Aug. 30, 1960 S. E. JACKE ET AL 2,950,725

ULTRASONIC CLEANING APPARATUS

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FIG. 1.

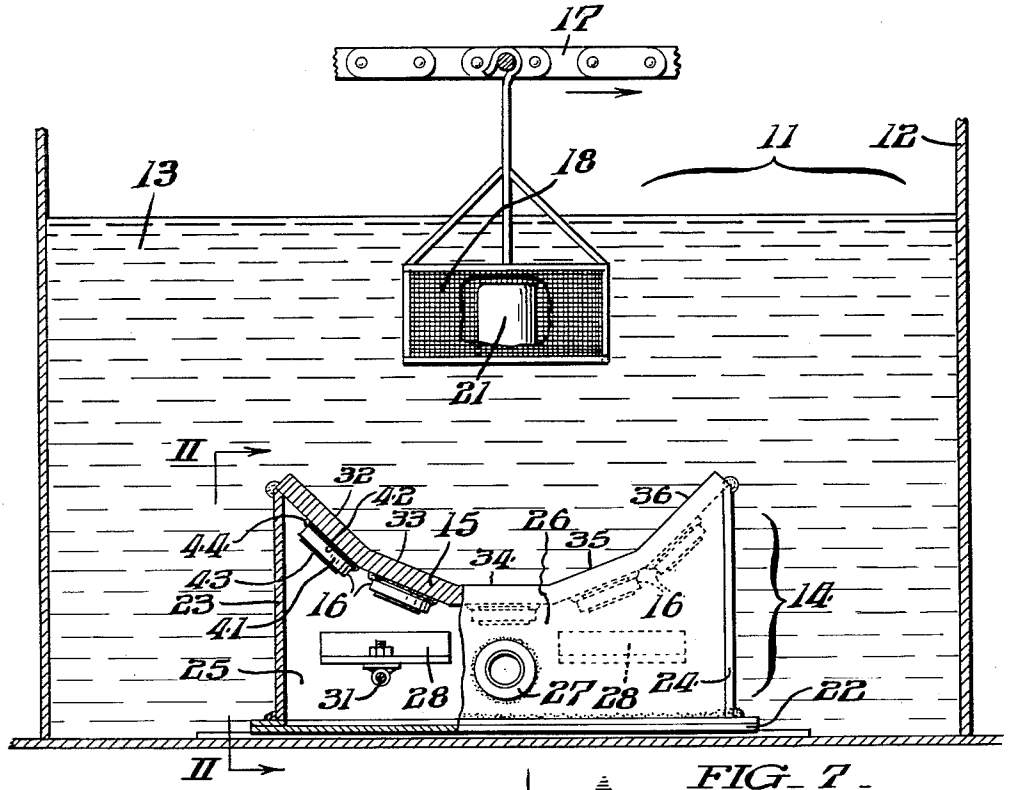


FIG. 4.

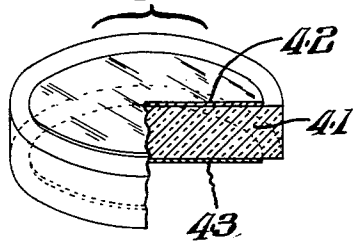
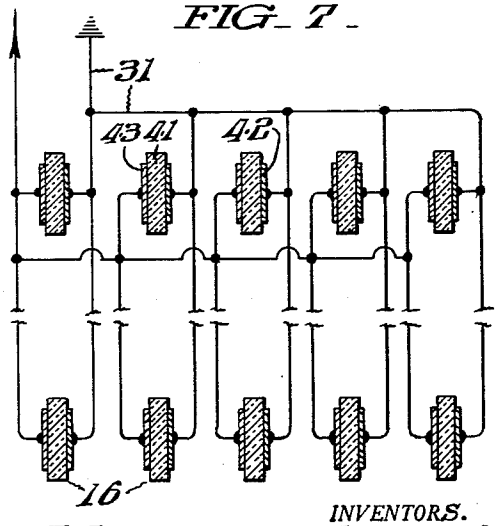


FIG. 7.



