④ United States Patent
Rissolo

[15] 3,700,937
[45] Oct. 24, 1972

[54] SUBMERSIBLE ULTRASONIC TRANSDUCER ASSEMBLY

[72] Inventor: **Herman A. Rissolo,** Norwalk, Conn.
[73] Assignee: **Branson Instruments Incorporated,** Stamford, Conn.

[22] Filed: **July 1, 1971**
[21] Appl. No.: **158,959**

[52] **U.S. Cl.**................**310/8.9,** 310/8.3, 259/DIG. 44
[51] **Int. Cl.** **H04r 17/00**
[58] **Field of Search**...........310/8.1, 8.3, 8.7, 8.9, 9.1, 310/9.4; 134/1, 184; 259/1 R, DIG. 44, 72

[56] **References Cited**

UNITED STATES PATENTS

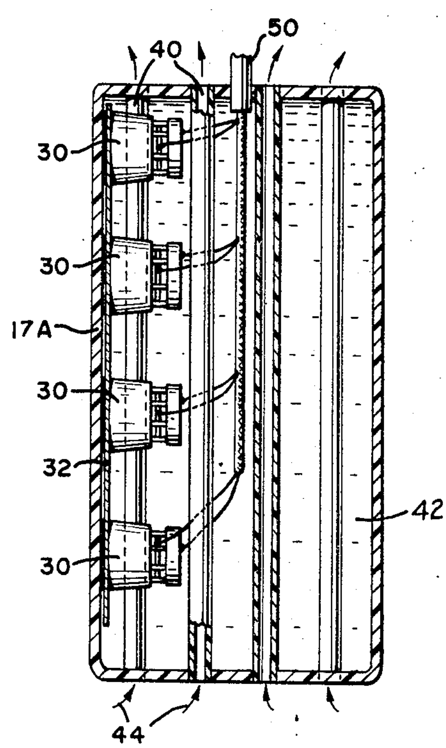
3,351,539	11/1967	Branson	310/8.1 X
2,941,908	6/1960	Logan	134/1
3,405,916	10/1968	Carmichael	259/1 R
2,826,396	3/1958	Murdoch, Jr.	259/DIG. 44
3,464,672	9/1969	Massa	259/72 X
2,855,526	10/1958	Jones	259/DIG. 44
2,257,997	10/1941	Barnes	259/DIG. 44
R25,119	1/1962	Rawding	259/DIG. 44
2,815,193	12/1957	Brown	259/DIG. 44

Primary Examiner—J. D. Miller
Assistant Examiner—Mark O. Budd
Attorney—Ervin B. Steinberg

[57] **ABSTRACT**

An ultrasonic processing apparatus includes an ultrasonic transducer assembly comprising a submersible enclosure made of material having a low thermal conductivity. Electroacoustic transducers are coupled to an interior surface of the enclosure which is filled with a heat conductive liquid. The interior of the enclosure is traversed by tubes which establish heat transfer between the interior of the enclosure and the liquid at the outside of the enclosure and in which the assembly is immersed.

