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Filed March 31, 1954

2 Sheets-Sheet 1

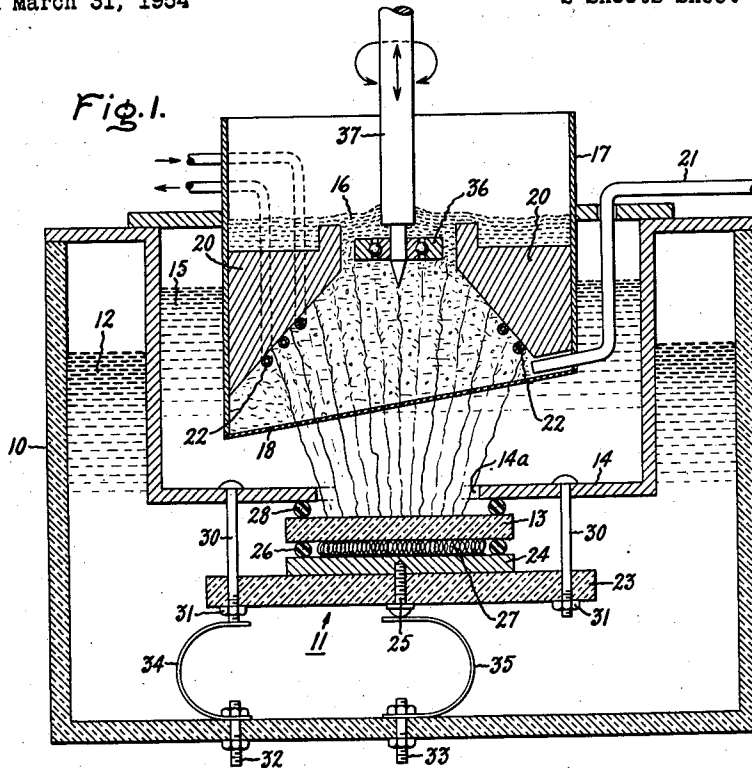
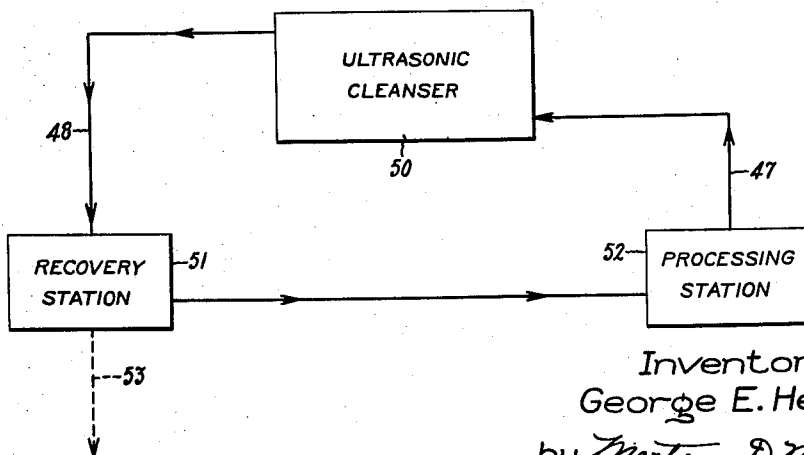


Fig. 3.