INVENTORS.
Stanley E. Jacke, Lowell C. Newsome &
John W. Collison,
BY Paul & Paul
ATTORNEYS.

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FIG. 2.

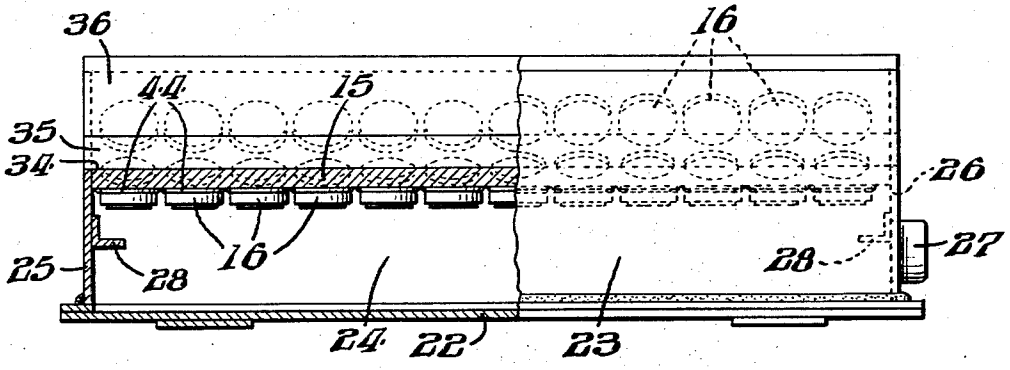
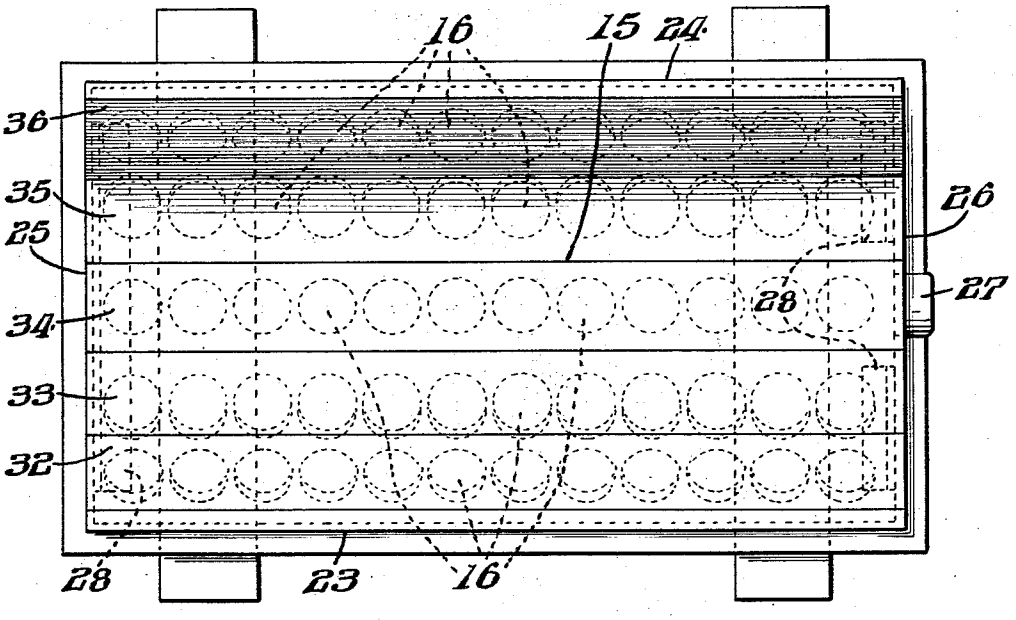


FIG. 3.



INVENTORS.
Stanley E. Jacke, Lowell E. Newsome &
John W. Collison,
BY Paul & Paul
ATTORNEYS.

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FIG. 5.