16 Claims, 4 Drawing Figures



PATENTED OCT 24 1972

3,700,937

FIG. 1

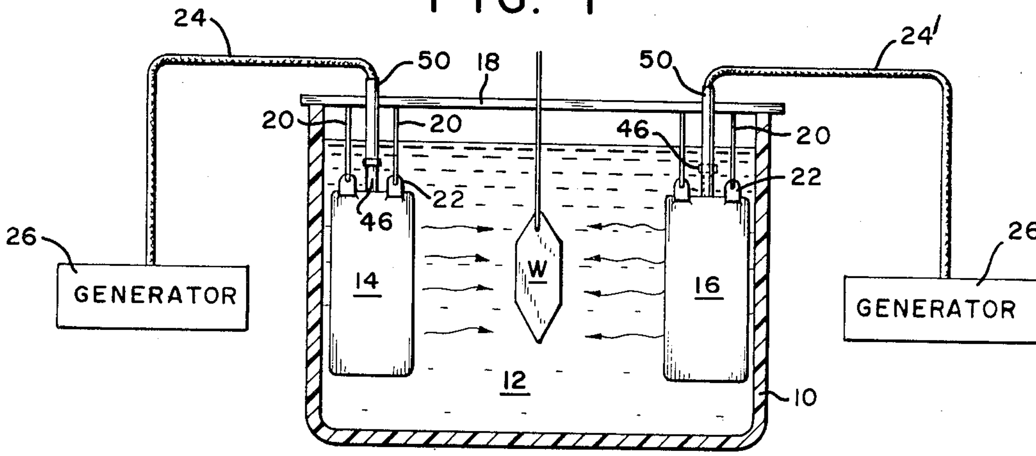


FIG. 2

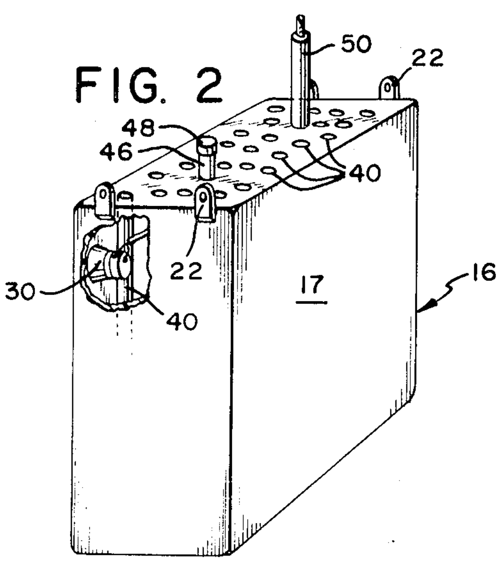
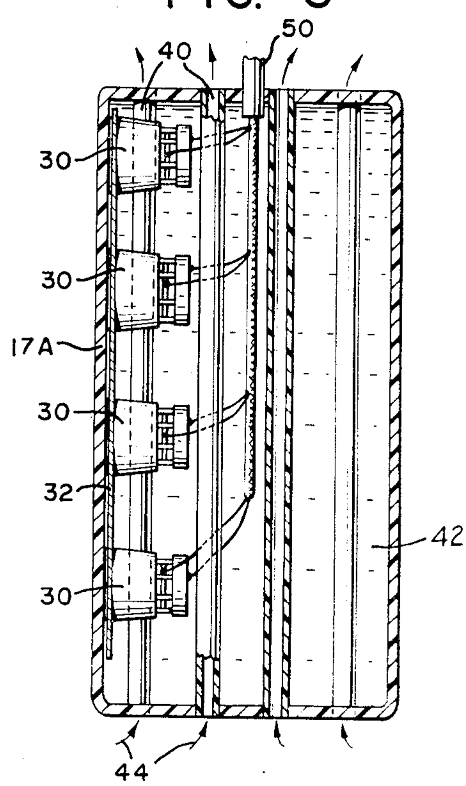


FIG. 3



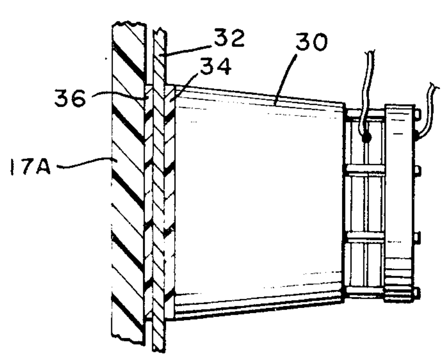


FIG. 4

INVENTOR,
HERMAN A. RISSOLO

BY:

Ervin B. Steinberg

SUBMERSIBLE ULTRASONIC TRANSDUCER ASSEMBLY

This invention refers to ultrasonic transducer assemblies and more particularly to those of the submersible type used for ultrasonic cleaning and ultrasonic processing.

The use of ultrasonic energy applied to a liquid for enhancing cleaning, degreasing, plating, etching, and similar processes is well known in the art. In a typical embodiment, a stainless steel tank is fitted with one or more ultrasonic transducer elements which are bonded to an exterior surface of the tank. Upon being energized with electrical energy the transducers provide ultrasonic energy to the processing liquid confined in the tank. This arrangement is shown, for instance, in "Ultrasonic Engineering" (book) by Julian R. Fredrick, John Wiley & Sons, Inc., New York, N. Y. (1965) pages 130 to 138. The ultrasonic transducers may be either of the magnetostrictive type or of the piezoelectric type.