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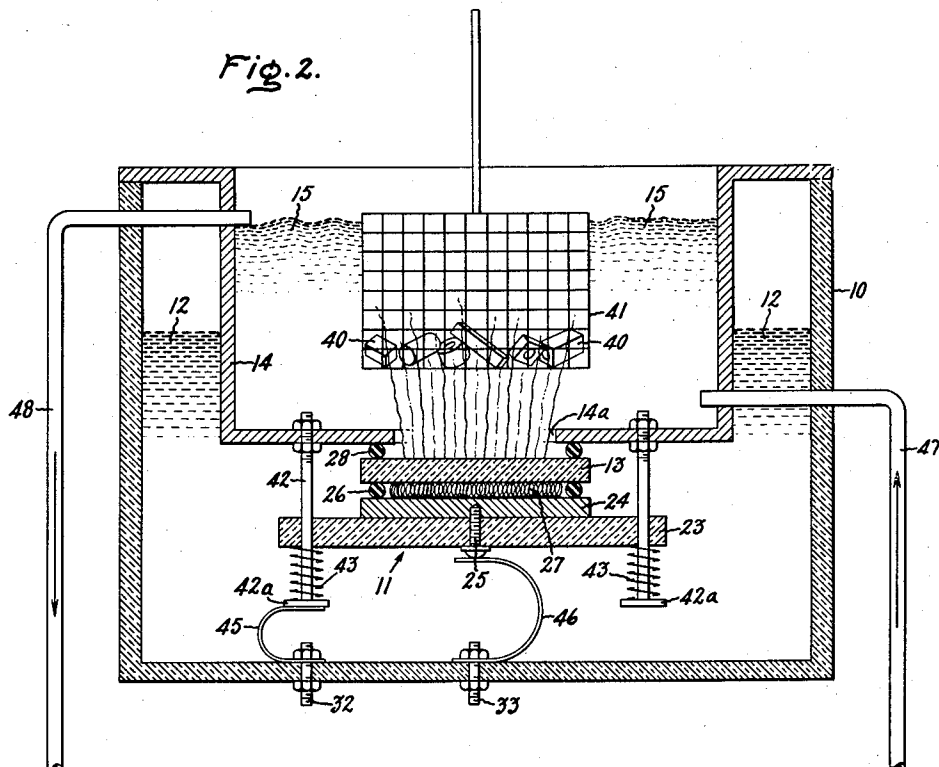
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METHOD AND APPARATUS FOR ULTRASONIC CLEANSING

Filed March 31, 1954

2 Sheets-Sheet 2



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2,828,231

METHOD AND APPARATUS FOR ULTRASONIC CLEANSING

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Application March 31, 1954, Serial No. 420,017

10 Claims. (Cl. 134-1)

This invention relates to the cleansing of objects, and more particularly to an improved method and apparatus, which utilize ultrasonic compressional waves as a cleansing mechanism.

The primary object of the present invention is to provide an improved method and apparatus for cleansing objects, wherein ultrasonic compressional waves are utilized as a cleansing agent, and which perform the cleansing operation more quickly and efficiently than presently known methods and apparatus.

The word "cleansing" is used in this specification in its broadest sense, and includes such acts as the removing of dirt, dust, scale, rust, and grease. That is, the method and apparatus of this invention are not limited to the removal of any particular matter from an object, but include the removal of any separable foreign matter, which may become attached to an object.

The method of the invention, by means of which the foregoing object may be attained, essentially comprises subjecting the object to be cleansed to ultrasonic compressional waves, while the object is immersed in a liquid which has dissolved gas maintained therein, and whose temperature may also be controlled. The liquid in which the object, or at least that part of the object which it is desired to cleanse, is immersed, may be a solvent to aid in the cleansing process, or it may be any liquid suitable for the cleansing process and for the transmission thereof of ultrasonic compressional waves. However, in either case, a substantial amount of dissolved gas is maintained in the liquid.

Apparatus, by means of which the method of the invention conveniently may be practiced, comprises an outer container for an ultrasonic transducer. The transducer may be energized by conventional generator means to produce ultrasonic compressional waves, which are transmitted into an inner container for a liquid in which the object or objects to be cleansed are immersed. Means are provided to maintain a substantial amount of dissolved gas in the liquid, and means may also be provided to maintain the temperature of the liquid within a certain range to tend to decrease the amount of gas that is driven off the liquid in the cleansing process. Controlling the temperature of the liquid may also be effective to obtain maximum cleansing action from the liquid itself.

