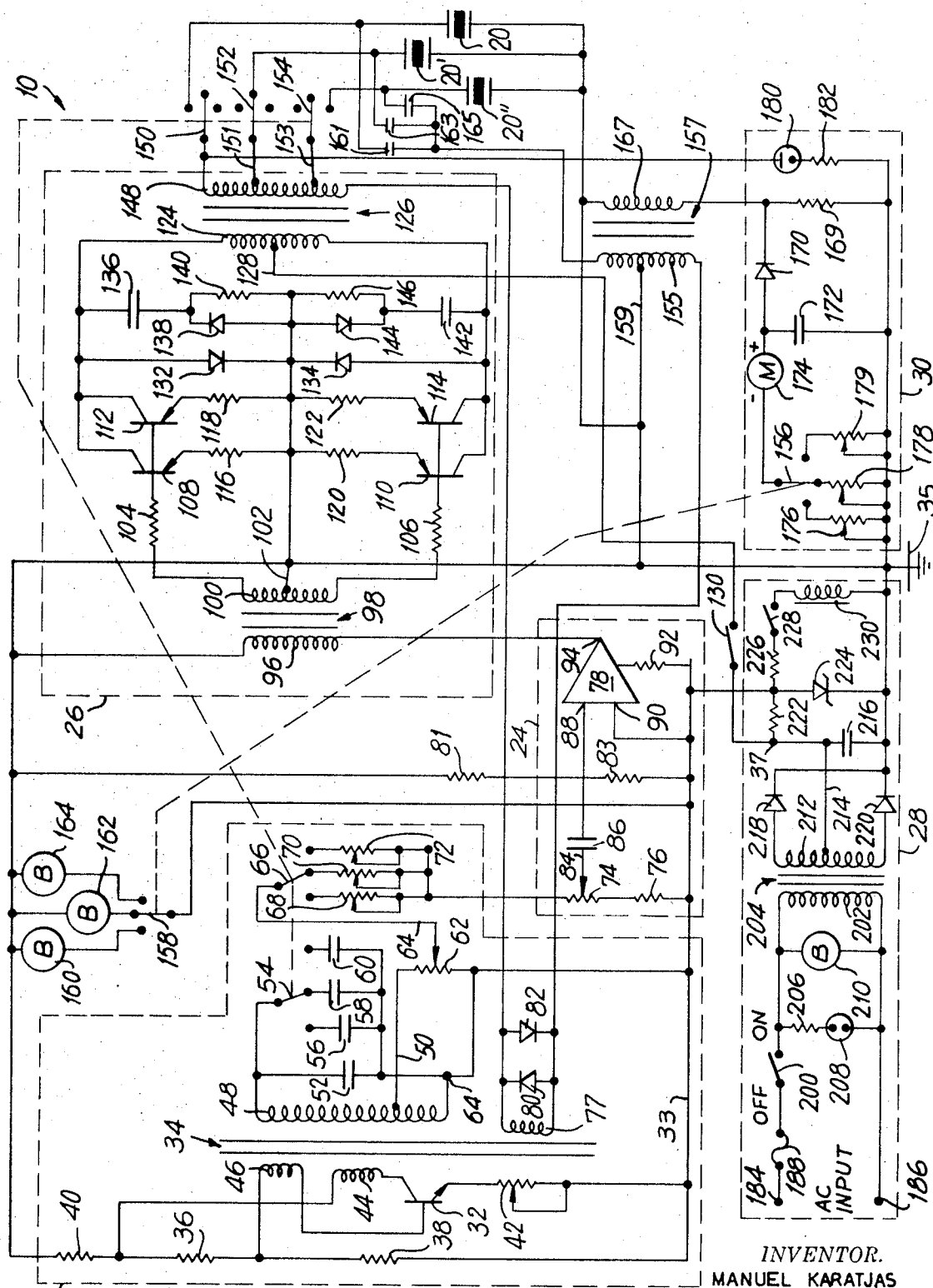
FIG. 4



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ULTRASONIC MULTI-FREQUENCY SYSTEM**BACKGROUND OF THE INVENTION**

The present invention provides a novel system in which a single converter means is capable of driving two or more sonic and/or ultrasonic motors at different frequencies to permit the utilization of these motors to perform a variety of functions.

