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T. J. KEARNEY
METHOD AND APPARATUS UTILIZING FOCUSED
ULTRASONIC TRANSDUCERS TO PRODUCE
RADIALLY DISPERSED
COMPRESSION WAVES
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FIG. 1

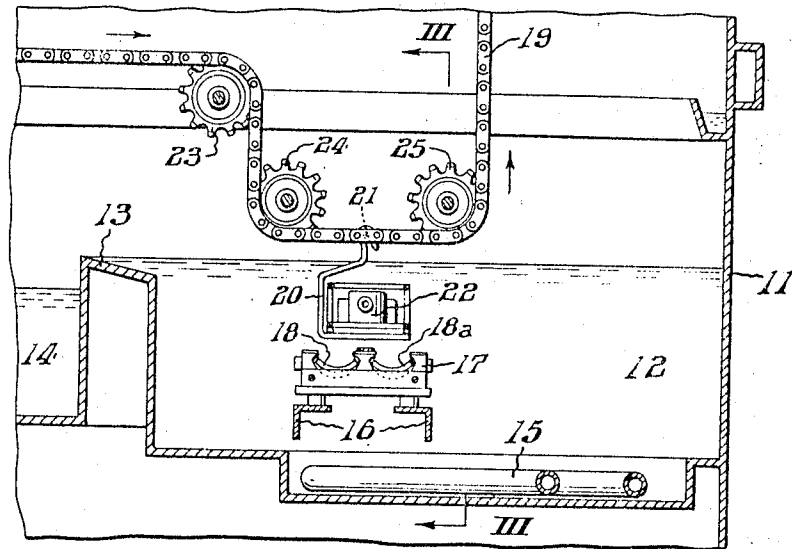


FIG. 2

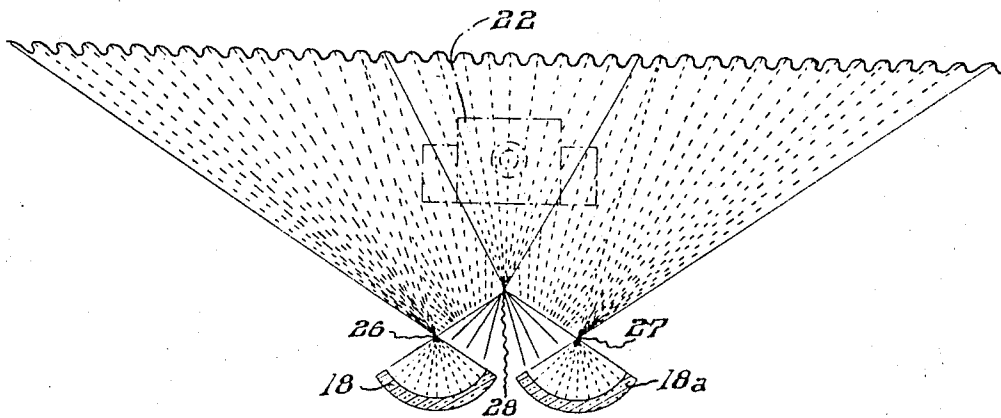
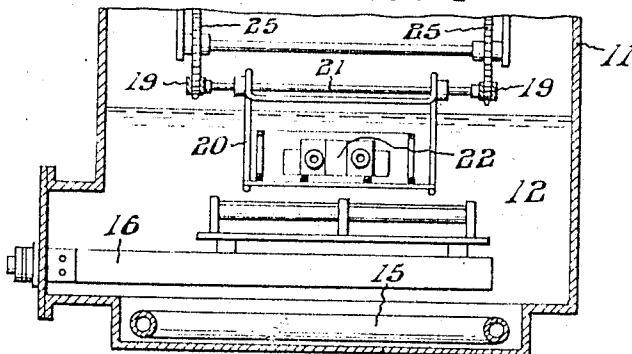


FIG. 3



INVENTOR.
Thomas J. Kearney,
BY Paul & Paul
ATTORNEYS.

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METHOD AND APPARATUS UTILIZING FOCUSED ULTRASONIC TRANSDUCERS TO PRODUCE RADIALLY DISPERSED COMPRESSION WAVES

Thomas J. Kearney, Detroit, Mich., assignor to Detrex Corporation, Detroit, Mich., a corporation of Michigan

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10 Claims. (Cl. 134—1)

This invention relates to apparatus and a process of treating a work object. More particularly it is concerned with the cleaning and degreasing of intricately formed metal parts by application of chlorinated hydrocarbon solvents and ultrasonic energy.

Finely machined parts which have been buffed, lapped or ground, as for example, heads for electric razors, hypodermic needles, deep drilled metal parts and the like, are very difficult to clean and previous methods and apparatus as ordinarily constructed did not accomplish the complete removal of grease and adhering dirt or "soil" from the hollows or interstices of intricately machined parts.