For a better understanding of the invention, reference is made to the following specification, taken in conjunction with the accompanying drawing, in which

Fig. 1 is a vertical cross-sectional view of one form of apparatus for carrying out the method of the invention;

Fig. 2 is a view similar to that of Fig. 1, showing another form of the apparatus; and

Fig. 3 is a flow diagram useful in understanding the method of operation of the form of apparatus shown in Fig. 2.

Fig. 1 illustrates an apparatus constructed in accordance with the invention, which is particularly well

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adapted for the cleansing of small parts such as ball bearings. It is to be understood, however, that the method and apparatus of the invention are not limited to the cleansing of any particular objects, but have many varied uses and applications. Furthermore, the invention is not limited to the cleansing of small parts, but may also be used in the cleansing of large objects, or portions of large objects. However, the size of the object cleansed must be such that at least that part of the object which it is desired to cleanse may be immersed in a liquid which has ultrasonic compressional waves transmitted there-through.

The apparatus illustrated in Fig. 1, which is adapted to rest upon a base (not shown), comprises an outer container 10, which may be conveniently constructed of glass, plastic, or other insulating material. The outer container 10 contains a transducer assembly, designated generally by the numeral 11, and is filled with a suitable dielectric fluid 12, such as oil, to a level above the transducer assembly 11. The transducer assembly includes a piezoelectric or electrostrictive element 13, and is mounted with the piezoelectric element aligned with an opening 14a in the bottom surface of an inner container 14. The transducer assembly may be energized by a conventional electronic generator (not shown) through electrical connections, which will be described hereafter, to produce ultrasonic compressional waves and transmit them upwardly into the inner container 14.

The inner container 14 may be constructed of any suitable conducting material, and is filled with an electrolytic liquid 15 such as water. It is necessary that the liquid in the inner container be an electrolyte because it must provide electrical contact with one face of the piezoelectric element 13 to complete the electrical circuit for energizing the element.

In the form of the invention shown in Fig. 1, it is desired to immerse the part being cleansed in a solvent 16, in order to aid the cleansing action. Because the majority of desirable solvents are not good conductors of electricity, the solvent 16 and the object being cleansed have been shown as being enclosed within a third container 17 made of a metal such as stainless steel, aluminum, or nickel-plated brass. The container 17 is provided with a bottom 18 that may be slanted somewhat to improve its acoustic transmission (as illustrated), and may be constructed of thin stainless steel, aluminum, or other material through which ultrasonic compressional waves will easily pass. The ultrasonic compressional waves produced by the piezoelectric element 13 are transmitted upwardly through the liquid 15 and through the bottom 18 of the third container 17. Because such a beam of ultrasonic waves normally will not be focused, a heavy metal reflector 20 may be placed inside the container 17 to reflect any ultrasonic waves striking it toward the object being cleansed.

It has been discovered that the ultrasonic cleansing process is greatly improved over that previously known if the condition of the liquid which is in contact with the object to be cleansed, in this case the solvent 16, is controlled in certain ways so as to maintain a substantial amount of dissolved gas in the liquid. Various gases are suitable for this purpose, but, of course, the most easily obtainable is air. In the embodiment of the invention shown in Fig. 1, air is continuously bubbled through the liquid 16 from a supply pipe 21, to which it may be supplied from a conventional compressor or other means (not shown). It has been found that the quantity of gas that must be dissolved in the liquid 16, in order to obtain optimum cleansing, is not important so long as it tends to keep the liquid near saturation, and it is

sufficient merely to bubble air or gas continuously through the liquid.

When a liquid is subjected to ultrasonic compressional waves, the liquid is alternately rarefied and compressed by the waves. If, at a point of low pressure of rarefaction, the pressure within the liquid equals the vapor pressure characteristic of the particular temperature of the liquid, this portion of the liquid tends to boil. When there are dissolved gases in the liquid, they furnish nuclei from which a vapor bubble can grow, and thus the tendency of the liquid to boil during alternate half-cycles of the ultrasonic wave is increased. This action, which has a beneficial effect on the cleansing process, tends to drive off the gases in the liquid, and thus reduce the likelihood of formation of vapor bubbles at pressure values near the value of the vapor pressure. It is to replace these driven-off gases that air or gas is continuously bubbled through the liquid. It has been found that if a substantial amount of dissolved gas is maintained in the liquid, the cleansing process is greatly improved.