Although the present invention will be hereinafter described in the context of providing an ultrasonic laboratory to the user for various applications, it is appreciated that other uses of this system of the present invention may be utilized for other purposes.

In the last decade, the applications for high frequency vibratory energy; for example, in the range of approximately 10,000 to 500,000 cycles per second, hereinafter referred to as the ultrasonic range, has found wide uses in a host of fields to produce a variety of results. Like the conventional rotary motor, the ultrasonic reciprocal motor has now been applied in various industries for both industrial as well as medical applications. Accordingly, there has been established a considerable amount of knowledge in the field of applied ultrasonics and various researchers throughout the country are presently in the process of utilizing ultrasonic energy to determine where new and more efficient uses may be found as well as improving applications that have already been found successful. One of the unique factors of ultrasonic energy is that one of the variables is frequency which, in turn, can produce different effects, as well as other variables such as exposure time, amplitude of vibration, power, etc. To date, commercial equipment in the field of ultrasonics is generally designed such that a single converter is designed for use with an ultrasonic motor operating at a particular frequency and in many instances a researcher, or other individual, attempting to utilize ultrasonic energy, has found that he has not been able to conveniently vary the frequency, and in order to obtain a change in frequency, another complete ultrasonic system of both a motor and converter would have to be purchased. In many instances, this equipment could either not be purchased or would be of special design and even at a greater cost than the conventional equipment. Obviously, this has hindered the further experimentation with ultrasonic energy since a change in frequency was not easily obtainable.

Applicant has now discovered that it is possible to provide a system in which a single converter is capable of individually driving two or more ultrasonic motors (three being shown herein for purposes of discussion) operating at for example 10 KHz (10,000 cycles per second), 20 KHz, and 30 KHz, all from a single power source. The present invention, therefore, fills a long-standing need of a single source of a sonic/ultrasonic technological system to be applied in diverse applications of applied energy for:

1. Fundamental Research,
2. Feasibility Studies,
3. Determination Of Effects, and
4. Production Development.

The ultrasonic system of the present invention is a portable source of intense ultrasonic energy and through its three primary variables, frequency, stroke, and time, provides the scientist as well as the researcher and lab technician an economical and versatile research vehicle. In this manner, the present system

provides an ultrasonic laboratory to the user giving him the wherewithall for proprietary research in any of the commercially applicable field of applied ultrasonics, as listed below under "SYSTEM UTILITY."

SYSTEM UTILITY**INDUSTRIAL APPLICATION**

1. Air Pollution
2. Cleaning
3. Compaction of Powder
4. Cutting and slitting (paper and soft materials with self cleaning action)
5. Deburring
6. Degassing. liquids, metals, etc.
7. Degreasing
8. Drilling ceramics, glass, minerals, etc.
9. Electroplating
10. Extrusion
11. Fluidization of Powders
12. Forging
13. Forming metals
14. Friction reduction
15. Impact grinding and machinery
16. Metal cutting
17. Metal - Metal join (weld)
18. Mixing, powder production, molecular distillation, friction reduction, nebulizing, poppution control
19. Plastic — Metal Assembly
20. Plastic — Plastic Assembly
21. Plastic forming
22. Plating
23. Soldering
24. Riveting
25. Weld — Slag removal
26. Wire drawing

FOOD PROCESSING

27. Ageing of whiskey
28. Chemical reactions
29. Homogenization
30. Improvement of wine and beer
31. Tenderizing

BIOLOGICAL AND MEDICAL RESEARCH

32. Animal physical therapy
33. Aid in assay of enzyme levels in connective tissue
34. Atomization
35. Catalysis
36. Cell Disruption
37. Cell wall synthesizing enzymes preparation
38. Cleaning
39. Deaerating
40. Defoaming
41. Degassing
42. Disintegration
43. Dispersion
44. Disruption of Chloroplasts subsequent to enzyme study
45. Disruption of bacteria to yield intact mitochondria
46. Disruption of bacteria for the study of viral replication and viral induced enzymes
47. Disruption of mitochondria in hair cells
48. Disruption of spermatozoa
49. Disruption of saureus in order to obtain histidine synthesizing enzymes
50. Disruption of tissue culture cells subsequent to enzyme studies

