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[72] Inventor **John A. Coleman**
1065 Bush St., San Francisco, Calif. 94109
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Primary Examiner—James Kee Chi

Attorney—Flehr, Hohbach, Test, Albritton and Herbert

[54] **ULTRASONIC CLEANING SYSTEM, APPARATUS
AND METHOD THEREFOR**
9 Claims, 5 Drawing Figs.

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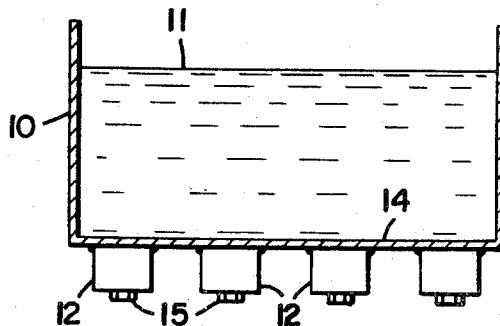
[50] **Field of Search**..... 259/72,
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ABSTRACT: An ultrasonic cleaning system in which at least one transducer unit includes a base bonded to the bottom of a cleaning tank each unit including a stud on which are placed two annular transducer elements, a pressure plate, and a nut. The stud is firmly fixed by tapered threads to the base so that removal of the compression nut does not disturb the stud but allows replacement of defective transducer elements. Pairs of the transducer units are associated with a single plug-in oscillator unit which supplied high frequency vibratory energy to it.



ULTRASONIC CLEANING SYSTEM, APPARATUS AND METHOD THEREFOR

BACKGROUND OF THE INVENTION

In the past ultrasonic cleaning systems where tanks containing cleaning liquid have been agitated by transducers coupled thereto have been difficult to repair except by time consuming and expensive means. For example, at the present time ultrasonic transducer units are permanently heat bonded by epoxy type glue or welding to the bottom plate of the tank used for cleaning. For a 20-gallon tank there may be as many as 30 to 40 transducers. Each transducer is essentially a permanently assembled unitary assembly which must be replaced as a unit. Thus if one transducer fails, it must be removed from the tank by heating the bond around that particular transducer and replaced with a new transducer assembly. However, in removing merely one transducer the heating of the tank and bond around the defective transducer tends to damage the bonds on other surrounding transducer units. Thus from a practical aspect, when one transducer unit is to be replaced several more than that must also be replaced and rebonded.

Also during initial installation of the transducer units the application of heat to initially bond the unit to a liquid containing tank must be limited in order not to damage the actual vibratory transducer elements contained in the transducer unit. As a consequence the initial bond may be unsatisfactory. With the use of a higher melting point bonding compound, a more durable bond results. This is especially necessary in an ultrasonic cleaning system where the vibrator tends to loosen a bond and where heat generated by the cleaning process will also loosen bonds.

Another difficulty in the prior ultrasonic cleaning systems is that all of the transducer units on a single tank were supplied power from a single oscillator unit. Thus, if any single transducer unit malfunctioned placing an open or short on the circuit, this would tend to make inoperative the entire power supply for the transducer units. Thus in addition to the reheating problem to remove the bonded or integrally mounted transducer unit from the base, malfunction of a unit would also necessitate replacement of the entire electrical power source unit for all transducer units.

OBJECTS AND SUMMARY OF THE INVENTION

It is therefore a general object of the invention to provide an improved ultrasonic cleaning system;

It is another object of the invention to provide an ultrasonic cleaning system in which each transducer unit may be easily repaired without deleteriously affecting the other transducer units in the system;

It is another object of the invention to provide an ultrasonic cleaning system in which when a transducer unit malfunctions only a portion of the electrical circuit supplying oscillatory energy to the transducer unit is affected.

