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Guntersdorfer et al.

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[54] **APPARATUS FOR ATOMIZING FLUIDS WITH A PIEZOELECTRICALLY STIMULATED OSCILLATOR SYSTEM**

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[73] Assignee: **Siemens Aktiengesellschaft,** Berlin and Munich, Germany

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[21] Appl. No.: **158,473**

[30] **Foreign Application Priority Data**

June 15, 1971 Germany ..... P 21 29 665.1

[52] **U.S. Cl.** **239/102**

[51] **Int. Cl.** **B05b 3/14**

[58] **Field of Search** 239/102

[56] **References Cited**

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[57] **ABSTRACT**

Apparatus for atomizing liquids having a piezoelectric oscillator system which includes an AC voltage stimulated piezoelectric transducer mechanically coupled to a vibrator plate for inducing bending vibrations therein, a fluid tank and a pump for delivering fluid to the vibrating plate which is disposed at an oblique angle with respect to the force of gravity above the tank, a wick extending from the tank with one end thereof in proximity to the lower edge of the vibrating plate to aid in diverting excess liquid from the plate, and means for controlling operation of the fluid delivery system for deactivating the same during periods when the oscillator system is inactive.

8 Claims, 3 Drawing Figures

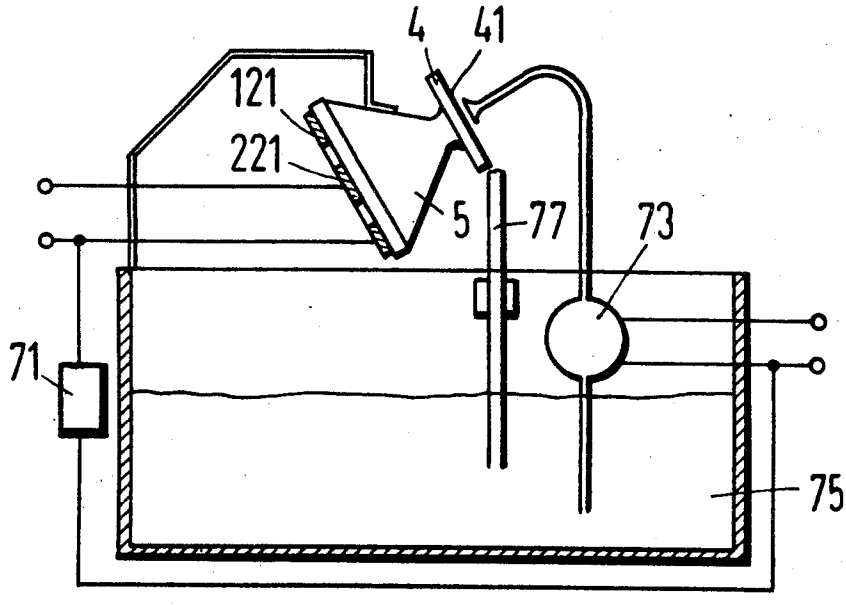


Fig. 1

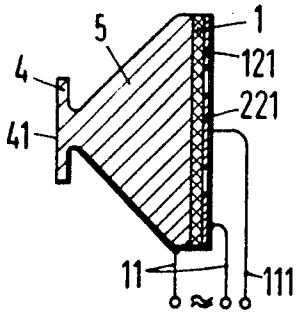


Fig. 2

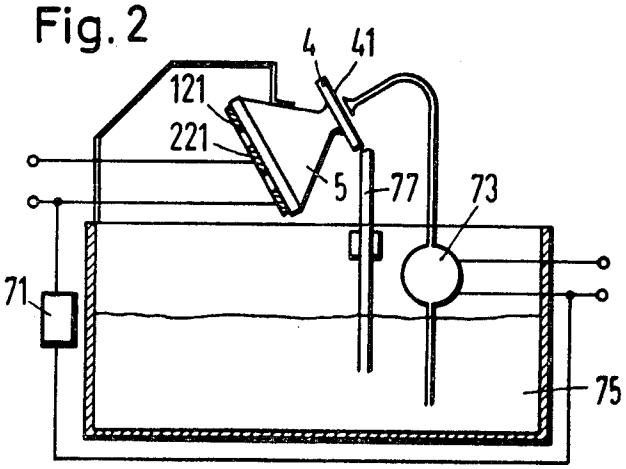
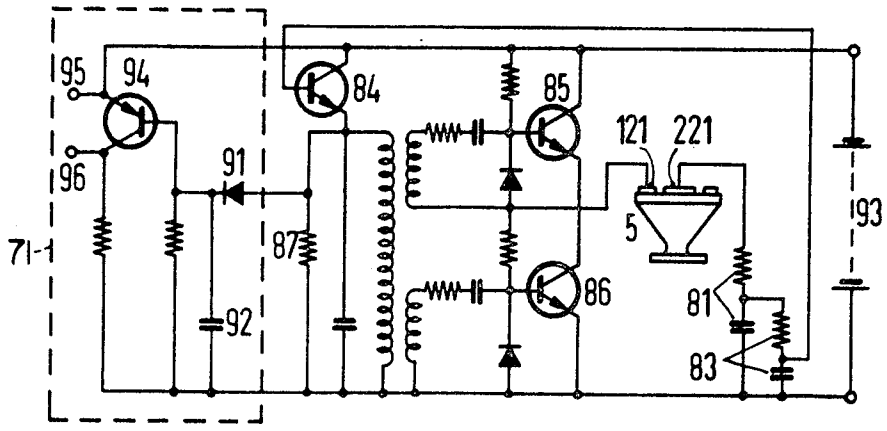


Fig. 3



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APPARATUS FOR ATOMIZING FLUIDS WITH A PIEZOELECTRICALLY STIMULATED OSCILLATOR SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an apparatus for atomizing liquids and is particularly concerned with such apparatus which comprises a piezoelectric oscillating system for effecting atomization.

2. Description of the Prior Art

A piezoelectric oscillating system for effecting atomization of liquids is described in a copending application for patent of Max Guntersdorfer, Ser. No. 158,472, filed June 30, 1971 and assigned to the same assignee as the present invention. Such a piezoelectric oscillating system comprises a coupling oscillator including a first plate and/or a frustum having a piezoelectric transducer carried thereon, and a second plate to be stimulated to bending vibrations, the second plate being coupled to the first plate by a mechanical connection having a low cross-sectional area. The coupling oscillator is stimulated to have bending oscillations by the application of an AC voltage to the piezoelectric transducer and the bending resonant frequency of the mechanically coupled second plate substantially agrees, preferably as a result of the selection of the diameter of the second plate, with the frequency of the bending oscillation of the piezoelectric transducer and first plate.

SUMMARY OF THE INVENTION