I have also discovered that the cleansing action is greatly improved if the liquid 16 is retained in a relatively cool state. The transmission of ultrasonic compressional waves of high power through a liquid generally raises the temperature of that liquid, and permits the gas dissolved in the liquid to be driven off more easily than when the liquid is cool. As previously mentioned, this action has a deleterious effect on the cleansing action of the apparatus. The exact temperature of the liquid necessary to obtain the most effective cleansing action varies from one application to another, but it has been discovered that the temperature generally should lie in the range from approximately 50° F. to 75° F. In order to maintain the temperature of the liquid within this range, cooling coils 22 are provided in the container 17. In the present case, the cooling coils 22 are located on the inner surfaces of the reflector 20, but their exact location within the container is relatively unimportant so long as the liquid 16 may be cooled thereby. A coolant may be supplied to the coils 22 from any suitable source, such as a conventional refrigerating mechanism or a cold water supply (not shown), and the cooling system may be closed so that the coolant may be continuously reused and there will be no need to replenish the supply.

If the liquid in which the object to be cleansed is immersed is a solvent, it may not be necessary to provide separate means for cooling the liquid, but only means to maintain a substantial amount of gas dissolved therein. Solvents are generally volatile, and, as the solvent evaporates, it tends to cool the remainder of the liquid. Thus, the temperature of the liquid may remain within the optimum range of 50-75° without cooling means being provided. It has also been found that certain solvents cleanse most effectively when they are maintained within certain temperature ranges. However, the range varies from one solvent to another, and must be determined for the particular solvent being used.

The transducer assembly 11 for generating the ultrasonic compressional waves comprises a supporting plate 23 made of a ceramic insulator such as that known commercially as Mycalex, to which is attached a conducting plate 24 which may be made of brass or some other suitable metal. The supporting plate 23 and conducting plate 24 are secured together by a screw 25 that also serves as part of the electrical circuit of the apparatus as will be later described. Supported above the conducting plate 24 and in spaced relation thereto is the piezoelectric or electrostrictive element 13, which may be a quartz crystal, a slab of barium titanate ceramic, or other suitable device. The piezoelectric element 13 is separated from the brass conducting plate 24 by a rubber or plastic O ring 26 that serves as a gasket, and a pad 27 of fine copper wire is interposed between the

conducting plate 24 and the piezoelectric element 13 to provide good electrical contact with both these elements. The piezoelectric element 13 is also separated from the bottom surface of the inner container 14 by a second rubber or plastic O ring 28 which operates to prevent the dielectric fluid 12 from reaching the upper surface of the piezoelectric element 13. The transducer assembly 11 is secured in position with the piezoelectric element 13 aligned with the opening 14a in the bottom surface of the inner container by means of bolts 30, which extend through the bottom surface of the inner container and through the supporting plate 23. By tightening down nuts 31 on the bolts 30, the O rings 26 and 28 may be compressed to maintain a seal between the electrolytic liquid 15 and the dielectric liquid 12, and also to maintain the transducer assembly securely mounted.

Electrical connections for the transducer assembly are made through studs 32 and 33, which extend through the bottom surface of the outer container 10, and may be provided with suitable packing to prevent the escape of dielectric oil 12 from the container. The studs 32 and 33 have a pair of small leaf springs 34 and 35, respectively, secured thereto inside the container 10, through which electric current for the transducer assembly is conducted. The leaf spring 34 is in contact with one of the bolts 30 that serve to secure the transducer assembly to the inner container 14, and the other leaf spring 35 is in contact with the head of the screw 25 that secures the supporting plate 23 to the brass plate 24. Thus, it is seen that the path of current flow between the studs 33 and 32 includes leaf spring 35, screw 25, brass plate 24, copper wire pad 27, piezoelectric element 13, electrolytic liquid 15, one of the bolts 30, and leaf spring 34.