51. Emulsification
52. Extractions
53. Heart mitochondria fragment preparation for the study of protein synthesis
54. Homogenization
55. Liver and uterine metabolic studies
56. Metabolic studies of cornea
57. Mixing
58. Nebulizing
59. Ovum and animal growth
60. Plant and seed growth
61. Release of tumor enzymes
62. Sonochemical activation
63. Sterilization
64. Study of vitamin B-12 related enzymes
65. Submitochondria particle preparation for the study of enzymes systems
66. Surgery
67. Viral and other serum extractions

CONSUMER PRODUCT RESEARCH

68. Arts and Crafts (drilling gems, glass, enamels, porcelain, etc; engraving glass; cutting, linoleum, wood; assembling)
69. Cleaning — contact type and tank type (teeth, hands, nails, feet, hair)
70. Plastic toys and plastic components for sculpture; editing plastic film

In the prior ultrasonic motor-converter systems, generally the only method varying the exposure of ultrasonic energy to matter has been by increasing or decreasing the time of exposure or by changing the horns and tips. But, it has been common knowledge that the frequency at which one material may homogenize, disintegrate, or assemble, another may not. Yet, prior to this invention, proper experimentation required the user to purchase several pieces of ultrasonic equipment, each designed for a specific phase of his experimentation. In contrast to this, the present invention gives the user a flexibility in an ultrasonic system.

Accordingly, the present invention is usable to solve research development and production problems by introducing vibratory motion at controlled levels of energy and frequency into the application being investigated. The utility of the present system has broad application in the following fields:

Industrial Application, Food Processing, Biological and Medical Research, and Consumer Product Research. The list entitled "SYSTEM UTILITY" contained above is merely indicative of the wide uses to which the present invention may be applied and is not intended to be all inclusive but is herein provided for illustrative purposes only.

OBJECTS OF THE INVENTION

An object of the present invention is to provide a system in which a single converter is capable of powering two or more ultrasonic motors each operating at a different frequency.

Another object of the present invention is to provide for a user an ultrasonic system in which a series of motors are individually connected to a converter and the converter is capable of driving each motor individually at a different frequency.

Another object of the present invention is to provide a system such that the user is equipped with a facility

for sonic and ultrasonic experimentation while selecting his variables, with reproducible measurements.

Other objects of the invention will become apparent as the disclosure proceeds.

SUMMARY OF THE INVENTION

The present invention relates to an ultrasonic system in which a variety of variables are utilized in combination with each other to provide new and novel results permitting the user with a greater degree of versatility. The ultrasonic system includes a new and novel converter which is capable of converting conventional 60-cycle per second alternating current to current at a frequency of 10 KHz, 20 KHz, or 30 KHz, merely by the flip of a frequency switch mounted on the converter such that the user may electrically connect three motors to individual connectors on the converter and sequentially operate each motor at its own frequency form the single power source of the converter.

BRIEF DESCRIPTION OF THE DRAWINGS

Although the characteristic features of this invention will be particularly pointed out in the claims, the invention itself, and the manner in which it may be made and used, may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part hereof, wherein like reference numerals refer to like parts throughout the several views and in which:

FIG. 1 is a diagrammatic flow chart illustrating the functional uses of the multi-frequency system of the present invention;

FIG. 2 is a diagrammatic illustration of the frequency range of the present invention compared to the prior art;

FIG. 3 is a diagrammatic view of the output section of an ultrasonic motor which produces a Zone Of Motion;

FIG. 4 is a perspective view of the ultrasonic system in use illustrated with three motors; and

FIG. 5 is a schematic circuit diagram of the preferred embodiment of the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

Referring now to the drawings and particularly to FIG. 1 thereof we have a diagrammatic illustration indicating that the coherent vibratory energy produced by the respective ultrasonic motor is applied to materials to produce an end result. The applications are broadly classified to fall within the categories indicated in FIG. 1, namely Removing, Adding, Mixing, Working, or Transforming, of various materials. This flow pattern as therein illustrated permits the user with the ultrasonic multi-frequency system of the present invention to apply the coherent vibratory energy in one of the aforementioned manners to one or more materials to obtain one or more end results. A review of the SYSTEM UTILITY will clearly indicate that the process occurring in the designated applications hereinabove enumerated will fall within the confines of these five broad areas, and the present invention as hereinafter illustrated in further detail permits just such utilization.