The improvement according to the present invention resides in the resolution of the problem, among others, of resetting the oscillating system after an operationally effected interruption of the vibration occurs to condition the system for a renewed start of oscillations as quickly as possible.

According to the present invention, the foregoing problem is solved through the utilization of the above described oscillator system in an atomizing system having a fluid conveying apparatus, such as a pump system, provided to supply fluid from a tank or reservoir to the surface of the second vibrating plate of the oscillator system, and a control system which is connected between the oscillator system and the conveying apparatus which operates to inhibit operation of the conveying apparatus in case of a sudden stop of the oscillatory movement of the oscillating system due to, for example, excess supply of liquid to the vibrating plate.

BRIEF DESCRIPTION OF THE DRAWING

Other objects, features and advantages of the invention, its organization, construction and operation, will best be understood from the following detailed description of a preferred embodiment of the invention, taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a cross-sectional elevational view of an oscillator system which may be employed in practicing the present invention;

FIG. 2 is a schematic diagram of an atomizing system which utilizes an oscillator system such as illustrated in FIG. 1; and

FIG. 3 is a schematic circuit diagram of means for providing self-energization for the oscillating system and a control system for controlling the activity of the fluid delivery portion of the apparatus illustrated in FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates an oscillator system, such as discussed above and more particularly set forth in the above-mentioned copending application of Max Guntersdorfer. The oscillator system essentially comprises a coupling oscillator which includes a piezoelectric transducer 1 carried on a plate, here in the form of a frustum 5. At the blunt tip of the frustum 5 a plate 4 is fastened. The plate 4 includes a surface 41 for receiving a flow of liquid, which will be discussed below, for atomization. The ceramic material of the piezoelectric transducer 1 is polarized in the direction of its thickness.

The piezoelectric transducer 1 is provided with a pair of electrodes, namely a circular electrode 221 in the center surrounded by an annular electrode 121. A counter electrode is formed by the surface between the frustum 5 and the piezoelectric transducer. Electrical feed connections 11 are provided for receiving the AC energizing voltage and a connection 111 is provided to the electrode 221 for providing a tap for taking off a feedback voltage. For operation of the system in accordance with the principle of self-energization, the feedback voltage should preferably be opposite in phase to the voltage applied to the conductors 11. This phase shift by 180° can be accomplished in a simple manner by polarizing the piezoelectric material in the area of the electrode 221 in a direction opposite to that adjacent the electrode 121.