The studs 32 and 33 may be connected to the output terminals of a conventional electronic generator, and because the liquid 15 and the inner container 14 are at the potential of the stud 32, it is normally desirable to have the stud 32 connected to the grounded side of the generator. Electronic generators which are suitable for this purpose are conventional and well-known in the art, and are available commercially from a number of sources. The particular frequency at which the piezoelectric element operates may vary for different applications, and, of course, the piezoelectric element must be selected for the particular operating frequency desired. However, it has been found with the method and apparatus of the present invention that an operating frequency lying between 250 kc. and 1200 kc. is usually suitable.

Fig. 1 illustrates the cleansing of a ball bearing 36, as an example of a typical small object which might conveniently be cleansed by the method and apparatus of the invention. The bearing 36 is mounted on an arbor 37, which may be rotated and reciprocated axially by conventional means (not shown). It has been found that a bearing such as is illustrated may be quickly and efficiently cleansed of grease, dust and other particles by rotating the arbor first in one direction and then in the other, and simultaneously reciprocating the arbor axially. The drag of the liquid 16 on the outer race of the bearing causes relative movement between the inner and outer races, which is desirable in the cleansing process. In addition, it has been found that a very beneficial result may be obtained if the object being cleansed is moved up and down through the agitated free surface of the liquid. Simultaneously, of course, the bearing is subjected to high power ultrasonic compressional waves through the liquid 16, whose physical characteristics are controlled in the manner previously described. It has been found that the cleansing power of the agitated liquid is far greater at or near the surface and that by moving the article repeatedly through said surface this increased cleansing action is applied over the surface of the article with the result of greatly increased rapidity of the cleansing operation.

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Fig. 2 illustrates a modification of the apparatus of the invention, which is adapted to the cleansing of a variety of small parts 40, retained in a mesh or wire basket 41, through which liquid may circulate freely. The parts to be cleansed are immersed directly in the liquid 15, rather than being immersed in a liquid which is retained within a separated container.

This form of the invention, which is generally similar to that previously described with reference to Fig. 1, comprises the outer container 10, which is filled with a dielectric liquid 12 to a level above the transducer assembly 11. The transducer assembly 11 is like that previously described, but the means by which it is secured to the bottom surface of the inner container 14 is somewhat different from that previously described. In this case, such means comprise a plurality of bolts 42, which are reversed in position from the bolts 30 shown in Fig. 1. Each bolt 42 is surrounded by a coil spring 43, which bears against the lower surface of the supporting plate 23 and against the head 42a of each bolt. In this manner, the transducer assembly may be firmly pressed against the bottom of the inner container 14, and, if the O rings 26 and 28 lose their resiliency with age, the springs will continue to cause pressure to be exerted on them in order to maintain a liquid-tight seal between the inner and outer containers. The remainder of the transducer assembly 11 is like that previously described.

The electrical connections to the transducer assembly are similar to those described in connection with Fig. 1, except that the springs 34 and 35 of Fig. 1 are replaced by springs 45 and 46, secured to the studs 32 and 33, respectively. The small spring 45 contacts the head of one of the bolts 42, and the large spring 46 contacts the head of the screw 25, that secures the conducting plate 24 to the supporting plate 23. If the liquid 15 in which the objects to be cleansed are immersed is a conductor of electricity, since it is in contact with the upper surface of the piezoelectric element 13, it may provide a part of the electrical circuit. In this case, the current path between the studs 33 and 32 is similar to that described in connection with the arrangement shown in Fig. 1, and includes spring 46, screw 25, conducting plate 24, wire pad 27, piezoelectric element 13, liquid 15, bolt 42, and spring 45. Thus, it is apparent that the production of ultrasonic compressional waves by the transducer assembly 11 is the same in the apparatus shown in Figs. 1 and 2.

