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(54) ULTRASONIC OPTICAL CLEANING SYSTEM

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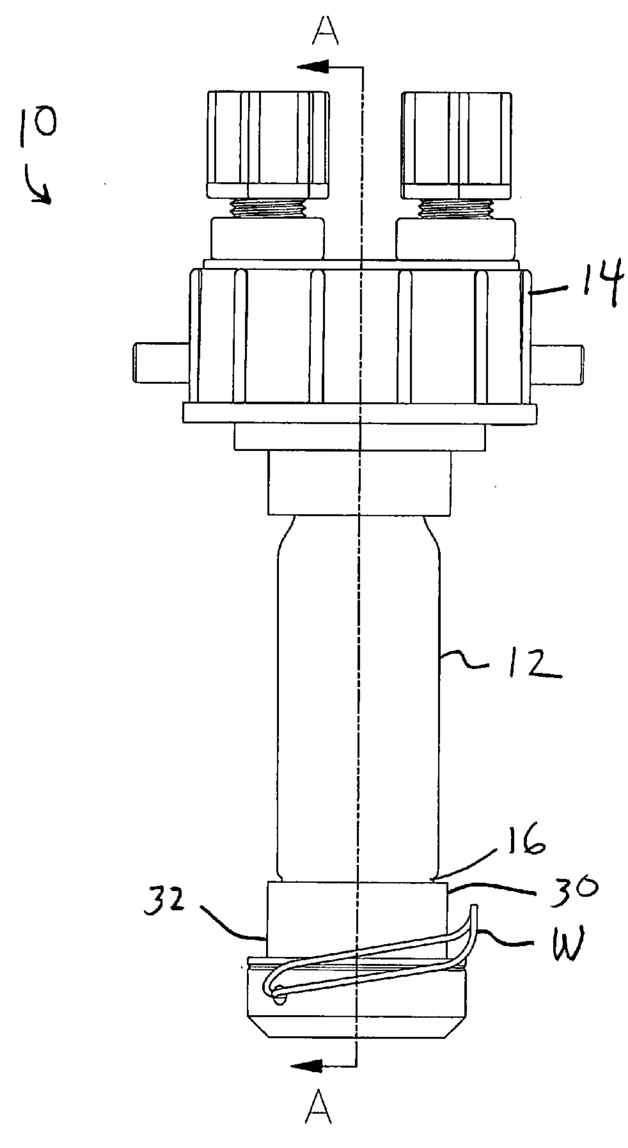
(57) **ABSTRACT**

An ultrasonic optical cleaning system is provided for cleaning and deterring the buildup of organic and inorganic particulates from the surface of glassware used in water testing instrumentation. The system includes a transducer that is attached to the surface of the glassware. A connector cap carrying a plurality of spring contacts interconnecting the transducer with an ultrasonic transducer control circuit. The control circuit operates continuously to provide an electrical signal to the transducer that vibrates the transducer and the glassware so that the glassware is cleaned of contaminates.