FIG. 2 is a diagrammatic illustration of the frequency range of the present invention which permits the the to apply the ultrasonic energy over a broad frequency range; i.e., 10 KHz-30 KHz, so that the importance of

frequency and stroke of vibration may be appropriately varied to permit three experiments to be conducted simultaneously with a different frequency motor in use for each experiment, and with the flip of a switch each experiment can be exposed to mechanical energy at a different frequency of vibration and stroke. As seen the present equipment in the field of ultrasonics has a limited range of frequency, and this is generally at approximately 20 KHz.

The importance of being able to vary the frequency of vibration is in part illustrated with respect to FIG. 3 which illustrates that the output of an ultrasonic motor produces a "Zone of Motion" (ZM) which is generally defined as the stroke times the radiating area produced under working conditions. Although this is a relatively simple relationship, it is an all important phenomenon since it in part produces the variety of uses for which the ultrasonic motors are employed.

The ZM is microscopic, its stroke ranging from a few microns to several thousandths of an inch. However, though the motion is minute, the total strokes per second (2 times the frequency of the motor) enable the output end or tip to displace 1.2 liters of volume per square inch of tip each second. Based on a stroke of 0.0035 inch at 20 KHz, the tip travels a distance of 12 feet in 1 second, with a peak velocity of 18 ft. per second.

During oscillation each stroke of the tip at 20 KHz is generally a peak acceleration of over 72,000 times the acceleration of gravity. Herein lies the unique function of the motor, the dynamics of which cannot be attained by any other known instruments. Whether you are joining materials, removing material, forming materials, disrupting cells, solubilizing or homogenizing, what the tip of the motor does is completely determined by the stroke, frequency and cross-sectional area of the vibrating tip end.

The table below indicates that the volume displacement, distance traveled and peak velocity illustrated above for a stroke of 0.0035 inch at 20 KHz can be achieved with a stroke of 0.0023 inch at 30 KHz or a stroke of 0.007 inch at 10 KHz. The present invention in addition to offering the capability of varying the ZM and time exposure, offers the user of the system the capability of maintaining equal, tip volume displacement, tip distance traveled and tip peak velocity, while he evaluates the sonic/ultrasonic effect with changes in frequency. With the present invention the researcher can now evaluate the sonic/ultrasonic effects in his particular area, with the capability of controlling all the basic sonic/ultrasonic variables.

Motor Dynamics		Suggested Unit
1. Peak speed = $\pi fs = V_{peak}$		Ft./sec
2. Peak acceleration = $\pi^2 f^2 s = a_{peak}$		Multiples of "g"
3. Zone of Motion (per unit Sonotip output area per half cycle) = Stroke		mil
4. Volume Displacement per second = fs (per unit of Sonotip output area)		Litre/in ² sec
5. Total distance traveled in one second $d = 2fs$		Ft.
6. Plane wave peak acoustic pressure $P_{peak} = ZV_{peak} = \pi Zfs$		Atmosphere
7. Plane wave peak acoustic intensity $E_{peak} = \pi(P/2)_{peak} fs$		Watt/cm ²

Note that all relevant motor quantities which express the potential use value of the motor are simple combinations of f and s , frequency and stroke. Therefore, the greatest versatility comes from an availability of s -range and f -range.

FIG. 4 illustrates the utilization of a system 10 containing the electronic equipment and coupled to three ultrasonic motors 20, 20' and 20'' each designed to operate at a different frequency of vibration. The converter means 10 has a front panel 11 which contains an on-off switch 200 with a panel light 208 and a frequency selector switch 66 designed to be manually positioned at three different positions i.e. 10 KHz, 20 KHz and 30 KHz, and an operator light 180.

The converter means 10 also includes a power regulating means 74 provided with a control knob so that the power to the respective motor may be controlled. In the procedure being demonstrated the user 15 has each motor 20, 20' and 20'' vertically supported on a stand 12 having a clamp 14 for positioning the motors respectively in separate containers 16 having fluid 17 therein. Cable means 18 connects each motor to the converter means 10 by individual receptacles. In this manner if only two or even one motor was desired to be used this is possible. Accordingly by the system herein described the user has the necessary flexibility to conduct various experimentation at different frequencies of vibration and power. A meter 174 is also provided on the front panel 11 for visible indication of the power emitted from the motor.

