Oct. 10, 1967 B. J. EISENKRAFT 3,346,189

ELECTROMECHANICAL ATOMIZER APPARATUS

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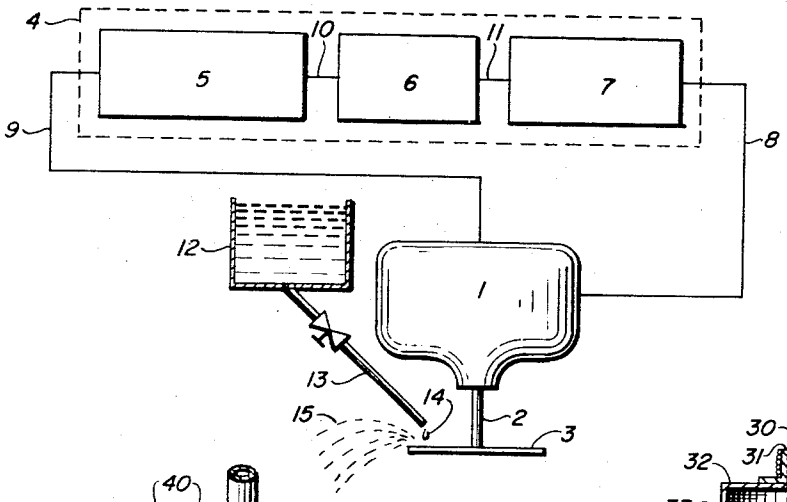