Alternatively, if the liquid 15 is not a good conductor of electricity, electrical contact to the upper surface of the piezoelectric element 13 may be made through the O ring 28. In this case, the O ring must be made of a conductive material, or, if made of a non-conductive material, it may be wrapped with a conducting metal foil. Of course, the top surface of the piezoelectric element 13 must be well silvered if the electrical contact with the surface is limited to a peripheral area.

The form of apparatus shown in Fig. 2 may be preferred for permanent or semi-permanent installations, in which the cleansing process is one of a sequence of operations and the cleansing apparatus will be in more-or-less continuous use. In this case, the liquid 15 in which the parts to be cleansed are immersed may be continuously circulated through the container 14. An inlet pipe 47 provides means for admitting fresh liquid, which has been properly cooled and provided with dissolved gas or air, and an outlet pipe 48, which may be located near the top of container 14 to act as an overflow pipe, conducts used or exhausted liquid away from the tank to a reprocessing station.

Fig. 3 shows in diagrammatic form a typical installation for reprocessing the liquid 15 on a continuous basis. This assembly comprises the ultrasonic cleanser described with reference to Fig. 2, which is designated by the numeral 50, a recovery station 51, and a processing

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station 52. The used liquid which flows from the ultrasonic cleanser 50 through the outlet pipe 48 is conducted to the recovery station 51 where the liquid may be distilled, filtered, or otherwise purified. The recovery station 51 may comprise conventional filtering or distillation equipment such as is available commercially from several sources. Unrecoverable or waste liquid may be removed from the recovery station 51 and discarded through discharge means 53. The purified liquid is then transferred to the processing station 52, which may comprise equipment having cooling means and means for bubbling gas or air through the liquid. From the processing station the reprocessed liquid is transferred through inlet pipe 47 to the ultrasonic cleanser. It is, of course, apparent that the outlet pipe 48 need not serve as overflow discharge means, but both the inlet pipe 47 and the outlet pipe 48 may be located at the bottom of the inner container 17 of the ultrasonic cleanser. In this case, it may be desirable to completely change the liquid 15 periodically as the needs of the particular process may dictate. If the apparatus operates in this fashion, the purifying and reprocessing functions would be performed periodically rather than continuously, as would be the case were the device constructed exactly as shown in Fig. 2.

In the cleansing system shown and described with reference to Figs. 2 and 3, the basket 41 containing the small parts 40 may be either held stationary in the liquid 23, or may be moved about by conventional means (not shown), if desired. For example, it may be found that when cleansing parts of certain shapes and sizes, it is desirable to provide the basket with certain types of motion, and, as previously mentioned, moving the parts up and down through the agitated free surface of the liquid may be quite beneficial. On the other hand, it has been found in certain operations that cleansing may be efficiently accomplished even though the objects are not moved during the operation.

It is now apparent that the present invention provides a novel method and apparatus for efficiently cleansing objects by means of ultrasonic compressional waves. The outstanding feature of the invention is that the cleansing process may be made more efficient and accomplished in a shorter time by controlling the amount of gas or air dissolved in the liquid, and by controlling the temperature of the liquid in which the parts are immersed.

Although several forms of the apparatus of the invention have been shown and described, it is apparent that many changes and modifications may be made therein by one skilled in the art. Therefore, it is intended to be limited only by the scope of the appended claims and not by the particular embodiments described herein.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A method of cleansing an object, which comprises immersing the object in a liquid, transmitting ultrasonic compressional waves through said liquid to said object in such a manner that the surface of said liquid is agitated thereby, repeatedly moving said object in and out of said liquid through the agitated free surface thereof, maintaining dissolved gas in said liquid, and controlling the temperature of said liquid to tend to prevent driving off of gas therefrom.