Referring now, more specifically to FIG. 5, which is a schematic circuit diagram of a preferred embodiment of an ultrasonic multi-frequency generating system 10. The ultrasonic motor or transducer 20 is shown symbolically as a crystal at the right hand edge of the schematic circuit diagram of FIG. 5. Ultrasonic motors 20' and 20'' are similar to motor 20 but, are designed to operate at 20 KHz and 30 KHz respectively, while motor 20 in the preferred embodiment is designed to operate at 10 KHz.

It is to be understood that the frequencies of 10, 20, and 30 KHz are chosen as merely illustrative and are not meant to limit the scope of the invention.

For convenience, and ease in explanation, the circuit diagram of FIG. 5 is sub-divided by bold dashed lines into functional sub-units. The functional sub-units are as follows: (a) oscillator unit 22, (b) the amplifier units 24, and 26, (c) the power supply unit 28, and (d) the metering unit 30. The oscillator unit 22 comprises a transistor 32, a transformer 34, a resistance divider including resistors 36, and 38, voltage dropping resistor 40, and an adjustable emitter resistor 42 connected in a conventional Hartley oscillator circuit.

The collector winding 44 is connected from the collector electrode of transistor 32 to the junction of resistors 36 and 40. The first feedback winding 46 is connected from the base electrode of transistor 32 to the junction of resistors 36 and 38 and is polarized to provide proper feedback to insure oscillations when current flows in the collector winding 44. The voltage divider comprised of resistors 36 and 38 are connected in series with resistor 40 between a source of DC voltage 33 which is approximately 36 volts in the preferred embodiment of the invention and a ground reference 35. Resistor 42 is coupled from the emitter electrode of transistor 32 to the source of DC voltage 33 and is adjusted to insure proper emitter current to sustain oscillations.

The output winding 48 of transformer 34 is provided with a tap 50 thereon. Across winding 48 is connected a fixed capacitor 52. The contacts of a switch 54 is arranged in a conventional manner to select the fre-

quency determining capacitors 56, 58 and 60. The function of switch 54 will be explained in connection with the operation of the system thereafter.

A potentiometer 62, which provided impedance matching, is connected from the tap 50, to one end 64 of winding 48 which is also connected to the source of B+ (33). The wiper arm 64 of potentiometer 62 is connected to a switch contact 66 which is ganged to switch contact 54 described earlier. Switch contact 66 is used to select either variable resistor 68, 70 or 72, which is serially connected to variable resistors 74 and fixed resistor 76. A second feedback winding 77 is provided on transformer 34. The function of second feedback winding 77 will be described hereinafter. Diodes 80 and 82 are poled for ease in conduction in opposite directions (back to back) and connected across second feedback winding 77, thereby, limiting the maximum voltage across the winding to approximately 0.6 volts peak-to-peak.

The amplifier unit 24 is referred to as the low power unit or buffer amplifier, and is comprised of an integrated circuit amplifier 78, in the preferred embodiment of the external resistors and capacitors, not shown, to provide a substantially flat frequency response from 10 KHz to 30 KHz. The DC bias for the amplifier 78 is provided by resistors 81 and 83 which are connected from the source of DC voltage 33 to the reference ground 35. The voltage appearing at the wiper arm 84 of potentiometer 74 is capacity coupled, via capacitor 86 to one input terminal 88 of amplifier 78. The second input terminal 90 of amplifier 78 is connected to the DC operating voltage 33. Further bias to amplifier 78 is provided by a resistor 92. The output terminal 94 of amplifier 78 is coupled to the primary winding 96 interstage transformer 98.

Interstage transformer 98 is part of power amplifier 26 and has mounted thereon a secondary winding 100 which is provided with a center-tap 62 that is connected to the reference ground 35. Power amplifier 26 is further comprised of resistors 104 and 106 which are coupled from the ends of winding 102 to the base electrodes of power transistors 108 and 110 respectively. Transistors 108 and 110 are connected in parallel with transistors 112 and 114, respectively.