The generation of ultrasonic vibrations in a bath of liquid solvent has presented some difficulty. Previously compression waves have been produced from flat piezoelectric or magnetostrictive devices and standing waves have been formed. Non-uniform washing is sometimes obtained. It is thought that standing waves produced between the source of the ultrasonic energy and the surface of the liquid solvent are the cause of alternate soiled and unsoiled strips on the work object being cleaned, the distance between strips being approximately equal to one-half the wave length of the ultrasonic wave energy being used.

United States Patent No. 2,650,872 to Goldwasser discloses a method and apparatus for eliminating the alternate soiled and unsoiled strip effect. Although devices of the character illustrated in the Goldwasser patent are entirely adequate for their intended service, the present invention performs more efficiently and is less complicated, being based on a new and entirely different principle.

Accordingly, the principal object of the present invention is to provide a new and improved apparatus and method for cleaning and degreasing with ultrasonic energy in a liquid solvent.

A further object of the invention is to provide new and improved apparatus for cleaning and degreasing in which the ultrasonic waves are focused and are diverging when they contact the work object. It has been found that contacting the work object with diverging ultrasonic waves produces remarkable cleanliness which is completely new and novel, and while the reason for such a result is not clearly known, the resulting cleanliness of the work object has heretofore been unobtainable.

Further features and objects of the invention, as well as the details of a typical and preferred embodiment thereof, will be understood from the detailed description to follow, throughout which reference is made to the accompanying drawings wherein:

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Fig. 1 represents a side elevation of a cleaning apparatus constructed in accordance with the invention.

Fig. 2 represents a view of the liquid in the well of Fig. 1 with the apparatus operating and illustrates the radially dispersed waves of sound energy generated therein.

Fig. 3 represents an end view taken along line III—III of Fig. 1, looking in the direction of the arrows.

Turning now to the drawings, the apparatus comprises a housing 11 which, in practice, is constructed of sheet metal. Located within the housing 11 is a well 12 which includes an overflow dam 13. Well 12 contains a chlorinated hydrocarbon liquid solvent which will rise no higher in the well than the level defined by overflow dam 13 which permits the liquid to overflow into well 14. Well 12 is provided at the bottom with pipe coil 15 through which either water or steam is circulated as may be required to maintain the liquid in said well at the temperature desired.

A pair of supporting angles 16 are fixed to the side of housing 11 and extend horizontally into the well 12 below the surface of the liquid. A transducer mounting assembly 17 supports freely a pair of transducers 18, 18a within the liquid. These transducers 18, 18a are caused to vibrate at ultrasonic frequencies by any well known means.

A double chain conveyor 19 has a work carrier 20 depending from a cross rod 21. A work object 22 to be cleaned is positioned on work carrier 20, and conveyor 19 operates to transport work object 22 around sprocket wheels 23, 24 and 25, immersing the work object 22 in the liquid of well 12. Work object 22 follows a substantially horizontal path through the liquid parallel to the liquid surface above the transducers 18, 18a.

The transducers 18, 18a are elongate and arcuate in cross section, being formed of a section of a cylinder. Such curvilinear transducers made of barium titanate or any other electrostrictive poly-crystalline aggregate, deliver intense sonic energy to the focus of the transducer. From the focus the waves disperse themselves radially over a very wide area. Ultrasonic waves are emitted by the transducer 18 and are focused along a line 26 which is uniformly spaced from the base of said transducer 18. Similarly, ultrasonic waves are emitted by the transducer 18a and are focused along a line 27 which is uniformly spaced from the base of said transducer 18a. In the specific embodiment of the invention illustrated in the drawings the transducers are spaced apart from one another in a horizontal plane and the ultrasonic waves from the respective transducers intersect at a line 28 which is spaced above the focal lines 26 and 27. The conveyor 19 is arranged to carry work object 22 in a horizontal path under the liquid surface at a level above line 28.

According to the present invention, the work object is immersed in a bath of chlorinated hydrocarbon liquid solvent. This solvent is preferably trichlorethylene. Perchlorethylene and methylene chloride have been used and have given satisfactory results. While immersed in the bath, ultrasonic waves in the range of about 200 to 1000 kilocycles are generated in the liquid which are focused and directed toward the work object, striking the work object while the ultrasonic waves are diverging. The work object is transported across the ultrasonic waves in a substantially horizontal path below the surface of the liquid.

The following specific examples serve to illustrate the process of the invention:

Example 1

The work object is immersed in a bath of trichlorethylene at a temperature in the range of about 110 to 140° F. and subjected to ultrasonic waves of a frequency of about 400 kilocycles.

Example 2

The work object is immersed in a bath of perchlorethylene at a temperature in the range of about 140 to 170° F. and subjected to ultrasonic waves of a frequency of about 400 kilocycles.

Example 3

The work object is immersed in a bath of methylene chloride at a temperature in the range of about 58 to 78° F. and subjected to ultrasonic waves of a frequency of about 400 kilocycles.

While the specific embodiment of the invention described herein has been confined to the cleaning or degreasing of a work object by contact with a chlorinated hydrocarbon solvent, it will be appreciated that the invention can be used to accomplish a variety of objects and is not limited to cleaning or degreasing. For example, the invention has application in the field of plating where the work object is immersed in a liquid and the ultrasonic vibrations induce an even coating to cover the work object. Further, the work object may be pre-dipped before being subjected to the invention.