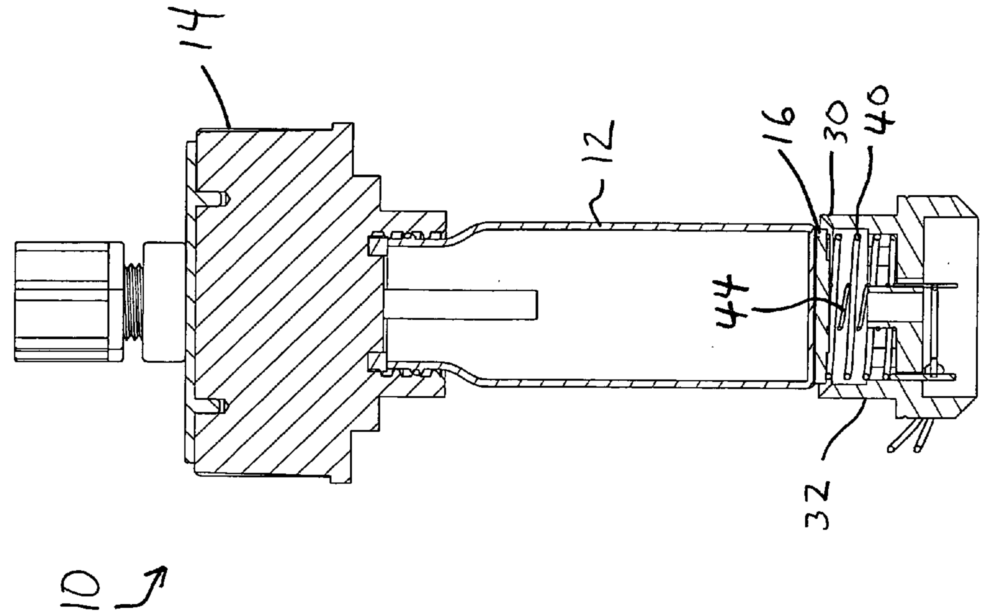



FIG 1B

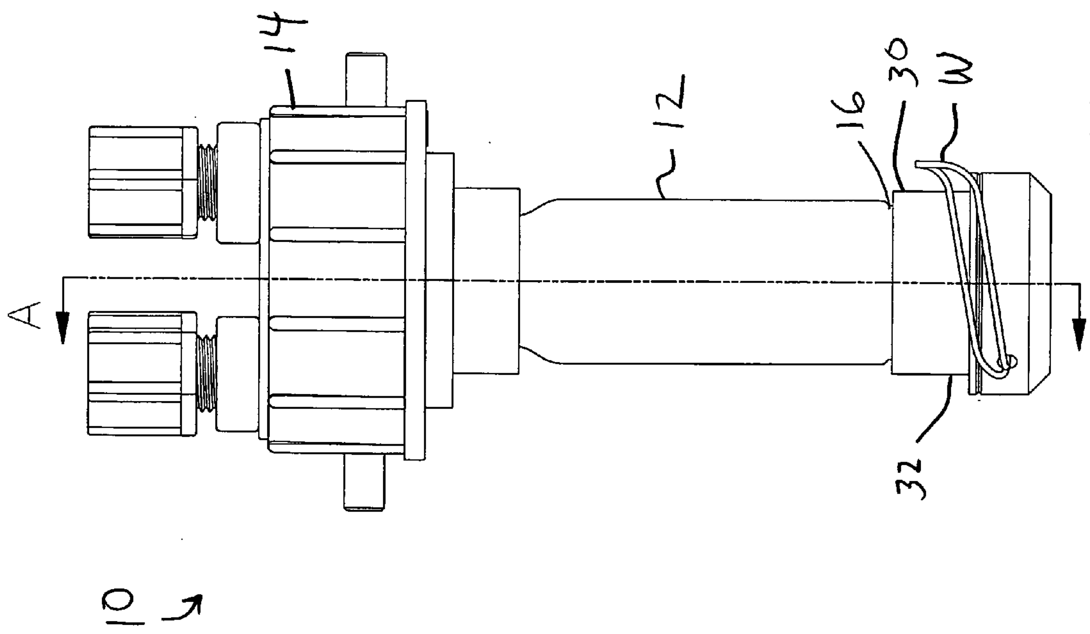



FIG 1A

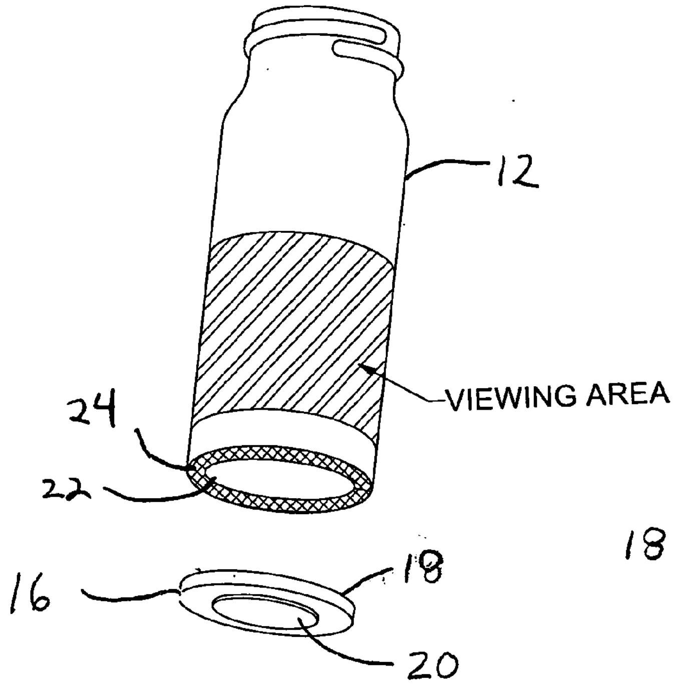



FIG 2

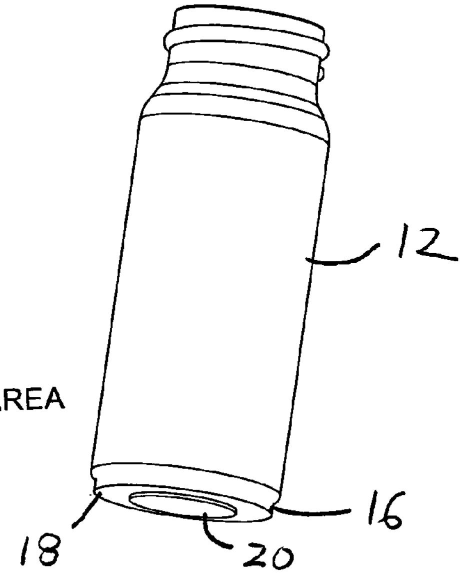



FIG 3

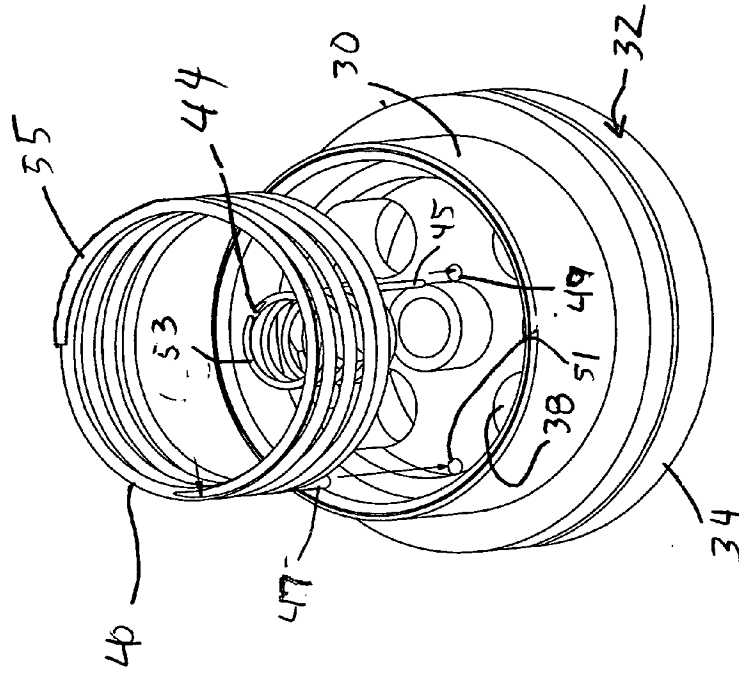



FIG4A

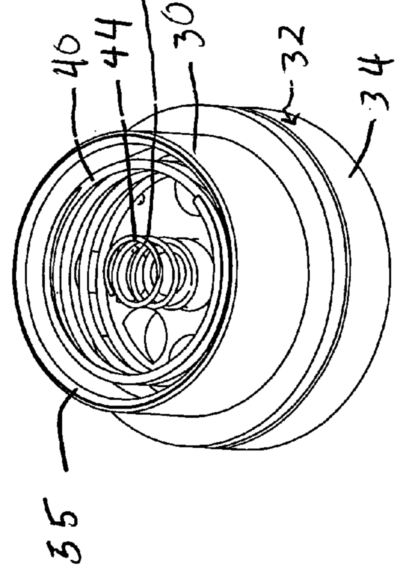



FIG4

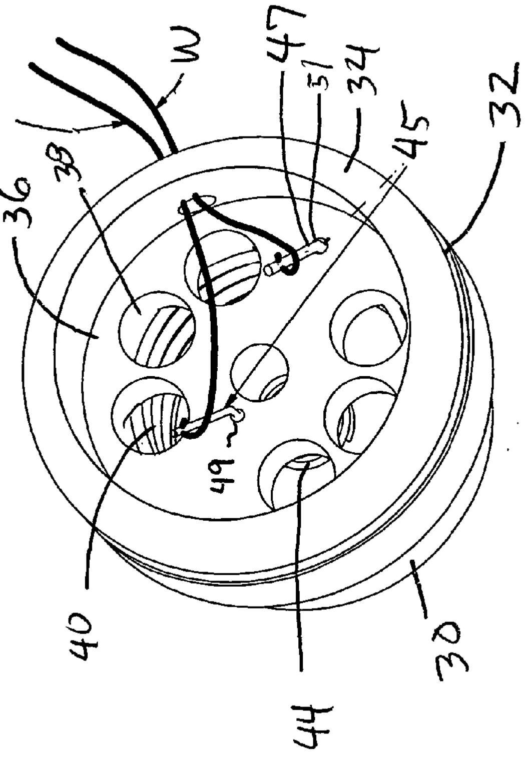



FIG5

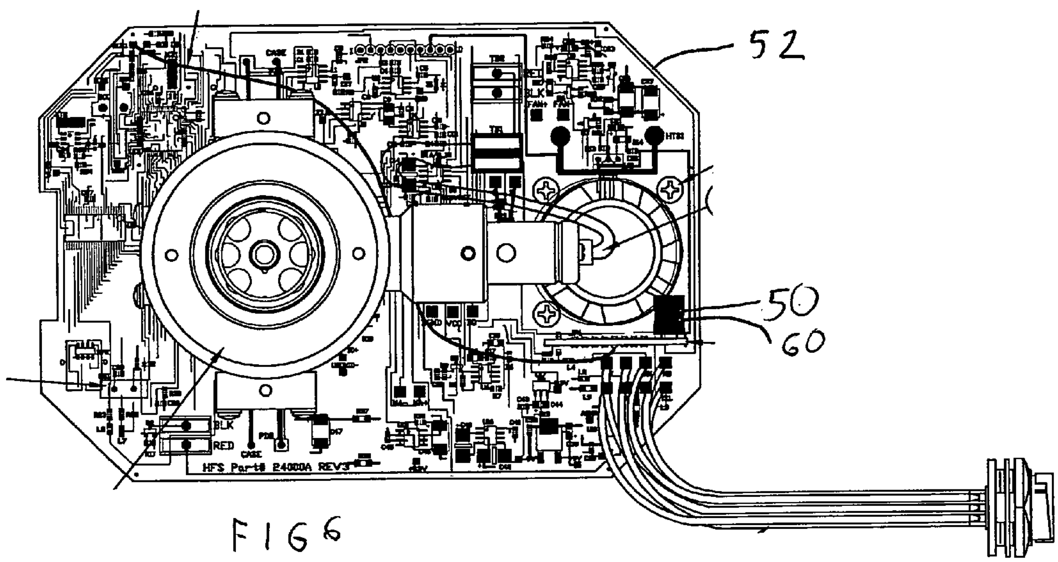



FIG 6

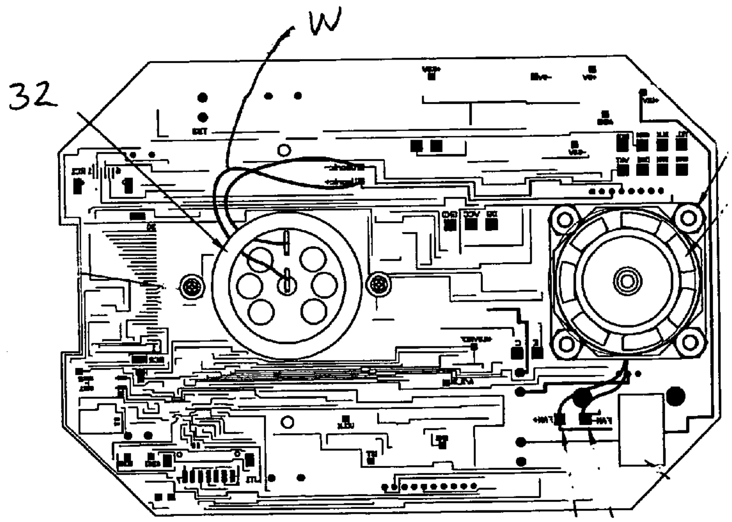
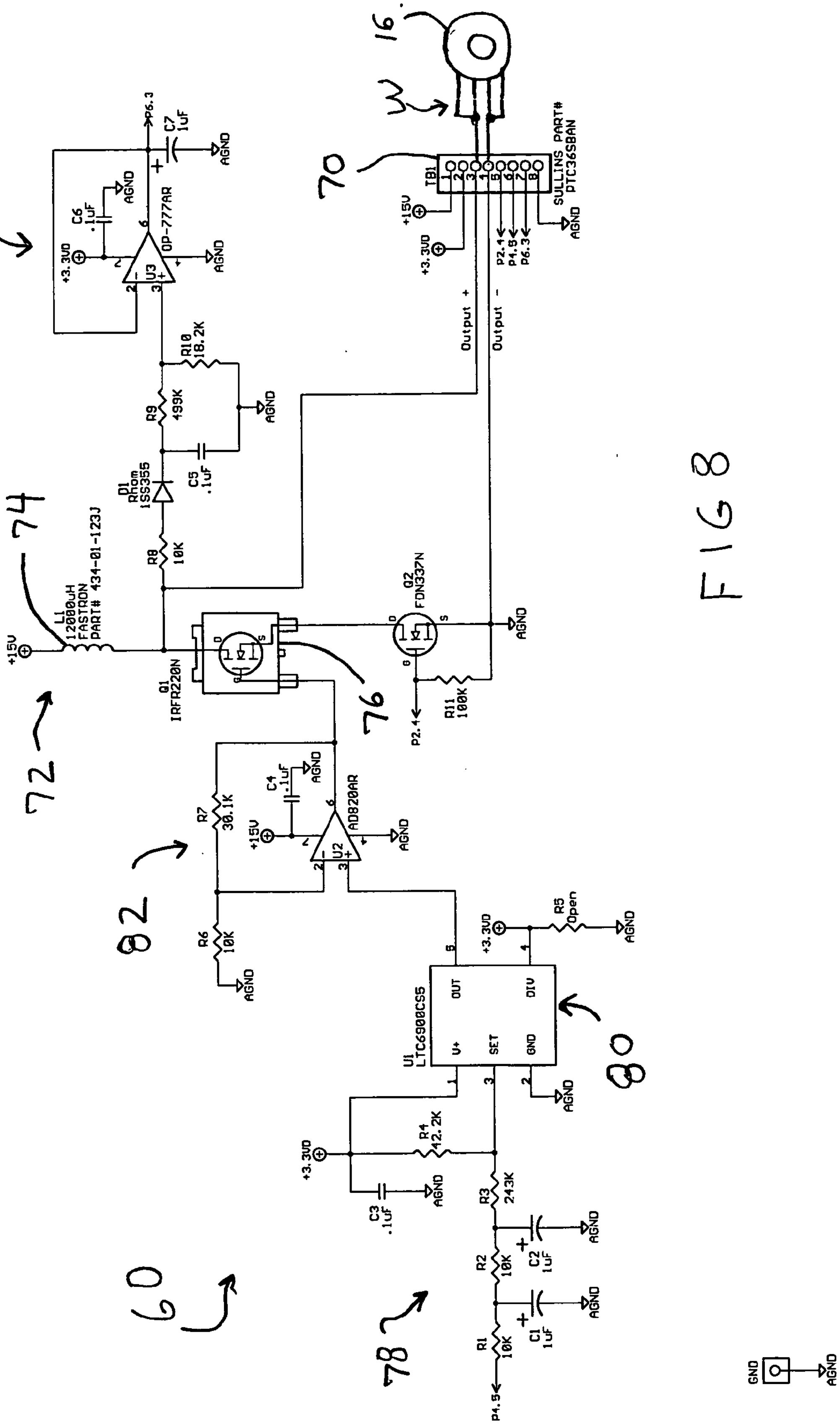



FIG 7



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W
70
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+3.3VD
P2.4
P4.5
P6.3
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Output +
Output -
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C6
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C7
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18.2K
R9
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U1
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OUT
DIV
V+
SET
GND
R5
Open
80
R4
42.2K
C3
.1uF
R3
243K
C2
1uF
R2
10K
C1
1uF
R1
10K
60
78
GND


FIG 8

## ULTRASONIC OPTICAL CLEANING SYSTEM

### RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 60/513,857 filed Oct. 24, 2003.

### FIELD OF THE INVENTION

[0002] This invention relates to a system that ultrasonically cleans and deters the buildup of particulate matter on glassware of the type used in optical water testing equipment. The apparatus is particularly suited for use in cleaning a tube or cuvette that supports a water sample in a turbidimeter.

### BACKGROUND OF THE INVENTION

[0003] Turbidimeters are widely utilized to test public water supplies for the presence of particulate matter suspended in the water. Examples of these instruments include the turbidimeter disclosed in U.S. Pat. No. 5,446,544, as well as the updated version distributed by HF Scientific, Inc. under the brand name MICRO TOL™. These and other varieties of turbidimeters typically employ a glass cuvette or tube that holds the water to be tested. Light is directed through the test sample and turbidity is electronically calculated and displayed.