When large tanks are employed, it has been found advantageous to use submersible transducer assemblies. In this arrangement, the transducer elements are enclosed within a liquid-tight portable enclosure, which in turn, is immersed in the treating liquid confined in the tank. This construction has the advantage that in the event a transducer assembly becomes defective, the tank structure itself does not need to be touched, instead the defective submersible enclosure is lifted from the tank and a new assembly is put in place. The use of such submersible transducer assemblies is well known.

For special applications it has been found necessary to use tanks made from material which is substantially inert to chemical attack. In typical cases, it has been found advantageous to use tanks made from polymeric plastic material, such as polypropylene, since such material is largely unaffected by acids commonly used for etching processes. The mounting of a transducer assembly to the exterior wall of such a tank presents several unique problems. Principally, the plastic material is of low thermal conductivity and the removal of heat from the bonding surface between the transducer frontal surface and the tank wall is a necessity. Unless such heat is removed, either the bond will fail, or the heat dissipated causes a melting of the tank wall or of the bottom at the location of transducer attachment, resulting in the destruction of the tank.

A solution for the stated problem is disclosed in U.S. Pat. No. 3,405,916 issued to J. J. Carmichael, dated Oct. 15, 1968, entitled "Ultrasonic Treatment Apparatus," which patent is assigned to the present assignee. This patent reveals the use of a layer having substantially high thermal conductivity (e.g., metal) interposed in the bond between the transducer frontal surface and the outer surface of the tank. The interposed layer extends beyond the bonding surface and conducts heat away from the bonding surface, thereby producing a solution for attaching ultrasonic transducers to a tank made of material having a relatively low thermal conductivity.

The present invention concerns a submersible transducer assembly wherein the transducer element or elements are confined within a liquid-tight enclosure made of material having a relatively low thermal conductivity. The removal of heat from the bond between

the transducer and the enclosure surface forms the major object of this invention and, as disclosed hereinafter, a heat exchange arrangement is shown which has proven to be successful and reliable over many hours of service.

One of the principal objects of this invention is, therefore, the provision of a novel submersible ultrasonic transducer assembly, the enclosure of the assembly being made of material having a substantially low thermal conductivity, such as polymeric plastic material.

Further and other objects of this invention will be more clearly apparent by reference to the following description when taken in conjunction with the accompanying drawings in which:

FIG. 1 is an elevational view, partially in section, of an ultrasonic processing apparatus which includes submersible transducer assemblies;

FIG. 2 is a perspective view of a submersible transducer assembly constructed in accordance with the present invention;

FIG. 3 is an elevational sectional view through the transducer assembly per FIG. 2, and

FIG. 4 is a detailed view showing the attachment of the ultrasonic transducer elements.

Referring now to the figures and FIG. 1 in particular, a tank **10** made, for instance, of neutral colored polypropylene or other suitable plastic material, is filled with a suitable liquid **12**, such as an etchant. Two submersible transducer assemblies **14** and **16** are suspended and immersed within the liquid **12** by means of a stationary beam **18**, inert wires **20**, and ears **22** which form a part of the submersible transducer assembly enclosure. Each transducer assembly is connected by a respective cable **24** and **24'** to a suitable electrical high frequency generator **26** and **26'**. As is well understood in the art, when the generator is operated, electrical high frequency energy is applied to transducer elements contained within a respective transducer assembly and ultrasonic energy, typically in the range from 16 to 50 kHz, is transmitted to the liquid **12**, causing the liquid to cavitate and act upon the workpiece W which is disposed between the transducer assemblies **14** and **16**.

The construction of the submersible transducer assembly is shown more clearly with reference to FIGS. **2**, **3** and **4**. The transducer assembly **16**, FIG. **2**, comprises essentially a rectangular housing **17**, made typically of polypropylene plastic material. Mounted to the inside surface of one wall **17A** are a plurality of ultrasonic transducers **30** which produce the ultrasonic energy which is then transmitted through the wall of the enclosure **17** to the liquid **12**. As shown, each transducer element includes piezoelectric disk means for converting the applied electrical high frequency energy to mechanical vibration and each of the transducers may be constructed as has been disclosed in detail in U.S. Pat. No. 3,066,232, issued to Normal G. Branson dated Nov. 27, 1962, entitled "Ultrasonic Transducer." It will be apparent that other transducer assemblies may be used including those making use of the magnetostrictive effect.