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. For example, the transducers can be mounted with their convex surface upward to focus the ultrasonic waves downward over a widely dispersed area. This arrangement permits passing the work object beneath the transducers where it is desired to subject the significant and difficult upper surface, including cavities, drilled and tapped holes and the like, of a work object directly to the impact of the emitted ultrasonic longitudinal wave motion.

Having thus described my invention, I claim:

1. A method of cleaning a work object comprising immersing the work object in a chlorinated hydrocarbon liquid, piezoelectrically creating ultrasonic waves by electrically energizing piezoelectric means submerged in said chlorinated hydrocarbon liquid at a zone within said chlorinated hydrocarbon liquid, said piezoelectric means being out of direct mechanical contact with said work object, causing said ultrasonic waves to diverge, focusing the waves prior to divergence, directing said waves toward the work object, and striking said work object with said waves while said waves are diverging.

2. The method defined by claim 1, wherein said liquid is trichlorethylene at a temperature in the range of about 110 to 140° F.

3. The method defined by claim 1, wherein said liquid is perchlorethylene at a temperature in the range of about 140 to 170° F.

4. The method defined by claim 1, wherein said liquid is methylene chloride at a temperature in the range of about 58 to 78° F.

5. Apparatus for cleaning a work object comprising a well, said well containing a cleaning liquid, a pair of transducers mounted in substantially the same horizontal plane below the surface of said liquid, support means supporting the work object below the surface of said

liquid and spaced from the transducers, each of said transducers being curvilinear in cross section to focus its ultrasonic waves at a point between said transducer and said work object, said transducers being spaced apart from one another in said horizontal plane and thereby positioned so that ultrasonic waves from one overlap the waves from the other between said transducers and said work object.

6. Apparatus for cleaning and degreasing a work object comprising a well, said well containing a cleaning and degreasing liquid, a pair of transducers, means in said well for supporting said transducers in a substantially horizontal plane below the liquid surface, said transducers having capacity to emit ultrasonic waves, each transducer having the form of a section of a cylinder thereby focusing the ultrasonic waves emitted along a line which is uniformly spaced from the base of said transducer, the focal axis of each of said transducers extended substantially vertically in said well, conveyor means extending into said well below the surface of said liquid for carrying said work objects along a substantially horizontal path which is spaced above each of said focal lines, said transducers being spaced apart from one another in a horizontal plane, whereby the ultrasonic waves from said respective transducers intersect at a second line which is spaced above said focal lines.

7. Apparatus for cleaning and degreasing a work object comprising a well, said well containing a cleaning and degreasing liquid, a pair of transducers, means in said well for supporting said transducers in a substantially horizontal plane below the liquid surface, said transducers having capacity to emit ultrasonic waves, each transducer having the form of a section of a cylinder thereby focusing the ultrasonic waves emitted along a line which is uniformly spaced from the base of said transducer, the focal axis of each of said transducers extended substantially vertically in said well, conveyor means extending into said well below the surface of said liquid for carrying said work objects along a substantially horizontal path which is spaced above each of said focal lines, said transducers being spaced apart from one another in a horizontal plane, whereby the ultrasonic waves from said respective transducers intersect at a second line which is spaced above said focal lines, and said conveyor being arranged to carry said work objects under the liquid surface at a level above said second line.

8. A method of cleaning a work object comprising immersing the work object in a chlorinated hydrocarbon liquid, piezoelectrically creating ultrasonic waves by electrically energizing piezoelectric means submerged in said liquid at a zone within said liquid, said piezoelectric means being out of direct mechanical contact with said work object, causing said ultrasonic waves to focus at a point through which substantially all of the said waves pass and from which said waves diverge, directing said waves toward the work object, and striking said work object with said waves while said waves are diverging.

9. Apparatus for cleaning a work object comprising a well, said well containing a liquid chlorinated hydrocarbon, means for supporting the work object below the surface of said liquid, a piezoelectric transducer mounted in the well below the surface of and submerged in said liquid and spaced at a predetermined distance from the work object for piezoelectrically generating ultrasonic waves at a zone within said liquid out of direct mechanical contact with said work object, said transducer being curvilinear in cross section and aimed at the work object and with a focal length less than said predetermined distance, whereby the ultrasonic waves are focused between said transducer and said work object, and at a location spaced away from said transducer and said work object.

10. Apparatus for cleaning a work object comprising a well, said well containing a liquid chlorinated hydrocarbon, an elongated piezoelectric transducer mounted in

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the well below the surface of and submerged in said liquid for piezoelectrically generating ultrasonic waves at a zone within said liquid out of contact with said work object, conveyor means extending below the liquid surface in said well and spaced at a predetermined distance from the transducer to transport the work object through said liquid, said transducer being curvilinear in cross section and aimed at the work object and with a focal length less than said predetermined distance whereby ultrasonic waves are focused between said transducer and said work object.

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