[0004] Over time, inorganic particulates and organic contaminates such as algae tend to build up on the surface of the glassware holding the test sample. This can distort the measurements taken by the turbidimeter, which can produce erroneous readings. To avoid inaccurate test results, the user must frequently clean the glass and recalibrate the turbidimeter. This tends to be tedious, time consuming and inefficient. The user is likely to experience undesirable "down-time" as turbidity readings cannot be taken while the instrument is being serviced.

[0005] Currently, a cuvette or other glassware used for optical testing of water must be cleaned manually on a periodic basis. There are no known devices available that automatically and continuously clean the glassware so that improved measurement accuracy is achieved, but tedious maintenance and repeated service interruptions are avoided.

### SUMMARY OF THE INVENTION

[0006] It is therefore an object of the present invention to provide an apparatus for automatically and continuously cleaning and deterring particulate build-up on the glassware that accommodates a test sample in a turbidimeter or other optical water-testing instrument.

[0007] It is a further object of this invention to provide an ultrasonic optical cleaning system that significantly reduces the inefficiency, tedium and service interruptions associated with manual cleaning.

[0008] It is a further object of this invention to provide an apparatus for ultrasonically cleaning turbidimeter glassware, which apparatus is not hard-wired to the electronics of the tubidimeter so that the glassware can be conveniently indexed and/or removed for recalibration, as needed.

[0009] It is a further object of this invention to provide an apparatus that effectively and efficiently cleans the glassware used in a water-testing instrument so that improved, accurate water quality measurements are obtained.

[0010] It is a further object of this invention to provide an apparatus for ultrasonically cleaning a turbidimeter cuvette, which apparatus cleans and deters the buildup of both inorganic and organic contaminates so that the user does not have to manually clean the glassware and recalibration of the turbidimeter is significantly reduced.

[0011] This invention features an ultrasonic optical cleaning system for use with glassware of the type used in optical water testing equipment. The system includes an ultrasonic transducer that is secured to the glassware to be cleaned. The transducer includes a material that vibrates when a selected voltage is applied to the transducer. The transducer is electrically connected to an ultrasonic control circuit by means of a contact connector cap. The ultrasonic control circuit delivers an electrical signal through the connector cap to the transducer so that the transducer vibrates to clean particulate matter from the glassware and prevent the buildup of particulates on the surface of the glassware.

[0012] In a preferred embodiment, the ultrasonic transducer includes a disk composed of a piezoelectric ceramic that is juxtaposed against and bonded to a lower surface of an aluminum disk. Preferably, the aluminum disk has a larger diameter than the piezoelectric disk. The surface of the aluminum disk opposite to the surface that carries the piezoelectric disk may be bonded directly to the surface of the glassware, such as on the bottom of the glassware. As a result, the piezoelectric disk faces away from the surface of the glassware. The transducer is preferably secured to the glassware by an appropriate adhesive.

[0013] The connector cap may include an upper portion that carries a plurality of contacts for electrically engaging the transducer. These may be spring contacts that are longitudinally retractable within the connector cap. An outer spring contact may be engagable with the aluminum disk and an inner spring contact may be interengagable with the piezoelectric disk. The upper surface of the cap may also include an annular wall that surrounds the contacts for receiving a lower end of the glassware. In this way, the glassware is held in place with the transducer engaging the contacts. Lower ends of the contacts may extend from a lower end of the connector cap and be wired or otherwise electrically connected to the ultrasonic control circuit.

[0014] The ultrasonic control circuit may comprise an ultrasonic printed circuit board that is operably mounted to the printed circuit board that controls operation of the water testing equipment. The ultrasonic control circuit may receive power from the principal operating circuit of the test equipment. The control circuit typically delivers a voltage through the connector cap to the transducer and sweeps through a series of frequencies over a predetermined time span. Typically, the frequencies include the resonant frequency for the transducer-cuvette assembly such that the transducer exhibits a maximum vibration and energy is transferred to the glassware at a sufficient level so that optimum cleaning is achieved. Because the glassware is maintained substantially free of organic and inorganic particulates, improved measurements of water quality are obtained. At the same time, maintenance requirements are reduced considerably.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

[0015] Other objects, features and advantages will occur from the following description of a preferred embodiment and the accompanying drawings, in which:

[0016] **FIG. 1A** is side elevational view of the ultrasonic optical cleaning system of this invention as used with a turbidimeter;

[0017] **FIG. 1 B** is a cross sectional view of the cleaning system;

[0018] **FIG. 2** is a perspective view of glassware comprising a cuvette and the ultrasonic transducer in position to be applied to the cuvette;

[0019] **FIG. 3** is a view similar to **FIG. 2** with the ultrasonic transducer bonded to a lower surface of glassware;