The attachment of such a transducer to the surface of a plastic tank, the plastic material having relatively low thermal conductivity, is accomplished in accordance with the disclosure in U.S. Pat. No. 3,405,916, supra. As seen in FIG. 4, the frontal surface of each transducer element 30 is bonded to a metallic plate 32 by means of a thin layer of epoxy resin 34 and the plate 32, in turn, is bonded to the inside surface of the plastic wall 17A by means of an epoxy layer 36. The plate 32, in a typical case, is made of aluminum in order to act as a heat sink which conducts heat away from the bonded areas.

Additionally, the assembly is provided with a plurality of vertical conduits or tubings 40 which traverse the interior of the enclosure 17 and which act as heat exchange tubings as will be more clearly apparent from the description below. The tubings, typically, are one-half inch polypropylene round tubings, one-sixteenth inch wall thickness with their ends sealed liquid-tight to the top and bottom surfaces of the enclosure. When immersed in the liquid 12, the tubings are oriented substantially in a vertical direction. The inside of the submersible assemblies 14 and 16 is filled with a suitable insulating and heat conducting medium, such as insulating oil 42, which conducts the heat away from the heat sink 32 and distributes such heat over a larger area. The tubings 40 when immersed in the treating liquid 12 provide for the natural flow of the liquid 12 through the tubings 40 as is indicated by the arrows 44. As the liquid 12, which is at a lower temperature, flows through the tubings 40, a heat exchange takes place, that is, the heat from the plate 32 conducted via the heat transmitting medium (oil) to the outside of the tubings 40 is transferred to the liquid 12 flowing at the inside of tubings 40. The upward flow of the liquid 12 through the tubings 40 is a natural occurrence and is well understood. Thus, the treating liquid 12 is used to cool the heat generated at the inside of the submersible assembly 16. In a typical example, a submersible transducer assembly having dimensions 18½ by 8½ by 6 inch is provided with twelve transducer elements and with 22 heat exchange tubings. A fill pipe 46 with cap 48 is used to fill the enclosure 17 with the suitable cooling medium, such medium being a liquid or a solid material, but suitably being an insulating, heat conducting transformer type oil. A further pipe 50 serves as a shield for the electrical cable and applying the electrical energy to the transducer elements 30.

It will be apparent that in order to provide effective cooling through the heat exchange tubes, the tubings 40 must remain substantially in a vertical position and that the quantity thereof must be selected to adequately cool the heat generated within the enclosure. In a typical case, with the dimensions described above satisfactory performance was experienced when for an extended period of time the liquid 12 was maintained in the temperature range from 150° to 200° F. Additionally, it will be understood that the submersible enclosure not only must be liquid-tight, but as indicated heretofore, the tubings 40 must be sealed liquid-tight to the end surface of the submersible enclosure. Thermoplastic material of the same kind for both the enclosure and the tubings appears to provide maximum assurance for a reliable weld or fusion joint. Standard welding techniques for thermoplastic material are used to provide such a joint. It will be apparent, moreover, that instead of round tubings, rectangular or square cross-sectional tubes can be used without deviating from the principle of the invention.

One of the salient features of the present invention resides in the fact that the tubings 40 have a wall thickness which is less than that of the enclosures 14 and 16. For the sake of rigidity and strength the enclosures must be made of relatively heavy wall thickness, typically one-fourth inch. Heat transfer through a plastic wall of this thickness is difficult to achieve. By selecting relatively thin-walled tubings 40, heat is more readily transferred from the interior of the enclosure to the exterior and since these tubings do not serve for structural purposes, their wall thickness can be thin.

What is claimed is:

1. An ultrasonic treatment apparatus comprising:
   a. a tank;
   b. a liquid disposed in said tank and adapted to act upon a workpiece immersed in said liquid;
   c. a submersible transducer assembly immersed in said liquid comprising:
      c–1. a liquid-tight enclosure made of material having a relatively low thermal conductivity;
      c–2. means coupled to said enclosure for supporting said enclosure in said liquid;
      c–3. a plurality of electroacoustic transducers, each adapted to receive electrical energy and transmit sonic energy via a frontal surface thereof;
      c–4. means coupling each of said respective frontal surfaces in sonic energy transmitting relation to an interior surface of said enclosure;
      c–5. a heat conductive medium associated with said means coupling said frontal surfaces to said interior surface for conducting heat away from the area between a respective frontal surface and said enclosure surface;
      c–6. a plurality of tubings traversing said enclosure in a generally vertical direction, the outer surface of said tubings being sealed in liquid-tight relation to the end surfaces of said enclosure, and the interior of said tubings being in contact with said liquid disposed in said tank;
      c–7. a liquid heat transfer medium disposed in said enclosure and filling the space between said tubings and said heat conductive medium;
   d. electrical generator means for providing said transducers with electrical energy, and
   e. means coupling said generator means to said transducers.