Fig. 1

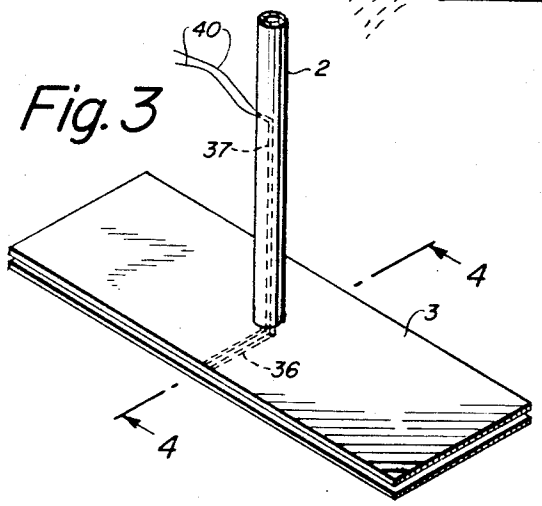

Fig. 3

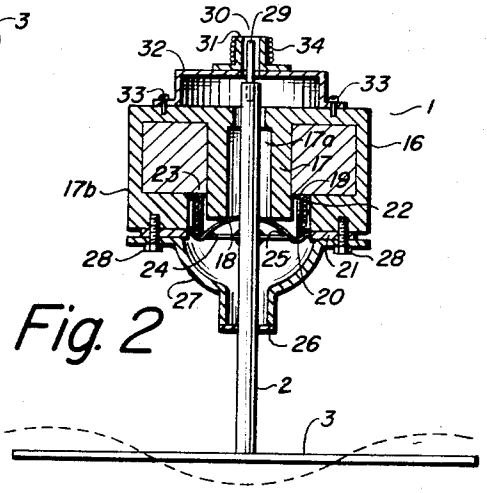

Fig. 2

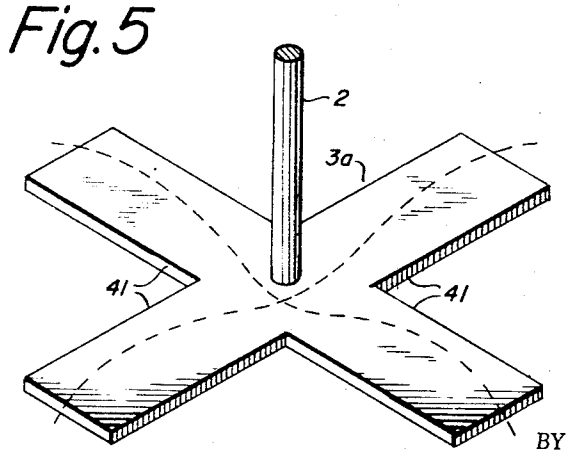

Fig. 5

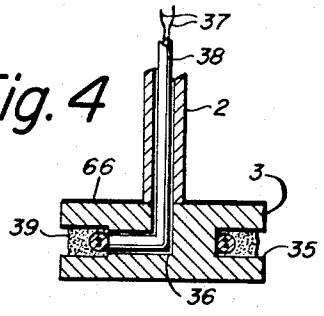

Fig. 4

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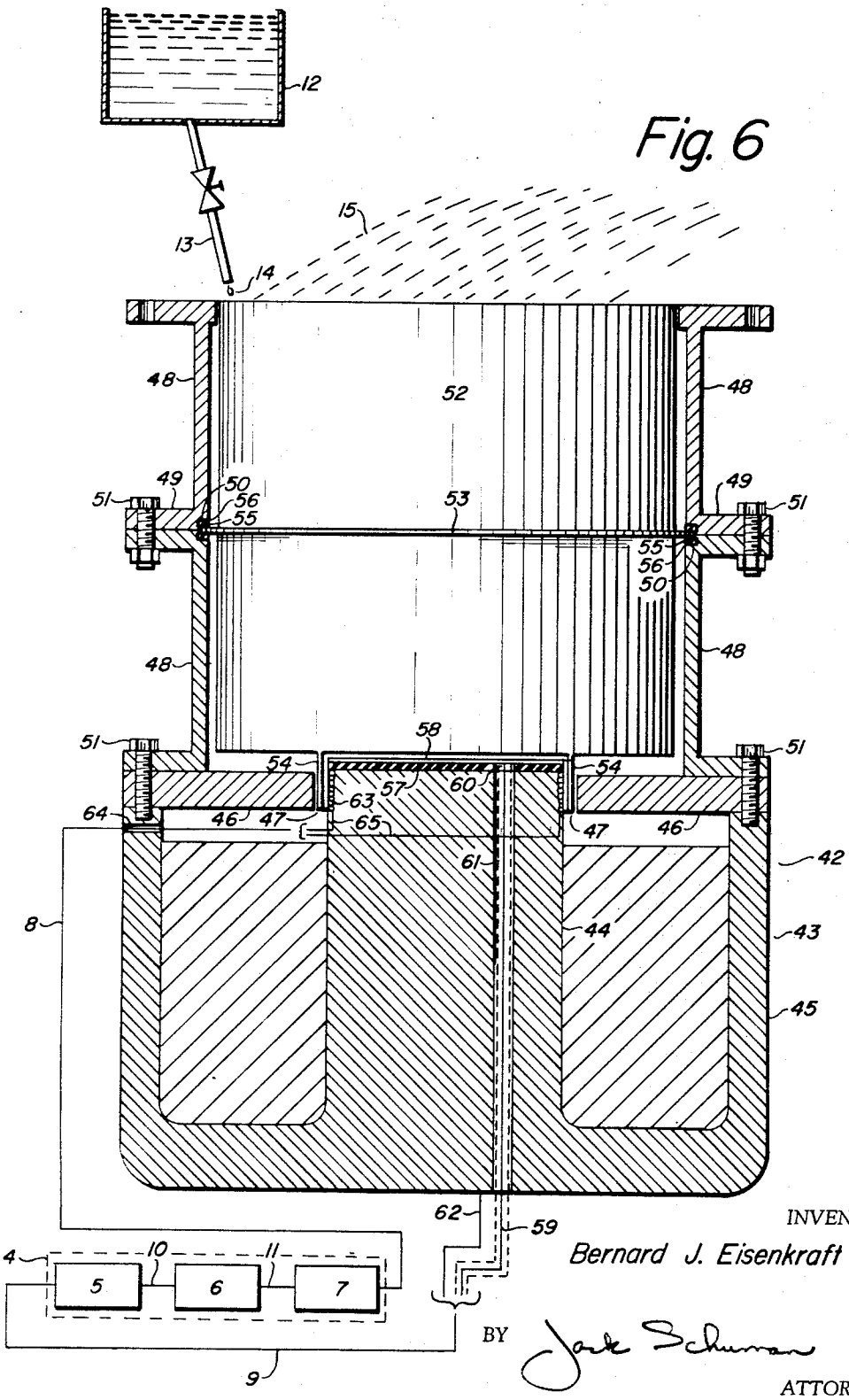
Fig. 6