In accordance with the above objects there is provided an ultrasonic system having receptacle means for retaining liquid which is agitated ultrasonically. Such a system comprises a plurality of transducer means for converting electrical energy to mechanical vibratory energy each including a base integrally mounted on the receptacle. A transducer element mechanically coupled to said base is included in the transducer means and has terminal means for coupling to a source of electrical energy. The transducer means also includes fastener means for coupling the transducer means to the base, the fastener means having a portion thereof removable to allow the transducer element to be replaced and a new transducer element recoupled to the base. A source of electrical energy including a plurality of oscillator means is provided each of the oscillator means being mounted in separate plug-in units associated respectively with each of the transducer means. Each of the oscillator means are coupled to respective terminals of the transducer means.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cross-sectional of a tank of an ultrasonic cleaning system showing transducer units attached thereto;

FIG. 2 is a bottom view in schematic form of the tank of FIG. 1 and also includes a diagrammatic showing of the electrical energy sources supplying energy to the transducer units;

FIG. 2A is a cross-sectional view taken along the lines 2A-2A of FIG. 2;

FIG. 3 is an enlarged cross-sectional view showing one of the transducer units mounted to the tank of FIG. 1; and

FIG. 4 is a circuit schematic of an electrical energy source for one of the transducer units.

DETAILED DESCRIPTION OF THE INVENTION

Referring first to FIG. 1, there is illustrated a receptacle 10 containing suitable cleaning liquid 11 which has mounted on its bottom plate 14 eight identical transducer units 12. FIG. 3 shows one of the units in detail which includes a cylindrical base 13 which is heat bonded to bottom plate 14 by either welding or epoxy glue. Base 13 would normally be composed of a suitable metal such as aluminum. Two annularly shaped piezoelectric type crystals 16 and 17 are coupled to base 13 by means of a tapered stud 15 which is screwed into a threaded receptacle 19 in the center of base 13. A nut 18 on stud 15 causes a compression plate 21 to compress elements 16 and 17 together and against base 13.

In practice stud 15 is screwed into receptacle 19 with a much greater torque than nut 18. For example, stud 15 may have applied to it more than 200 inch-pounds of torque while in the case of nut 18 a maximum of 120-140 inch-pounds is applied. This differential allows nut 18 to be removed while stud 15 remains in place.

From a method standpoint stud 15 is threaded into base 13 before the base is bonded to receptacle 10. This allows a torque force to be used on the stud which is much greater than the relative bonding force.

Intermediate the elements 16 and 17 is a conductive sheet 22 which has a terminal 23 to which high frequency electrical energy is supplied. The respective opposite sides of elements 16 and 17 are conductively coated to make contact with grounded conductive layers 24 and 25. This provides a potential difference across the piezoelectric elements 16 and 17 which places them in vibration upon application of high frequency voltage to cause liquid 11 in the tank 10 to be agitated to thus perform a cleaning function. Each transducer element 16 and 17 also includes collars 16a and 17a to prevent any short circuit by stud 15. A stud 15, as is apparent, in conjunction with compression plate 21 and nut 18 serve as a fastener for the transducer elements 16 and 17. Since nut 18 was applied to the stud with a lower torque it may be easily removed allowing any defective transducer elements 16 and 17 to be removed and replaced with a working element.

Stress concentrations in the piezoelectric elements are relieved by the circular configuration of base 13 and the provision of the stud 15 in the center of the base. This is because no sharp corners are present and stresses that are present are uniformly distributed.

The method of providing an ultrasonic cleaning system in accordance with the invention comprises the following steps. Base 13 with its stud 15 inserted and torqued down to the desired tension is bonded to bottom plate 14. The bonding process is carried out in compliance with the manufacturer's instructions of the bonding compound used. The base during bonding is loaded with sufficient weight to force out all air bubbles and allowed to set cold. Thereafter it is heated above the Curie point of crystals 16 and 17. With this high temperature maximum strength and adhesive force are achieved.

The Curie point or rating of a crystal is the temperature at which the crystal begins to lose its power rating. Once heated

to this temperature the crystal permanently loses at least a portion of the rating. Thus, the crystals 16 and 17 are not placed on base 13 until the base has cooled to room temperature.

Crystals 16 and 17 are mechanically coupled to base 12 by tightening nut 18 on stud 15. The nut is torqued to a value determined by the manufacturer's specifications. For example, a crystal available from Channell Industries of Santa Barbara, California, has a free frequency of 160 kHz. This frequency is reduced to a desired 20 kHz by a torque pressure of 120—140 inch-pounds. Spot checks however should be made with an oscilloscope to verify the manufacturer's specifications.