[0020] **FIG. 4** is a perspective top view of the connector cap;

[0021] **FIG. 4A** is an exploded view of the connector cap;

[0022] **FIG. 5** is a bottom perspective view of the connector cap;

[0023] **FIG. 6** is a plan view of the upper, component side of the main printed circuit board employed in a turbidimeter featuring the cleaning system of this invention; the ultrasonic printed circuit board is depicted as being mounted to the main board;

[0024] **FIG. 7** is a plan view of the bottom, solder side of the main circuit board with the connector cap of the cleaning system attached thereto; and

[0025] **FIG. 8** is a schematic view of a preferred version of the ultrasonic control circuit.

[0026] There is shown in **FIGS. 1A and 1B** an ultrasonic optical cleaning system **10** used for cleaning the glassware of a turbidimeter. In the version disclosed herein, the glassware comprises a conventional cuvette **12** of the type commonly employed in water quality testing equipment. This type of glassware may be used in a wide variety of optical instrumentation presently used in the water testing industry. Cuvettes of this type are used especially widely in turbidimeters such as the product disclosed in U.S. Pat. No. 5,446,544 and the previously referenced MICRO TOL™ turbidimeter. It should be understood, however, that cleaning system **10** is not limited to use with such products. The cleaning system may be used effectively in a wide range of optical test instruments and is suitable for cleaning all types of liquid-accommodating glassware. The particular type of instrumentation that uses the cleaning system does not constitute a limitation of this invention. It should also be noted that a wide variety of sizes and shapes of glassware may be utilized. These may include all types of glass cuvettes, tubes and other varieties of transparent containers.

[0027] In the embodiment depicted in **FIG. 1**, cuvette **12** is carried by a flow head **14**, which comprises a part of a component of the tubidimeter (otherwise not shown). The cuvette is supported so that optical measurements may be taken and turbidity determined by the instrument in a known fashion. Over time, organic and inorganic particulates tend to collect on the surface of cuvette **12**. These contaminates distort the optical measurements taken by the turbidimeter; as a result, the cuvette normally has to be cleaned manually on a frequent and periodic basis. Cleaning system **10** is specifically designed to reduce the need for such periodic cleanings and resultant "down-time" and to enable the turbidimeter to produce continuously accurate readings over a prolonged period of operation.

[0028] The cleaning system specifically includes an ultrasonic transducer **16**, which is shown also in **FIGS. 2 and 3**. Transducer **16** includes a relatively large diameter aluminum disk **18** and a relatively small diameter piezoelectric ceramic (i.e. piezoceramic) disk **20** that is bonded to disk **18**. More particularly, disk **20** is fastened to a lower surface of disk **18** by means of a suitable adhesive. This may include Loctite™ E-20HP epoxy or a similar product. Preliminarily, the lower surface **22** of cuvette **12** is roughened by using a coarse sandpaper or similar product. At least an outer ring **24** of lower surface **22** should exhibit deep scratches that facilitate bonding. The bottom of the cuvette is then cleaned with alcohol. The upper surface of the transducer (i.e. the upper surface of aluminum disk **18**) is similarly cleaned. The adhesive is then applied between ring **24** of lower cuvette surface **22** and the upper surface of aluminum disk **18**. Adhesive should not be applied to the lower surface of cuvette **12** within the area bounded by ring **24**. The upper surface of the transducer is engaged against the lower surface of the cuvette and the adhesive is allowed to cure. As a result, the transducer is bonded to the lower surface of cuvette **12** in the manner shown in **FIG. 3**.

[0029] As shown in **FIGS. 1A and 1B**, the lower end of cuvette **12** and the ultrasonic transducer supported by the cuvette are received within a ring or annular lip **30** of a connector cap assembly **32**. The connector cap assembly is shown alone in **FIGS. 4, 4A** and **5**. In particular, the connector cap includes a generally circular base **34** having a recessed lower surface **36**, **FIG. 5**. Ring **30** extends upwardly from an upper surface of base **34**. A plurality of holes **38** are formed through the base such that the upper surface of the base communicates with the recessed lower surface of the base. Connector cap **32** is composed of a suitable plastic. Holes **38** reduce the amount of plastic required and also provide an emergency drain in the event of cuvette breakage.