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ELECTROMECHANICAL ATOMIZER APPARATUS

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11 Claims. (Cl. 239—102)

ABSTRACT OF THE DISCLOSURE

An atomizing bar, mounted to a drive rod extending through a bore in the central pole of a pot magnet, is vibrated by means of A.C. current passing through a winding around one end of the drive rod and reacting with the field of the magnet. A heating element extends through the drive rod and around a recess in the periphery of the bar. The bar may have more than two arms radiating from a central point and may also be specially coated with material wettable by the liquid being atomized. In another species, an atomizing cylinder adjacent the central pole of a pot magnet is vibrated by A.C. current passing through a driving coil adjacent the central pole of tre magnet.

This invention relates generally to apparatus for dispersing a liquid into finely divided droplets and, specifically, to electromechanical atomizer apparatus for this purpose.

There are numerous areas in many industries, notably the chemical, pharmaceutical and metallurgical fields, that require the production of finely divided particles from a substance in liquid form. The substance may be liquid at ambient temperatures, or may exist as a liquid only at elevated temperatures. Thus, in a spray chilling process, solid substances are heated to the liquid state and, in this state, are atomized in air which may be at ambient temperature, the finely divided particles freezing to a beaded powder which comprises spherical droplets. My earlier patents, U.S. 2,779,623 and 3,038,532, disclose electromechanical atomizer apparatus eminently suited to the foregoing applications, particularly in the field of spray chilling, and I have produced with such apparatus beaded powders having a size distribution of approximately 100–1000 microns with unusually narrow size distribution, practically eliminating dusting problems and further sieving.

The present invention is directed to improvements in the electromechanical atomizers disclosed in my earlier patents. In one aspect of my invention, an improved electromechanical transducer is provided to drive vibrating bar means or vibrating cylinder means. In another aspect of my invention, means are provided for heating the vibrating bar means while in operation. In yet another aspect of my invention, a cruciform arrangement of vibrating bar means is provided for operation by a single electromechanical transducer to increase the capacity of the system.

One of the objects of my invention is to provide improved electromechanical atomizer apparatus.

Another object of my invention is to provide electromechanical atomizer apparatus employing improved electromechanical transducer means.

A further object of my invention is to provide electromechanical atomizer apparatus which includes means to heat the vibrating bar while the same is in operation.

Still another object of this invention is to provide electromechanical atomizer apparatus employing a cruciform arrangement of vibrating bars operated by a single electromechanical transducer to increase the capacity of the system and the concentration of atomized droplets in a fixed area.

Yet a further object of this invention is to provide electromechanical atomizer apparatus in which the pickup for the feedback circuit is located at a distance from the vibrating bar and well away from the liquid spray area.

Still a further object of this invention is to provide electromechanical atomizer apparatus employing an improved electromechanical transducer with a cylindrical atomizing element.

Another object of this invention s to provide an atomizing member with a surface that is wettable by the liquid being atomized for optimum atomization and narrow droplet size distribution.

Other and further objects of my invention will become apparent during the course of the following description.

Referring now to the drawings in which like numerals represent like parts in the several views:

FIGURE 1 represents a view in elevation, partially diagrammatic, showing one form of the present invention.

FIGURE 2 represents an enlarged medial section of the electromechanical transducer and vibrating bar shown in FIGURE 1.

FIGURE 3 represents an enlarged perspective view of the vibrating bar and drive rod and showing the means for heating the vibrating bar while the same is in operation.

FIGURE 4 represents a transverse section of the bar of FIGURE 3, taken along the line 4—4 of FIGURE 3.