2. A method of cleansing an object, which comprises immersing the object in a liquid, transmitting ultrasonic compressional waves through said liquid to said object in such a manner that the surface of said liquid is agitated thereby, repeatedly moving said object in and out of said liquid through the agitated free surface thereof, and maintaining dissolved gas in said liquid.

3. A method of cleansing a ball bearing assembly, which comprises immersing the assembly in a liquid, transmitting ultrasonic compressional waves through said liquid to said assembly, rotating the races of said as-

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sembly relative to each other, moving said assembly in and out of said liquid through the agitated free surface thereof, maintaining dissolved gas in said liquid, and controlling the temperature of said liquid to tend to prevent driving off of gas therefrom.

4. A method of cleansing a ball bearing assembly, which comprises immersing the assembly in a liquid, transmitting ultrasonic compressional waves through said liquid to said assembly, rotating the races of said assembly relative to each other, moving said assembly in and out of said liquid through the agitated free surface thereof, maintaining said liquid substantially saturated with dissolved gas, and controlling the temperature of said liquid to tend to prevent driving off of gas therefrom.

5. A method of cleansing a ball bearing assembly, which comprises immersing the assembly in a liquid, transmitting ultrasonic compressional waves through said liquid to said assembly, rotating the races of said assembly relative to each other, moving said assembly in and out of said liquid through the agitated free surface thereof, and maintaining dissolved gas in said liquid.

6. A method of cleansing a ball bearing assembly, which comprises immersing the assembly in a liquid, transmitting ultrasonic compressional waves through said liquid to said assembly, rotating the races of said assembly relative to each other, moving said assembly in and out of said liquid through the agitated free surface thereof, and maintaining said liquid substantially saturated with dissolved gas.

7. Apparatus for cleansing a ball bearing assembly comprising means for immersing said assembly in a liquid, means for transmitting ultrasonic compressional waves through said liquid to said assembly whereby the surface of said liquid is agitated, means for rotating one of the races of said assembly, means for moving said assembly in and out of said liquid through the agitated free surface thereof, means for maintaining a substantial amount of dissolved gas in said liquid, and means for controlling the temperature of said liquid to tend to prevent driving off of gas therefrom.

8. Apparatus for cleansing a ball bearing assembly

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comprising means for immersing said assembly in a liquid, means for transmitting ultrasonic compressional waves through said liquid to said assembly whereby the surface of said liquid is agitated, means for rotating one

5 of the races of said assembly, means for moving said assembly in and out of said liquid through the agitated free surface thereof, means for maintaining said liquid substantially saturated with dissolved gas, and means for controlling the temperature of said liquid to tend to prevent driving off of gas therefrom.

10 9. Apparatus for cleansing a ball bearing assembly comprising means for immersing said assembly in a liquid, means for transmitting ultrasonic compressional waves through said liquid to said assembly whereby the surface of said liquid is agitated, means for rotating one

15 of the races of said assembly, means for moving said assembly in and out of said liquid through the agitated free surface thereof, and means for maintaining a substantial amount of dissolved gas in said liquid.

20 10. Apparatus for cleansing a ball bearing assembly comprising means for immersing said assembly in a liquid, means for transmitting ultrasonic compressional waves through said liquid to said assembly whereby the surface of said liquid is agitated, means for rotating one

25 of the races of said assembly, means for moving said assembly in and out of said liquid through the agitated free surface thereof, and means for maintaining said liquid substantially saturated with dissolved gas.

30 References Cited in the file of this patent

UNITED STATES PATENTS

101,129	Hobson	Mar. 22, 1870
574,606	Heideman	Jan. 5, 1897
1,766,208	Anstiss	June 24, 1930
2,468,538	Benioff	Apr. 26, 1949
2,468,550	Fruth	Apr. 26, 1949
2,549,837	Merritt	Apr. 24, 1951

FOREIGN PATENTS

1592/31	Australia	Apr. 13, 1931
548,960	Great Britain	Oct. 30, 1942