The emitter electrodes of transistors 108, 112, 110, and 114 are coupled via resistors 116, 118, 120 and 122 respectively to the center tap 102. Resistors 116, 118, 120 and 122 are of equal value and insure the equal distribution of emitter current in transistors 108, 112, 110, and 114. The collector electrodes of transistors 108 and 112 are connected to one end of primary winding 124 of output transformer 126. The collector electrodes of transistors 110 and 114 are connected to the other end of winding 124. The center-tap 128 of winding 124 is coupled via the power amplifier ON-OFF switch 130 to a source of operating DC voltage 37 which, in the preferred embodiment of the invention is a higher DC voltage value than the operating voltage 33.

The power amplifier 26 is connected in a conventional manner and is capable of functioning as a class B or class C push-pull amplifier depending on the peak-to-peak amplitude of the driving voltage appearing across winding 100.

Further included in power amplifier 26 and coupled across the emitter-collector electrodes of transistors 112 and 114 are diodes 132 and 134 respectively. Di-

odes 132 and 134 limit the reverse voltage that appears across the emitter-collector junctions of transistors 112 and 114.

Capacitor 136, connected in series with the parallel connection of diode 138 and resistor 140, are connected across the emitter-collector electrodes of transistor 112 and functions to reduce transients which occur when the transistors 108 and 112 are driven from cut-off into conduction.

Capacitor 142 connected in series with the parallel connection of diode 144 and resistor 146 are connected across the emitter-collector electrodes of transistor 114 and function in a manner similar to capacitor 136, diode 138 and resistor 140.

It is to be noted that although PNP transistors are schematically shown in FIG. 5 for transistors 108, 112, 110, and 114; and a PNP transistor is schematically shown for transistor 32, transistor with reversed polarity types may be used by proper reversal of the source of operating voltage, in a conventional manner, by those familiar with the transistor art.

The secondary winding 148 of transformer 126 has one end connected to switch contact 152, a first tap 151 connected to switch contact 152, a second tap 153 connected to switch contact 154. Switch contacts 150, 152, and 154 are ganged together and select which transducer 20, 20', or 20'' is to be energized.

The other end of winding 148 is connected to one end of the second feedback winding 78 transformer 34. The other end of winding 78 is connected to the primary winding 158 of transformer 157. A tap 159 on winding 155 is connected to ground. The other end of winding 115 is coupled to feedback capacitors 161, 163 and 165 which are connected together. The other ends of feedback capacitors 161, 163 and 165 are connected to the high voltage side of transducers 20, 20' and 20'' respectively.

Secondary winding 167 of transformer 157 is coupled has one end connected to the ground reference 35 and the other end connected to one end of resistor 169 located in the metering unit 30, the other end of resistor 169 being connected to the ground reference 35.

A diode 170 is coupled from the high voltage end of resistor 169 to capacitor 172 rectifying the AC voltage appearing across resistor 169 and storing it as DC voltage in capacitor 172. Serially connected across capacitor 170 is a meter 174, switch contact 156, and either resistor 176, 178 or 179, which is selected by the position of switch contact 156. Resistors 176, 178, and 179 are adjustable and are used to give a relative indication of the power being supplied to the transducers 20, 20' or 20''. The resistors 176, 178 and 179 are variable and are adjusted to compensate for the losses in transformer 157 due to changes in the operating of each transducer.

A neon bulb connected in series with a resistor 182 is connected from the high voltage side of winding 148 to the ground reference and is illuminated when the power amplifier unit 26 is on and high voltage, approximately 700 volts, is present.

Switch contacts 150, 152, 154 are also ganged to switch contacts 54, 66, 156, which is part of the metering unit 30, and switch contact 158 which energizes the blower 160, 162 or 164. Blowers 160, 162, and 164 are mounted in close proximity with transducers 20, 20', and 20'' respectively and function to provide the necessary cooling for them. Switch contact 158 supplies

the necessary energizing voltage to either 160, 162, or 164.

The power supply unit 28 has in the preferred embodiment of the invention, a source of commercial AC voltage connected to it across input terminals 184 and 186. Terminal 184 is coupled via fuse 188, main power switch 200, to the primary winding 202 of transformer 204. Resistor 206 is coupled in series with resistor 208 across primary winding 202 of transformer 204. A blower 10 is also coupled across winding 202 and is used for cooling the power transistors 108, 110, 112 and 114.