FIGURE 5 represents a perspective view of the cruciform vibrating bar arrangement.

FIGURE 6 represents a medial vertical section of another form of electromechanical transducer with a cylindrical atomizing element, showing also in diagrammatic form the related circuitry and feed means.

Referring now to the form of invention shown in FIGURE 1, electromechanical transducer **1** is provided with drive rod **2** rigidly connected to atomizing bar **3** at the center thereof. Electromechanical transducer **1** is powered by the circuitry encompassed by block **4**, which circuitry is shown diagrammatically as comprising a preamplifier **5**, phase shifter **6** and power amplifier **7**. As taught in my U.S. Patent 2,779, 623, power amplifier **7** drives electromechanical transducer **1** through line **8**, said electromechanical transducer **1** in turn reciprocating drive rod **2** thereby causing atomizing bar **3** to vibrate, it being apparent that the point of connection of drive rod **2** with atomizing bar **3** will be an antinode. Feedback line **9**, connected to means in the electromechanical transducer **1** electrically responsive to the vibrations of drive rod **2** and atomizing bar **3** which means will hereinafter be described, communicates to preamplifier **5** an electrical signal indicative of the state of vibration of atomizing bar **3** and sensing any tendency of atomizing bar **3** to depart from vibrating at the resonant flexural mode to which it has initially been tuned to vibrate. This preamplified signal is fed through line **10** to phase shifter **6** and thence through line **11** to power amplifier **7**, whereby the output of power amplifier **7** is corrected and adjusted to maintain atomizing bar **3** vibrating at the desired resonant flexural mode, all as taught by my U.S. Patent 2,779,623. Reservoir **12**, provided with valved feed line **13**, introduces liquid feed **14** to be atomized to a face of said atomizing bar **3** which disperses said liquid feed **14** into a spray **15** of finely dispersed droplets. Instead of the one valved feed line **13** shown in FIGURE 1, additional valved feed lines **13** leading to other portions of atomizing bar **3** may be employed.

The electromechanical transducer **1** of FIGURE 1 is shown in enlarged medial section in FIGURE 2, it being understood that such electromechanical transducer is generally circular in plan and hence symmetrical about the longitudinal axis thereof. Electromechanical transducer

1 comprises magnet 16 provided with a central pole 17 having a bore 17*a* through which drive rod 2 freely extends. Magnet 16 is what is commonly termed a "pot" magnet, and the field coil winding is indicated diagrammatically by diagonal lines. Diaphragm 18 mounted on drive rod 2 and supporting coil form 19 concentrically with respect to drive rod 2 is connected through resilient ring 20 with flange 21. Power coil 22, wound around coil form 19 and extending into annular gap 23 between the central pole 17 and the outer pole 17*b* of pot magnet 16, is connected to power amplifier 7 through line 8. Metallic guide disc 24 is secured, as by welding or soldering, to drive rod 2 and is also secured at its periphery to diaphragm 18, for example by a bead 25 of an "epoxy" type cement. Guide disc 26, which may for example be of rubber, is mounted to drive rod 2 and is secured to bell housing 27, assuring rectilinear motion of drive rod 2. Screws 28 mount bell housing 27 and flange 21 securely to magnet 16. That end of drive rod 2 remote from atomizing bar 3 is provided with rod magnet 29 extending upwardly therefrom through bore 30 of pickup coil form 31 mounted to bracket 32, the latter in turn being mounted to magnet 16 by means of screws 33. Pickup coil 34, wound around pickup coil form 31, communicates with preamplifier 5 through line 9.