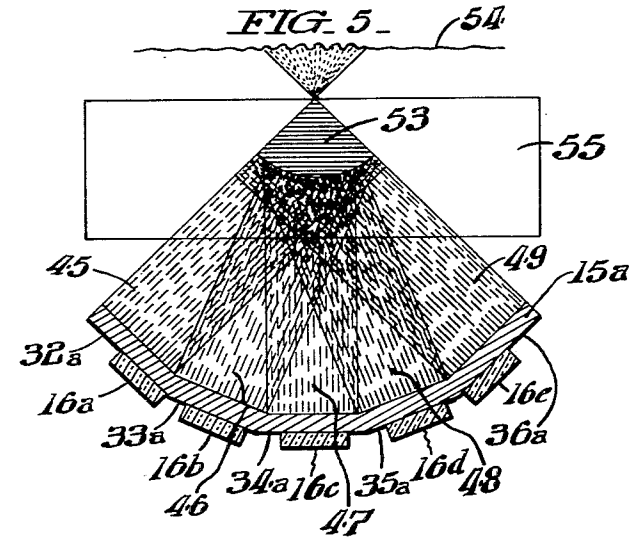
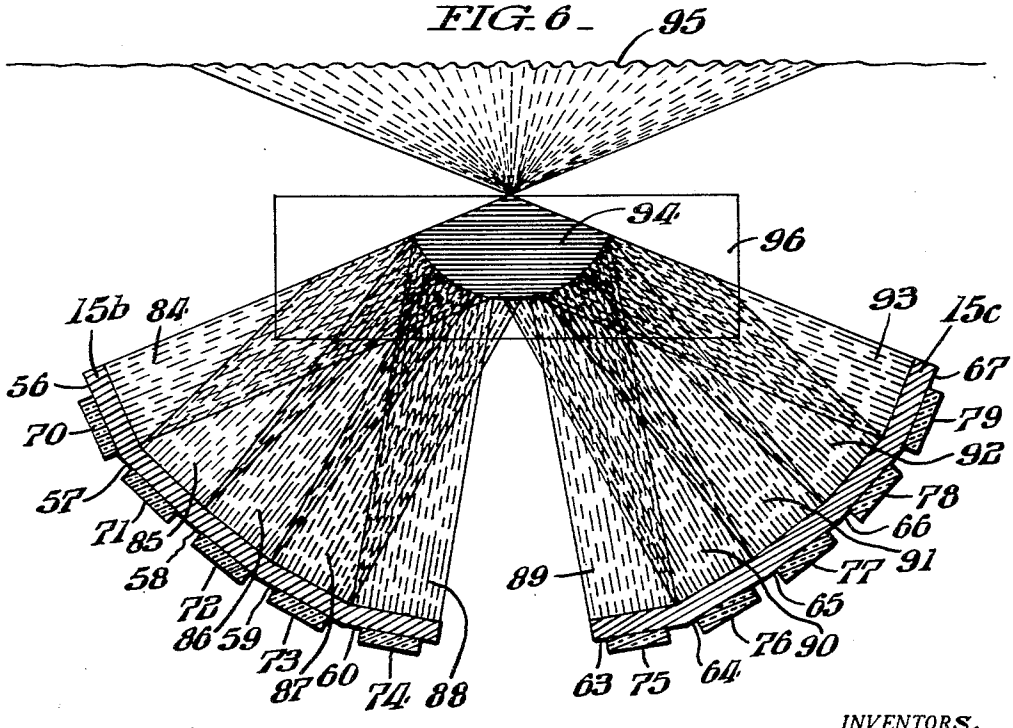


FIG. 6.



INVENTORS.
Stanley E. Jacke, Lowell C. Newsome &
John W. Collison,
BY Paul & Paul
ATTORNEYS.