The oscillating system, particularly the coupling oscillator, is so designed that at a frequency of the AC voltage to be applied to the conductors 11, it is energized in a bending resonance, preferably of the fundamental wave of the bending resonance. It has proven to be advantageous to operate the oscillating system with an AC rectangular voltage whose fundamental frequency agrees with the bending resonant frequency of the basic wave of the oscillating system and/or of the coupling oscillator. The use of an AC rectangular voltage led to an increase in performance, based particularly on the fact that as a result of the harmonic content of the rectangular waveform, even bending resonances of a higher order were stimulated. With regard to increased safety against flashovers, the use of an AC voltage also offers advantages because peak values can be limited with greater control.

The oscillating system illustrated in FIG. 1 may also be replaced by one wherein lieu of the frustum 5, as mentioned above, a plate with a bridge is provided to connect the coupling oscillator to the vibrating plate 4. In such a case, the plate has substantially the diameter of the transducer 1 and the bridge has a considerably smaller diameter in relation thereto. The coupling connection between this latter plate and the plate 4 is established with the aid of the bridge. Such an oscillation system is also described in the above-mentioned copending Guntersdorfer application.

FIG. 2 illustrates an apparatus for atomizing liquid with an oscillating system such as illustrated in FIG. 1. A trough tank, or reservoir 70 is provided for holding a fluid 75. The fluid 75 is supplied from the reservoir 70 to the surface 41 of the plate 4 by means of a conveyor system 73, such as a pump system. A control sys-

tem 71 is operatively interposed between the oscillating system and the fluid conveyor device 73 to control the supply of fluid. The control apparatus 71 is so designed that it interrupts the operation of the conveying device upon a shutdown of the oscillatory movement of the oscillating system, or at a reduction of the oscillating amplitude and the resulting reduction of the amplitude of the feedback voltage due to excessive supply of fluid upon the surface 41. It is contemplated to have the shutdown continue until excessive loading of the surface 41 with liquid has been eliminated.

According to improvements of the invention, special measures are provided to eliminate excessive quantities of liquid on the surface 41. To be specific, the surface 41 and/or the entire oscillating system, according to the invention, is arranged and positioned so that the surface 41 is inclined in relation to the direction of the force of gravity. This disposition favors a discharge of fluid from the surface 41 back into the reservoir 70. In order to favor this discharge, particularly with fluids having relatively high cohesion and/or adhesion, means is provided in proximity to the lower edge of the surface 41 of the plate 4. As soon as the overhanging fluid reaches this means, the fluid is diverted therealong and back into the reservoir 70. The use of a wick 77 has proven to be particularly favorable as a fluid diversion means. Preferably, the electrodes of the oscillating system are provided with an electrically insulating, preferably moisture-resisting coating.

In an oscillating system according to the invention, one other advantage is obtained which results from the heating caused by the stimulating energy and the mechanical oscillation losses of the system. This advantage is the evaporation which occurs, particularly with respect to excess fluid, at the surface 41. This evaporation is advantageously stressed particularly when the supply of fluid has already been shut down and the continuous supply of fluid for cooling the oscillating system has accordingly been cut off.

FIG. 3 illustrates a circuit arrangement for generating a self-energizing alternating voltage, whereby the self-energization is controlled by feedback with the aforementioned third electrode 221 of the oscillator, according to the invention, for example, an oscillator as disclosed in FIG. 1 and/or FIG. 2.

The circuit arrangement is designed to generate a rectangular voltage. The feedback voltage is supplied from the electrode 221 by way of two RC circuits 81, 83 for phase shifting the feedback voltage by 90° for application to the base of an emitter follower stage comprising the transistor 84. This stage is employed to uncouple the RC circuits from the performance stage which includes the transistors 85 and 86 in which the rectangular voltage is generated for application to the electrode 121. The additional circuit details for this type of circuit, including the transformer coupling for the transistors 85 and 86 are well known in the art and will not be discussed in detail here. It is sufficient to note that the transistors 85 and 86 are caused to be alternately conductive for generating the rectangular waveform in response to the receipt of the feedback voltage at the base of the transistor 84.