The secondary winding 212 of transformer 204 is provided with a center-tap 214 which is coupled to one said of capacitor 216. The other side of capacitor 216 is coupled to the ground reference 35. Diodes 218 and 220 are connected to each end of winding 212 in a conventional full-wave rectifying circuit with the center-tap 214 of winding 212 functioning as the negative DC voltage connected to point 37 mentioned earlier. The cathode electrodes of diodes 218 and 220 are coupled in common to the reference ground 35.

A dropping resistor 222 is coupled to the anode electrode of Zener diode 224 to bias the Zener diode to its operating point which has its cathode electrode coupled to the reference ground 35. Zener diode 224 provided a regulated DC of approximately 36 volts, in the preferred embodiment of the invention, for use by the low power amplifier unit 24, and oscillator unit 22. The Zener diode also provided energizing voltage through resistor 226, switch 228 to stepping relay 230. Stepping relay 230 has its other end coupled to the reference ground 35. Intermittent closing of switch 228 energizes stepping relay 230 which in turn steps ganged contacts 54, 66, 150, 152, 154, 156 and 158 to their first (10 KHz), second (20 KHz), or third (30 KHz) positions.

Although a manual stepping switch 228 and stepping relay 230 has been shown in the preferred embodiment of the invention it is understood that multiple combinations of switches and relays may be connected in a conventional manner to provide the equivalent selection of the first, second, or third multiple switch positions.

In operation, the commercial source of AC power is connected across terminals 184 and 186. Closing the main the power switch 200 energizes pilot light 208 and supplies an AC voltage to the primary winding 202 of transformer 204 which in turn couples the AC electrical energy to the secondary winding 212. The diodes 218 and 220 rectify the AC electrical energy and changes it to a DC voltage which is stored across capacitor 216 and lowered by resistor 222 to cause Zener diode 224 to be biased to its operating point.

The DC voltage across Zener diode 224 provides the negative DC operating voltage 33 for the oscillator unit 22 (transistor 32), which will start oscillating at a frequency depending upon the preselected position of switch contact 54, which is shown in FIG. 5, in the 20 KHz position. The frequency response of transformer 34 in conjunction with the capacitors 52, 56, 58 and 60; and the feedback winding 46 insure oscillations at approximately 20 KHz in the second position shown, at 10 KHz in the first position, and 30 KHz in the third position. The frequency response of the secondary winding 48 of the transformer 34 in conjunction with capacitor 52 and 58 in parallel is sufficiently narrow to prevent the oscillator from oscillating at a multiple of the frequency selected.

The AC energy is coupled via wiper arm 64 of potentiometer 62 through resistor 70, to potentiometer 74 and resistor 76. Resistors 68, 70 and 72 are adjusted to provide a fixed voltage at the common junction of resistors 68, 70, 72, and potentiometer 84. Moving wiper arm 84 to the top of potentiometer increases the output signal while moving wiper arm 84 to the bottom of potentiometer 74 lowers the output signal.

The AC signal is coupled, via capacitor 86 to the input of integrated circuit amplifier 78 where it is amplified. The signal is then coupled to primary winding 96 of transformer 98 where it is coupled to the base of transistor 108 and 112 via resistor 104, and transistors 110 and 114 via resistor 106.

Depending on the signal polarity either transistors 108 and 112 or transistors 110 and 114 will conduct if switch 130 has been closed to supply operating voltage to the collector electrodes of the power transistors, via center tap 128 of winding 124. The AC signal will then be coupled, via switch contact 152, to the transducer (electronic motor 20') but, will be very small in magnitude. The low signal voltage will also be coupled, via feedback capacitor 163, to winding 155 of transformer 157 which in turn couples the signal to the second feedback winding 77 of transformer 34 in the proper polarity to reinforce or sustain the signal appearing there from the oscillations produced by transistor 32. The signal is then coupled into secondary winding 48 on transformer 34 where it sustains the voltage appearing there also. The low level voltage is rapidly coupled through the stages as described earlier and provides sustaining or reinforcing voltages at each stage and assumes a frequency of operation which is determined by the transducer.

The magnitude of the feedback signal is limited in its peak-to-peak value by diodes 80 and 82 and is of greater magnitude than the value provided by the oscillator. The function of the oscillator is merely to insure starting at the proper frequency since the transducer is capable of operating at frequencies other than its fundamental frequency. Once the feedback loop is completed the oscillations are self sustaining and the oscillator can be removed from the circuit.