United States Patent Office 2,950,725 Patented Aug. 30, 1960

2,950,725

ULTRASONIC CLEANING APPARATUS

Stanley Emil Jacke, Milford, Lowell C. Newsome, Inkster, and John W. Collison, Bloomfield Hills, Mich., assignors to Detrex Chemical Industries, Inc., Detroit, Mich., a corporation of Michigan

Filed Mar. 26, 1958, Ser. No. 724,138

5 Claims. (Cl. 134—184)

This invention relates to improvements in ultrasonic cleaning apparatus, and more particularly concerns such apparatus which includes a piezoelectric transducer contained within a hermetically sealed housing which is submerged in a cleaning liquid. It has long been desired to submerge piezoelectric transducers in a cleaning liquid and to protect the piezoelectric ultrasonic transducers, and the cleaning apparatus of which they form a part, from electrical disturbances caused by submerging the tranducers in a cleaning liquid that is electrically conductive. It has also been desired to protect the transducers and cleaning apparatus from contamination, and from physical and chemical attack by cleaning liquids. Electrically non-conductive cleaning liquids, such as trichlorethylene, may not cause electrical disturbances but may otherwise attack the transducers.

Heretofore to provide this protection it has been suggested to enclose the piezoelectric transducers in a housing which has an emitting membrane with a thickness that is very small, a few percent of the wave length of the ultrasonic waves emitted. A membrane of this thickness has a negligible effect on the acoustic coupling between the transducer and the cleaning liquid. At 400 kilocycles the thickness of such a membrane is .005 inch or less.

However, problems arise in the sealing of this thin membrane to the remainder of the housing containing the transducers. This sealing is difficult to accomplish and the housing is therefore prone to leaks which permit the cleaning fluid to enter the housing to attack the transducers. Another disadvantage of the thin membrane is that it does not afford much protection to the transducers if an object should accidentally be dropped onto it.

It is accordingly an object of this invention to overcome the hereinbefore mentioned disadvantages, and to provide ultrasonic cleaning apparatus which has increased protection, increased efficiency, and increased intensity of the ultrasonic waves. It is another object of this invention to provide ultrasonic cleaning apparatus which includes an emitting plate which is strongly constructed to afford protection to the transducers. It is another object to substantially reduce the frequency and impedance matching problems in such apparatus. It is another object to reduce the frequency drift caused by change in tank temperature, and thereby substantially reduce adjustment to the electrical generator when the tank temperature varies. It is another object of the invention to protect the transducers or electrical connections from being shorted out by the soils in the cleaning fluid. It is another object of the invention to prevent electrical arcs and shorts. It is another object to eliminate the use of liquid seals and their associated gaskets, clamps, or bolts. It is another object to eliminate rubbing contacts between the electrical leads and the transducers. It is another object to provide a transducer assembly which is a separate entity, which is not necessarily attached to the well containing the cleaning fluid, and which therefore can be

submerged at any desired angle in any shape or size tank large enough to contain it.

Other objects and advantages of this invention will further become apparent hereinafter and in the drawings, in which:

Fig. 1 is a view in elevation of ultrasonic cleaning apparatus constructed in accordance with this invention with parts being broken away in order to illustrate important details;

Fig. 2 is a view in elevation and with parts broken away taken as indicated by the lines and arrows II—II which appear in Fig. 1;

Fig. 3 is a view in top plan of the apparatus shown in Fig. 2;

Fig. 4 is a view on an enlarged scale and partly in section of one of the ultrasonic transducer elements;

Fig. 5 is a view of the cleaning liquid and a portion of the ultrasonic cleaning apparatus of Fig. 1, and shows the apparatus operating and generating beams of ultrasonic waves which are focused at a focal zone;

Fig. 6 is a view similar to Fig. 5 and illustrates the operation of two ultrasonic generating units; and

Fig. 7 is a diagrammatic view of the electrical circuit of the transducers.

In describing the preferred embodiment of the invention illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, it is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

Turning now to the specific embodiments of the invention selected for illustration in the drawings, the number **11** designates generally an ultrasonic cleaning apparatus including a well or tank **12** containing a cleaning liquid **13** such as trichlorethylene, and a hermetically sealed housing **14** which has a focused emitting plate **15** and a plurality of transducers **16** connected in an electrical circuit with a high frequency electrical generator (not shown). Positioned above the level of the cleaning liquid **13** is a conveyor **17** from which is suspended a basket **18** which contains a work object **21** submerged in cleaning liquid **13** to be cleaned or degreased.