A portion of FIG. 3 is framed in broken lines and identified with the reference character 71. This circuit is representative of circuits which may be employed for effecting control of the conveyor device 73.

The feedback voltage is applied, at the emitter of the transistor 84, to an emitter resistor 87. This signal is rectified by means of a diode 91 to generate a DC voltage across a capacitor 92. This voltage is applied to the base of a transistor 94 and as long as it is lower than the operating voltage of the source 93, the transistor 94 is conductive so that no voltage is applied to the terminals 95, 96. If the DC voltage generated across the capacitor 92 rises to the value of the source voltage, the transistor 94 becomes blocked and the terminals 95 and 96 are different potentials. These terminals are for connection to the fluid conveying device 73. It has been demonstrated that under normal conditions of atomization, an amplitude is present at the resistor 87 which corresponds to the voltage of the source 93, while with the overflowing oscillator, the voltage drops to about ¾ of its normal value. By connecting the apparatus 71 to the terminals 95 and 96, the control takes place precisely in the manner contemplated.

The phase shifting of a total of about 90° effected by the RC circuits 81, 83 and which is additionally provided by the phase shifting between the voltages at the electrodes 121, 221 is utilized to stimulate the coupling oscillator at a low-ohmic series resonant frequency.

The self-energization feature has the additional advantage that there is an automatic resynchronization of the oscillator when the resonant frequency of the oscillating system changes, for examples, due to heating and/or the build up of calcium deposits.

Although we have described our invention by reference to specific illustrative embodiments, many changes and modifications of our invention may become apparent to those skilled in the art without departing from the spirit and scope of the invention, and it is to be understood that we intend to include within the patent warranted hereon, all such changes and modifications as may reasonably and properly be included within the scope of our contribution to the art.

What we claim is:

1. Apparatus for atomizing liquids, comprising: a piezoelectric oscillator system for energization by an AC voltage, said oscillator system comprising a plate to be stimulated to bending vibrations and a coupling oscillator connected to said plate and including a piezoelectric transducer having input electrodes and operable to provide bending vibrations in response to the AC voltage; a fluid reservoir below said oscillator system for holding fluid to be atomized; a fluid conveyor associated with said reservoir operable to deliver a flow of the fluid from said reservoir to said plate; and control means connected between said oscillator system and said fluid conveyor for sensing oscillations and controlling the energization of said fluid conveyor so that fluid delivery is terminated during intervals when operation of said oscillator system is suspended.

2. The atomizing apparatus of claim 1, wherein said plate is disposed over said reservoir at an oblique angle with respect to the force of gravity whereby fluid not atomized returns to said reservoir.

3. The atomizing apparatus of claim 1, comprising fluid diversion means disposed in proximity to said plate and extending into said reservoir to divert excessive quantities of the fluid from said plate to said reservoir.

4. The atomizing apparatus of claim 1, wherein said oscillator system includes means for generating the AC voltage including a voltage tap electrode mounted on

said piezoelectric transducer for providing a feedback voltage, and a feedback amplification circuit connected between said tap electrode and said input electrodes.

5. The atomizing apparatus of claim **4**, wherein said feedback amplification circuit includes phase shifting means operable to provide substantially a 90° phase shift of the feedback voltage.

6. The apparatus according to claim **4**, wherein said control means includes an input circuit connected to said feedback amplification circuit for receiving the amplified feedback voltage, means for rectifying the amplified feedback voltage, and means connected to said rectifying means for effecting operation of said fluid conveyor in response to a rectified voltage greater than a predetermined magnitude.

7. Apparatus for atomizing liquids, comprising: a piezoelectric oscillator system for energization by an AC voltage, said oscillator system comprising a plate to be stimulated to bending vibrations and a coupling oscillator connected to said plate and including a piezoelectric transducer having input electrodes and operable to provide bending vibrations in response to the AC voltage; a fluid reservoir below said oscillator system for holding fluid to be atomized; a fluid conveyor associated with said reservoir operable to deliver a flow of the fluid from said reservoir to said plate; fluid diversion means disposed in proximity to said plate and extending into said reservoir to divert excessive quantities of the fluid from said plate to said reservoir, said fluid diversion means including a wick; and control means connected between said oscillator system and said fluid conveyor for sensing oscillations and controlling the energization of said fluid conveyor so that fluid delivery is terminated during intervals when operation of said oscillator system is suspended.

8. The atomizing apparatus of claim **1**, wherein said oscillator system comprises a frustum-shaped member having said plate and said piezoelectric transducer mounted thereon.

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