In the operation of the apparatus shown in FIGURES 1 and 2, the AC output of power amplifier 7 is fed through power coil 22 generating an alternating magnetic field which reacts with the magnetic field of pot magnet 16 causing diaphragm 18 to vibrate and also drive rod 2 to execute longitudinal vibrating motion. In this manner, atomizing bar 3 is caused to vibrate at the selected resonant flexural mode. Rod magnet 29 at the remote end of drive rod 2 also vibrates in unison with drive rod 2 and, pickup coil 34 being in close proximity thereto, an alternating current is generated in said pickup coil 34, which alternating current corresponds with the vibrative state of atomizing bar 3 and senses any tendency of said atomizing bar 3 to depart from the resonant flexural mode to which it has been driven, said alternating current being fed through line 9 to preamplifier 5 and thence to phase shifter 6 as taught by my U.S. Patent 2,779,623, whereby the output of power amplifier 7 is corrected and adjusted to maintain atomizing bar 3 vibrating at the selected resonant flexural mode as shown by the dashed lines in FIGURE 2. Meanwhile, liquid feed 14 is introduced from reservoir 12 through valved feed line 13 to said atomizing bar 3 for atomization thereon.

If feed 14 is normally solid at ambient temperatures, and this may for instance apply to various metals, urea, stearic acid, waxes, naphthalenes, etc., reservoir 12, valved feed line 13 and atomizing bar 3 will require heating to maintain their respective temperatures above the melting point of the substance to be atomized in part to liquefy the said substance and also to prevent premature freezing of the substance once it has been liquified and before it has been atomized. Reservoir 12 and valved feed line 13 may be heated by any means known to the art. FIGURES 3 and 4 show means for heating atomizing bar 3 while it is in the vibrative state. Atomizing bar 3 is provided around its periphery and on its neutral axis with an inwardly etxending slot 35. Drive rod 2 is hollow for at least part of its length and its interior communicates with bore 36 which in turn communicates with slot 35. Resistance heating wire 37, covered by insulation 38 such as fiberglass braid, is placed in slot 35 around atomizing bar 3, and is held in place by cement packing 39. Wire 37 leads through bore 36 into the interior of drive rod 2 and thence to line 40 exiting from drive rod 2 at a convenient point and connecting to a suitable source of electrical power.

An alternate form of atomizing bar for use with electromechanical transducer 1, with or without means for heating the same, is shown in FIGURE 5. As shown, bar 3*a* comprises a cruciform arrangement of arms 41 of equal

length, drive rod 2 being rigidly connected to the intersection thereof, said intersection being an antinode and arms 41 vibrating as shown by the dashed lines. Atomizing bar 3*a* may be fabricated from a single sheet of metal. Liquid feed may be fed through valved feed lines (not shown in FIGURE 5) to the ends of each of the arms 41 for increased atomization capacity of the system. Symmetrical arrangements of three arms 41, or five or more arms 41, may also be employed, so long as the arms 41 are symmetrical about their intersection to which drive rod 2 is connected.

Referring now to the form of invention shown in FIGURE 6, an electromechanical transducer similar to that shown in an article appearing in Review of Scientific Instruments, May 1941, at pages 250–256, entitled "An Electromagnetic Sound Generator for Producing Intense High Frequency Sound," is employed with liquid feed means to provide a unique electromechanical atomizer for dispersing a liquid into fine droplets. Thus, electromechanical transducer 42 comprises pot magnet 43 with a central pole 44 and an outer pole 45, field windings being indicated diagrammatically by diagonal lines. A magnetically permeable annular disc 46 is mounted to outer pole 45 concentrically to central pole 44 leaving annular gap 47 thereabout. Metallic tubular sections 48, flanged as at 49 for ease in assembling the same to each other and to pot magnet 43 are provided with circular notches for a purpose which will hereinafter appear, and screws 51 secure the said tubular sections 48 to each other and, through disc 46, to pot magnet 43. A solid metallic cylinder 52, provided with integral medial transversely extending flange 53 and integral coaxial longitudinally extending ring 54 is mounted within tubular sections 48, flange 53 extending into notches 50 and resiliently held therein by rubber shims 55 covered with aluminum or other metallic foil 56 so as to electrically ground flange 53, and hence cylinder 52, to tubular sections 48 and pot magnet 43. Ring 54 extends into gap 47. Insulating disc 57 is mounted to the top of central pole 44, and a thin metallic disc 58 is mounted to the top of disc 57, insulated thereby from central pole 44. It will be noted that disc 58 is vertically spaced from the bottom of cylinder 52 so as to constitute one side of a capacitor the value of which varies with the dimension of the air gap between cylinder 52 and disc 58. Shielded wire 59 communicates between disc 58, through perforation 60 in disc 57 and bore 61 in central pole 44, and preamplifier 5 through line 9. The potential of the other side of the said capacitor is, as previously mentioned, the same as that of the pot magnet 43 and a line therefrom to the preamplifier may be provided, as line 62 shown as communicating with one of the elements of line 9, it being understood that line 9 is actually a pair of wires.