Housing **14** is provided with a bottom plate **22**, side walls **23** and **24**, and end walls **25**, **26**. These elements welded together so that housing **14** is hermetically sealed. An aluminum half-coupling **27** is welded in end wall **26** and through this coupling pass the electrical wires or coaxial cable which extend from the 400 kilocycle electrical generator to supply transducers **16** with power. These electrical wires or cable are encased within an outer conduit which is sealed to coupling **27**.

Aluminum ground brackets **28** are welded to the interior of end walls **25**, **26** and the brackets **28** support ground connectors **31**.

Focused emitting plate **15** is constructed of aluminum and in 400 kilocycle apparatus is 0.325 inch, plus or minus 0.002 inch, thick. Plate **15** is formed into five segments **32**, **33**, **34**, **35**, and **36** with an angle of 22½ degrees between the planes of each adjoining segment. It is to be understood that the invention is not limited to five segments or an angle of 22½ degrees.

As shown in Fig. 4, transducers **16** include barium titanate discs **41** which have an upper silver electrode **42** and a lower silver electrode **43**. These discs are attached to the underside of focused emitting plate **15** by a layer of glue **44** which may be epoxy resin. Transducers **16** form rows along the underside of segments **32**—**36**. The lower silver electrodes **43** of all transducers **16** are electrically connected to the electrical generator and the upper silver electrodes **42** are all connected to ground.

Any desired electrical circuit may be used to effect these connections and one such circuit is shown in Fig. 7. In Fig. 7 the electrical connectors are soldered directly to electrodes 42, 43 before the transducers 16 are potted in the glue layers 44 and attached to the underside of segments 32—36.

Referring to Fig. 5, there is shown a focused emitting plate 15*a* which is formed by segments 32*a*—36*a*. Attached to the underside of the segments are transducers 16*a*—16*e*. These transducers, which form rows along the segments, generate ultrasonic waves which are emitted from focused emitting plate 15*a* in the form of beams 45—49 which are perpendicular to the segment emitting them. Beams 45—59 are focused by emitting plate 15*a* and form focal zone 53 whose cross-section is a polygon. The volume formed by projecting the polygon along the entire length of the transducer has a considerable concentration of ultrasonic energy. The surface of the cleaning liquid is indicated by numeral 54 and the work object to be cleaned is indicated by the numeral 55.

Referring to Fig. 6, there is shown the emitting plates 15*b* and 15*c* of two transducer housings and these emitting plates are formed of segments 56—60 and 63—67 which have attached to their undersurface the transducers 70—74 and 75—79. These transducers generate ultrasonic waves which form beams 84—88 and 89—93 of ultrasonic waves which converge on a focal zone 94. The polygonal focal zones generated by plates 15*b* and 15*c* may be positioned so they overlap or not, as desired. The surface of the beam liquid is indicated by the numeral 95 and the work object to be cleaned is indicated by the numeral 96.

In operation, the work object is submerged in cleaning liquid 13, the electrical generator is turned on, and the transducers 16 generate ultrasonic waves which are emitted through the focused emitting plates 15 in the form of beams which converge on the focal zone of intense ultrasonic energy.

The work object is passed through this focal zone where it is thoroughly cleaned and degreased.

It is to be noted that the focusing of the ultrasonic beams is of considerable advantage and that it provides for striking the work object with ultrasonic waves from various angles. Work objects may be passed below the focal zone as well as at the focal zone or above it.

With work objects having large recesses or cavities, there is a distinct advantage in passing the work object through the cleaning liquid in such a manner that the recess or cavity passes through the focal zone of ultrasonic energy where this intensified energy can do the most good to produce a thoroughly cleaned work object.

Among the advantages of the hereinbefore described invention is the protection given the transducers from electrical disturbances caused by submerging the transducers in a cleaning liquid that is electrically conductive. Since the transducers are contained within a hermetically sealed housing 14, such electrical disturbances cannot affect them. Further, hermetically sealed housing 14 protects the transducers from contamination and from physical and chemical attack by the cleaning liquids, and the thickness of focused emitting plate 15 protects the apparatus from damage caused by falling objects.