Each plug-in unit 27 includes an oscillator means as shown in FIG. 4 which has a transformer T₁ to which is supplied a source of AC voltage which may, for example, be 115 volts, 60 hertz. This is coupled into a bridge circuit which includes diodes D1, D2. The center tap of the bridge is coupled between two identical halves of an inductance designated L2, L2. Transistors Q1 and Q2 provide a push-pull oscillation circuit with feedback being provided by winding L1 through the phase shift capacitor C1. Resistors R1 and R2 couple the bases of transistors Q1 and Q2 to diodes D1 and D2 and resistors R3 and R4 couple to the bases to the center tap of the bridge. Output winding L3 is coupled to L1 and L2 which provides the necessary high frequency oscillatory voltage which is applied to the transducer units 12. A light source 28 is mounted in parallel with a series resistor 29 to indicate an open circuit in the transducer element. This is the normal failure mode of a piezoelectric transducer element. Plug-in units 27 include male and female connectors 31 (FIG. 2A) which allow for easy replacement upon failure of either the current and/or associated transducer units.

The following component values and specifications will provide an ultrasonic generator with a frequency of 20 kilohertz and power capacity of 250 watts:

C1—1 mfd.

D1, D2—1N3492

Q1, Q2—2N1970

R1, R2—5 ohms

R3, R4—470 ohms

T1—300 Volt-amperes, 19 volts each side of center tap

T2—L1=11 turns #18 wire

L2=24 turns #16 wire with tap at center

L3=98 turns #20 wire

Thus, the present invention provides an improved ultrasonic cleaning system, apparatus and method therefore in which the transducer units are easily repaired by simple removal of the nut 18. At the same time if one of the units fails, only a portion of the associated electrical power source is affected and these are also easily replaced.

I claim:

1. An ultrasonic cleaning system having receptacle means for retaining liquid which is agitated ultrasonically comprising, a plurality of transducer means for converting electrical energy to mechanical vibratory energy each including a base integrally mounted on said receptacle, a transducer element mechanically coupled to said base and having terminal means

for coupling to a source of electrical energy, fastener means for coupling said transducer element to said base said fastener means having a portion thereof removable to allow said transducer element to be replaced said portion being reusable to recouple a transducer element to said base, and a source of electrical energy including a plurality of separate oscillator means each mounted in separate plug-in units associated respectively with each of said transducer means, each of said oscillator means being coupled to respective terminals of said transducer means.

2. An ultrasonic cleaning system as in claim 1 in which said bases are affixed to said receptacle by a bonding process in which heat is applied.

3. An ultrasonic cleaning system as in claim 1 in which said fastener means includes a stud having a removable nut and in which said base is threaded to receive said stud.

4. An ultrasonic cleaning system as in claim 1 in which each of said oscillator means includes indicator means for indicating a malfunction of such oscillator or associated transducer means.

5. Ultrasonic cleaning apparatus comprising, a base having a relatively substantial mass and a predetermined depth, a transducer element mechanically coupled to said base and having terminal means for coupling to a source of electrical energy, fastener means for coupling said transducer element to said base including a threaded stud having one end screwed into said base less than one-half said depth by application of a predetermined torque said fastener means including a pressure plate which in conjunction with said base forms a sandwich construction with said transducer element there between said stud extending through apertures in said transducer element and pressure plate and including nut means screwed onto the other end of said stud by application of a torque less than said predetermined torque to mechanically couple said transducer element to said base.

6. Apparatus as in claim 5 where said base is cylindrical and said stud is centered on the axis of said base.

7. A method of providing an ultrasonic cleaning system having receptacle means for retaining liquid which is agitated ultrasonically and having a transducer unit with a base to which is coupled an annular transducer element by a threaded stud, pressure plate and nut comprising the steps of, providing a threaded receptacle in said base, screwing said stud into said threaded receptacle by application of a predetermined torque, thereafter bonding said base to said receptacle means, placing said annular transducer element on said base with said stud extending therethrough, mechanically coupling said element to said base by placing said pressure plate on said element and said nut on said stud and applying a torque to said nut less than said predetermined torque.

8. A method as in claim 7 in which the bonding force holding said base to said receptacle means is less than said predetermined torque.

9. A method as in claim 7 in which said base is bonded to said receptacle at a temperature greater than the Curie point of said transducer element and said element is placed on said base with said base at a substantially lower temperature.