The amount of power supplied to the transducer 20' may be adjusted by the setting of the wiper arm 84 of potentiometer 84 and the greater the power supplied to the transducer the greater the mechanical deviations.

An indication that the power amplifier is on, is obtained by lamp 180 being illuminated. The meter 170 indicates the relative amount of energy being supplied to the transducer 20' and blower 210 insures that the power transistors 108, 110, 112 and 114 do not over-heat.

Operation at 10 KHz or 30 KHz is exactly the same as that described above for 20 KHz and may be selected by choosing the first or third position of the ganged switch contacts in the manner described.

Thus, heretofore has been disclosed a multi-frequency converter capable of operating in the sonic through ultrasonic frequency range which utilizes a frequency preselected oscillator and a single amplifier which is capable of driving a multiple of preselected transducers.

While the invention has been described by means of a specific embodiment, it is not intended to be limited thereto, and obvious modifications will occur to those

skilled in the art without departing from the spent and scope of the invention.

I claim:

1. A system for providing multi-frequency mechanical energy in the sonic and ultrasonic frequency range comprising:

A. starting oscillator means adapted to be connected to a source of electrical energy, capable of oscillating at several preselected frequencies responsive to a preselected command for providing a starting voltage, said oscillator means including:

a. a transistor, having emitter, base, and collector electrodes, said emitter electrode being adapted to be resistively coupled to a source of DC voltage, said collector electrode being resistively coupled to a reference ground,

b. a transformer having a primary winding, a secondary winding having an impedance matching tap thereon, and a first and second feedback winding, said primary winding being coupled between said collector electrode and said reference ground, one end of said secondary winding being connected to said source of voltage, said second feedback winding being coupled to transducer means,

c. first and second resistors being coupled in series, having a junction point, between said source of DC voltage and said reference ground, said junction point being coupled to said base electrode via said first feedback winding, and

d. capacitor means coupled across said secondary winding for determining the frequency of said oscillator;

B. amplifier means coupled to said oscillator means for amplifying said starting voltage at each said preselected frequency; and

C. said transducer means coupled to said amplifier means for changing the amplified starting voltage to mechanical energy and providing a feedback voltage to said oscillator transformer sustaining each said preselected frequency.

2. A system for providing multi-frequency mechanical energy in the sonic and ultrasonic frequency range according to claim 6 wherein said amplifier means comprises a low level integrated circuit amplifier and a power amplifier.

3. A system for providing multi-frequency mechanical energy according to claim 2 wherein said power amplifier comprises:

a. an interstage transformer, having a primary winding adapted to be coupled to said low level amplifier and a secondary winding with a center-tap

thereon,

b. at least two power transistors having emitter collector and base electrodes, said base electrodes being adapted to be resistively coupled to the ends of the secondary of said interstage transformer winding, said emitter electrodes adapted to be resistively coupled to said interstage transformer center-tap, and

c. a power output transformer having a primary winding with a center-tap thereon, and a secondary winding having multiple taps thereon, adapted to be connected to said transducer means, said primary winding being connected to the collector electrodes of said power transistors, said center-tap being adapted to be connected to a source of operating potential.

4. A system for providing multi-frequency mechanical energy according to claim 3 further including a pair of diodes coupled from the collector electrodes of said power transistors to said center-tap of said interstage transformer.

5. A systems for providing multi-frequency mechanical energy according to claim 3 further including a capacitor connected in series with a resistor and diode connected in parallel, coupled between the collector electrodes of said power transistors and said interstage transformer center-tap.

6. A system according to claim 1 further including a potentiometer coupled between said source of DC voltage and said secondary winding impedance matching tap for providing an adjustable output voltage.

7. A system according to claim 1 further including a pair of diodes connected in parallel across said second feedback winding, said diodes being oppositely poled in ease of conductivity.

8. A system according to claim 1 wherein said capacitor means includes:

a. first, second, third and fourth capacitors, said first capacitor being connected across said secondary winding, said second, third and fourth capacitors having one side of each coupled in common to said source of DC voltage and one end of said secondary winding, and

b. switch means connected from the other end of said secondary winding and either of the other ends of said first, second, or third capacitors.

9. A system according to claim 8 wherein said switch means comprises a three position selector switch.

10. A system according to claim 8 wherein said switch means comprises two relays connected to effectively function as a three position switch.

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