Another advantage of the apparatus is that a high intensity focused zone of ultrasonic energy has been obtained even though flat transducers are used as the ultrasonic wave emitter. Additionally, the above described construction substantially reduces the frequency and frequency matching problems heretofore encountered, and it reduces the impedance drift caused by change of temperature of the cleaning liquid in the tank, thereby substantially reducing the number of adjustments to the electrical generator due to variation in cleaning liquid temperature in the tank. The present construction also protects the transducers and their electrical connectors from being shorted out by soils in the cleaning fluid, since such soils do not penetrate the hermetically sealed housing 14. Electrical arcs and shorts are prevented and the welded construction eliminates the use of liquid seals and their associated gaskets, clamps or bolts. The electrical leads are soldered directly to the transducer electrodes, which eliminates the rubbing contacts between and which have been heretofore proposed. The ultrasonic wave emitting apparatus comprises a separate package contained within housing 14, and it is easily inserted into any tank and positioned therein so as to emit its ultrasonic energy at any desired angle.

It is to be understood that the form of the invention herein shown and described is to be taken as a preferred embodiment. Various changes may be made in the shape, size, and arrangement of parts. Equivalent elements may be substituted for those described herein, parts may be reversed, and certain features of the invention may be utilized independently of the use of other features, all without departing from the spirit of the invention or the scope of the subjoined claims.

Having thus described our invention, we claim:

1. Ultrasonic cleaning apparatus for cleaning a work object in a well containing a cleaning liquid, said apparatus comprising a hermetically sealed housing submerged in said liquid; a focused emitting plate for emitting ultrasonic waves, said emitting plate forming part of said housing and being spaced away from said work object, said emitting plate being formed of flat segments with the exterior surface of the emitting plate being of generally concave conformation; and a plurality of flat transducers attached to the interior surface of each of said segments with the interior surface of the emitting plate being of generally convex conformation, said transducers and said plate operating to emit a plurality of beams of ultrasonic waves, each of said beams being normal to the surface of the flat segment to which it is attached, whereby the beams of ultrasonic waves are focused and converge at a focal zone outside of the housing.

2. The ultrasonic cleaning apparatus defined in claim 1, wherein said hermetically sealed housing is of welded aluminum construction.

3. Ultrasonic cleaning apparatus for cleaning a work object in a well containing a cleaning liquid, said apparatus comprising a hermetically sealed housing submerged in said liquid; a focused emitting plate for emitting ultrasonic waves of desired wave length, said emitting plate forming part of said housing and being spaced away from said work object, said emitting plate being formed of flat segments with the exterior surface of the emitting plate being of generally concave conformation, said emitting plate being one half of said wave length in thickness; a plurality of flat transducers attached to the interior surface of each of said segments with the interior surface of the emitting plate being of generally convex conformation; and a high frequency electrical generator connected in circuit with said transducers; said transducers and plate operating to emit a plurality of beams of ultrasonic waves, each of said beams being normal to the surface of the flat segment to which it is attached, whereby the beams of ultrasonic waves are focused and converge at a focal zone outside of the housing.

4. The ultrasonic cleaning apparatus defined in claim 3, wherein said flat transducers are discs of barium titanate.

5. Ultrasonic cleaning apparatus for cleaning a work object in a well containing a cleaning liquid, comprising a hermetically sealed, welded aluminum housing submerged in the cleaning liquid; a focused emitting plate for emitting ultrasonic waves of desired wave length, said emitting plate forming part of said housing and being spaced away from said work object, said emitting plate being formed of flat segments with the exterior surface of the emitting plate being of generally concave conformation, said emitting plate being one-half of said

wave length in thickness; a plurality of barium titanate discs glued to the interior surface of each of said segments with the interior surface of the emitting plate being of generally convex conformation; and a high frequency electrical generator connected in circuit with said discs; said discs and plate operating to emit a plurality of beams of ultrasonic waves, each of said beams being normal to the surface of its flat segment, whereby the beams of ultrasonic waves are focused and converge at a focal zone outside of the housing.

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