Driving coil 63 is wound around central pole 44 adjacent ring 54, and is powered from power amplifier 7 through line 8 extending through bore 64 in outer pole 45 and insulated therefrom, it being understood that line 8 is actually a pair of wires 65 communicating with the two ends of driving coil 63.

In operation, disc 58 may be charged relative to the bottom of cylinder 52 through wire 59 by suitable means to approximately 300 volts, for example. Alternating electric current from power amplifier 7 is fed through line 8 to driving coil 63. Ring 54 adjacent driving coil 63 has induced in it alternating currents. Attraction and repulsion of magnetic fields in gap 47 produces vibratory motion of cylinder 52 which is initiated at a selected resonant flexural mode. The capacitor comprising, as "plates" thereof, the bottom of cylinder 52 and disc 58, will fluctuate in value and sense any tendency of cylinder 52 to depart from vibrating at the selected resonant flexural mode, and the signal from the capacitor is fed to preamplifier 5 and thence to phase shifter 6 whereby the output of power amplifier 7 is corrected and adjusted to maintain cylinder 52 vibrating at the selected resonant flexural

mode. Meanwhile, liquid feed **14** is introduced from reservoir **12** through valved feed line **13** to the top of cylinder **52** for atomization thereon.

For optimum atomization and narrow droplet size distribution, the liquid (including heated substances such as metals which are normally solid at ambient temperatures) should wet the surface of the atomizing member (bar **3** or **3***a* or the top surface of cylinder **52**). The atomizing member is usually metallic and, if it is clean and free from contaminants, organic and inorganic solutions and melts readily wet the atomizing member. However, when atomizing molten metals, the materials from which the atomizing member is made should be carefully selected to promote wetting by the metal being atomized. Thus, when atomizing molten solder from a stainless steel atomizing member, the solder does not wet the atomizing member and poor atomization may result. If, however, the surface of the stainless steel atomizing member is previously coated with a solder of higher melting point or clad with a metal that is wet by the molten solder, optimum atomization of the molder solder will be attained. With some metal melts to be atomized, it can be broadly stated then that, where the base metal itself constituting the atomizing member is not readily wet by the metal being atomized, the atomizing member can be coated with a layer of another metal, a ceramic or a ceramet, the coating being chosen so as to be wet by the metal being atomized. While the meaning of the term "wet" as herein employed should be clear to those familiar with the art, it will be stated for purposes of clarity and in full compliance with the statute that, when a substance such as molten metal "wets" the atomizing member, this means that the substance forms a film on the atomizing member (strictly speaking, on the atomizing face of the atomizing member) and, conversely, when a substance such as a molten metal does not "wet" the atomizing member, this means that the substance does not form a film on the atomizing member but rather appears as drops or balls on the said atomizing member.

While I have shown the best embodiments of my invention now known to me, I do not wish to be limited to the exact structures shown and described herein, but may use such substitutions, modifications or equivalents as are embraced within the scope of the specification and drawings and claims.

I claim:

1. Atomizing apparatus to disperse a liquid into fine droplets, comprising:

(a) a pot magnet having:
  a central pole,
  an annular outer pole surrounding said central pole in concentric relation therewith,
  an annular gap between said central pole and said annular outer pole,

(b) electrically conductive means interposed in said annular gap and adapted to react with the magnetic field of said pot magnet,

(c) a source of alternating electric current in electrically operative relation with said electrically conductive means,

(d) atomizing means connected to said electrically conductive means and adapted to be vibrated thereby,

(e) means to deliver liquid to be atomized to a face of said atomizing means,

(f) pickup means adjacent said atomizing means and adapted to have impressed thereon an electrical value responsive to the vibrative state of said atomizing means,

(g) phase shifting means placing the electrical value impressed on said pickup means in modulating relationship with said source of alternating electric current to maintain said atomizing means vibrating at a resonant flexural mode.