2. An ultrasonic treatment apparatus as set forth in claim 1, said transducers operating at a frequency of at least 16 kHz.

3. An ultrasonic treatment apparatus as set forth in claim 1, said tank and said enclosure being made of polymeric plastic material.

4. An ultrasonic treatment apparatus as set forth in claim 1, said enclosure and tubings being made of the same polymeric plastic material.

5. An ultrasonic treatment apparatus as set forth in claim 1, said liquid disposed in said tank being an etchant.

6. An ultrasonic treatment apparatus comprising:
   a. a tank adapted to contain a liquid;
   b. a submersible transducer assembly adapted to be immersed in liquid contained in said tank, said assembly comprising:
      b–1. a liquid-tight enclosure made of material having a relatively low thermal conductivity;

b–2. means coupled to said enclosure for supporting said enclosure in the tank for contact with liquid contained in said tank;

b–3. a plurality of electroacoustic transducers, each adapted to receive electrical energy and transmit sonic energy via a frontal surface thereof;

b–4. means coupling each of said respective frontal surfaces in sonic energy transmitting relation to an interior surface of said enclosure;

b–5. a heat conductive medium associated with said means coupling said frontal surfaces to said interior surface for conducting heat away from the area between a respective frontal surface and said enclosure surface;

b–6. a plurality of tubings traversing said enclosure in a generally vertical direction, the outer surface of said tubings being sealed in liquid-tight relation to the end surfaces of said enclosure, and the interior of said tubings adapted to be in contact with liquid contained in said tank;

b–7. a liquid heat transfer medium disposed in said enclosure and filling the space between said tubings and said heat conductive medium;

c. electrical generator means for providing said transducers with electrical energy, and

d. means coupling said generator means to said transducers.

7. An ultrasonic treatment apparatus as set forth in claim 6, the resistance to heat conduction interposed by the wall thickness of said tubings being less than that of said enclosure.

8. An ultrasonic treatment apparatus as set forth in claim 6, said enclosure and said tubings being made of polymeric plastic material, and the wall thickness of said tubings being less than that of said enclosure.

9. An ultrasonic treatment apparatus as set forth in claim 8, said enclosure and tubings being made of the same material.

10. An ultrasonic treatment apparatus which includes a transducer assembly adapted to be immersed in a liquid provided for treating a workpiece comprising:

a liquid-tight enclosure made of material having a relatively low thermal conductivity;

a plurality of electroacoustic transducers, each such transducer adapted to receive high frequency electrical energy and transmit ultrasonic energy via a frontal surface thereof;

means coupling each of said transducers with its respective frontal surface in sonic energy transmitting relation to an interior surface of said enclosure;

a heat conducting medium filling said enclosure and being in contact with said means coupling said transducers to said interior surface for conducting heat away from the area between a respective frontal surface and said enclosure surface, and

a plurality of tubings traversing said enclosure, the outer surface of said tubings being in contact with said heat conducting medium filling said enclosure and being sealed in liquid-tight relation to the end surfaces of said enclosure, and the interior surface of said tubings being adapted to be in contact with the liquid in which said enclosure is immersed and providing a conduit through which such liquid flows when said transducers are operated.

11. An ultrasonic treatment apparatus as set forth in claim 10, said enclosure being made of polymeric plastic material.

12. An ultrasonic treatment apparatus as set forth in claim 10, said enclosure and tubings being made of the same polymeric plastic material.

13. An ultrasonic apparatus as set forth in claim 12, the wall thickness of said tubings being less than the wall thickness of said enclosure.

14. An ultrasonic apparatus as set forth in claim 10, said heat conducting medium being an electrically insulating liquid.

15. An ultrasonic apparatus as set forth in claim 10, and means disposed on said enclosure for supporting said enclosure immersed in the liquid so that said tubings are disposed in a substantially vertical direction.

16. An ultrasonic apparatus as set forth in claim 10, said enclosure and tubings being made of material suitable for being immersed in an etching solution.

* * * * *