2. Apparatus as in claim **1**, further comprising:

(h) said atomizing means comprising a cylinder,

(i) said electrically conductive means comprising a metallic ring secured to said cylinder.

3. Apparatus as in claim **2**, further comprising:

(j) said pickup means comprising a capacitor having:
  a conductive disc interposed between one face of said cylinder and said central pole, said conductive disc being spaced from said one face of said cylinder,
  means insulating said conductive disc from said central pole,
  means charging said conductive disc relative to said cylinder,
  means communicating the capacitance of said capacitor to said phase shifting means.

4. Apparatus as in claim **3**, further comprising:

(k) said source of alternating electric current comprising:
  a power amplifier,
  a driving coil wound around said central pole adjacent said metallic ring,
  electric conduit means communicating between said power amplifier and said driving coil.

5. Apparatus as in claim **1**, further comprising:

(h) said central pole having a bore extending completely therethrough along the longitudinal axis of said central pole,

(i) said atomizing means comprising:
  a bar,
  a drive rod secured to the central portion of said bar and extending through said bore.

6. Apparatus as in claim **5**, further comprising:

(j) a coil form secured to said drive rod and extending into said annular gap,

(k) said electrically conductive means comprising a coil wound around said coil form.

7. Apparatus as in claim **6**, further comprising:

(l) a magnetic member secured to that end of said drive rod remote from said bar,

(m) a coil form secured to said pot magnet and having a bore through which said magnetic member extends,

(n) said pickup means comprising a coil wound around said last mentioned coil form.

8. Atomizer apparatus to disperse a liquid into droplets comprising:

(a) a pot magnet having:
  a central pole,
  an annular outer pole surrounding said central pole in concentric relation therewith,
  a bore extending through said central pole along the longitudinal axis of said pot magnet,
  an annular gap between said central pole and said annular outer pole,

(b) drive rod means extending through said bore and having a first end and a second end,

(c) power coil means secured to said drive rod means and extending into said annular gap,

(d) atomizing bar means secured to said first end of said drive rod means and adapted to be vibrated thereby,

(e) magnet means secured to the second end of said drive rod means,

(f) pickup coil means adjacent said magnet means and adapted to have induced therein electrical currents when said magnet means is reciprocated by said drive rod means relative to said pickup coil means,

(g) a source of alternating electric current in communication with said power coil means,

(h) means placing the electrical currents induced in said pickup coil means in modulating communication with said source of alternating electric current to maintain said atomizing bar means vibrating at a resonant flexural mode,

(i) means to introduce liquid to be dispersed to a face of said atomizing bar means.

9. Apparatus as in claim **8**, further comprising:

(j) a slot formed around the periphery of said atomizing bar means adjacent the neutral axis thereof, said slot extending inwardly from the periphery thereof,
(k) a bore in said drive rod means,
(l) a bore in said atomizing bar means communicating between said first mentioned bore and said slot,
(m) an electrical heating element extending through said bores from said drive rod to said slot and along said slot,
(n) means to retain said electrical heating element in said slot.

10. Apparatus as in claim **8**, further comprising:
(j) said atomizing bar means comprising more than two arms symmetrically radiating from a central point,
(k) said drive rod means being rigidly secured to said central point.

11. Atomizing apparatus adapted to be vibrated by an electromechanical transducer, comprising:
(a) drive rod means adapated to be reciprocated by said electromechanical transducer,
(b) atomizing bar means rigidly secured at its center to said drive rod means,

(c) a slot formed around the periphery of said atomizing bar means adjacent the neutral axis thereof, said slot extending inwardly from the periphery thereof,
(d) a bore in said drive rod means,
(e) an electrical heating element extending through said bore and along said slot,
(f) means to retain said electrical heating element in said slot.

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