[0030] Connector cap **32** includes an outer coil spring contact **40** and an inner coil spring contact **44**. These comprise respective coil springs which are mounted in base **34** of cap **32** such that they are longitudinally retractable relative to the base. The end posts **45** and **47** of spring contacts **40** and **44** respectively are received through respective holes **49**, **51** in base **34** and bent as shown in **FIG. 5** to hold contacts **40** and **44** in place. Each of the springs **40** and **44** is disposed within the area surrounded by ring **30**. As best shown in **FIGS. 4 and 4A**, the upper end **53**, **55** of each spring is ground flat for engaging transducer **16**. As shown in **FIG. 5**, the lower ends of the springs protrude from the recessed region **36** of cap **32** and are connected through associated wiring W to a transducer control circuit, as is described more fully below. Other types of contacts, and preferably spring contacts, may be utilized within the scope of this invention.

[0031] As shown in **FIG. 6**, an ultrasonic printed circuit board **50** is secured to the component side of the main printed circuit board **52** used to operate the turbidimeter. Board **50** supports an ultrasonic transducer control circuit **60**, shown in detail in **FIG. 8**. More particularly, the components of circuit **60** are mounted on ultrasonic printed circuit board **50** in a conventional manner. Circuit **60** is electrically interconnected between the microcontroller and power supply of the main circuit board **52** and the wiring W that joins circuit **60** to connector cap **32**. (See **FIGS. 7 and 8**).

[**0032**] The transducer control circuit includes a contact strip **70**, **FIG. 8**, which has eight contact pins **1**-**8**. Pins **1** and **8** are connected to and provide power from the conventional principal power source (not explicitly labeled) of the turbidimeter or other instrument. In this version, 15 volts are delivered to a high voltage circuit **72**. This circuit, which comprises a coil **74** and a MOSFET **76**, increases the voltage to approximately 48 VAC peak-to-peak for use by the transducer in a manner described below. Pin **2** of contact strip **70** provides a lower voltage (e.g. 3.3 volts) to operate various components of control circuit **60** such as pulse width modulator **78**, voltage controlled oscillator **80** and detection circuit **84**.

[**0033**] Pin **6** of contact strip **70** provides a signal P**4**.**5** from the CPU of the turbidimeter or other instrument to pulse width modulator **78**, which converts the signal to DC voltage. This voltage is then delivered to oscillator **80**, which functions as a voltage-to-frequency converter. A variable frequency output signal, which varies between approximately 30 and 55 KHz, is produced at output **5** of oscillator **80**. This signal is transmitted to a buffer circuit **82**, which controls the operation of gate G of transistor **76**. As previously stated, circuit **72** increases the output voltage delivered from the main power source considerably. A high voltage alternating current signal is thereby provided to pins **3** and **4** of strip **70**. The signal sweeps across the frequency range described above so that such a range of frequencies are delivered to the components of transducer **16** over wiring W. This sweep is performed over a span of approximately thirty seconds. During that time, the resonant frequency of the transducer-cuvette assembly is generated so that the transducer vibrates especially vigorously and particulate matter is dislodged from the glass surface of the cuvette or other glassware.

[**0034**] Detection circuit **84** monitors operation of the transducer and provides a signal P**6**.**3** to pin **7**, which indicates a problem with the cuvette or the cleaning system. In particular, a drastic change in the voltage produced by circuit **84** may reveal that a cuvette is missing, that one or more of the contact springs are broken or that no contact is being made between the springs and the transducer. Corrective action may then be taken.

[**0035**] It should be understood that in alternative embodiments, various other types of circuits and alternative electrical components known to persons skilled in the art may be employed to deliver an electrical signal to the transducer so that the transducer is vibrated to clean the glassware in the manner previously described. The particular components described in this circuit and the frequency and voltage levels described herein are intended to be illustrative only and do not constitute limitations of the invention.

[**0036**] In operation, circuit **60** remains continuously "on" during use of the turbidimeter or other water testing instrumentation with which system **10** is employed. As a result, a sweep of frequencies are delivered from control circuit **60** to transducer **16**. As previously stated, this preferably includes the resonant frequencies of the transducer-cuvette assembly so that maximum vibration and optimum cleaning are achieved. More particularly, the transducer is supplied with a signal of approximately 50 volts (peak to peak) and the control circuit sweeps the frequency between 30 and 55 KHz to assure that the resonant frequency of each individual transducer-cuvette assembly is generated. This provides for maximal vibration and optimal cleaning of the glassware.

[**0037**] The use of the connector cap is particularly advantageous. The springs provide for flexible and yet positive interengagement and electrical contact between the control circuit and the transducer. As a result, the control circuit does not have to be "hard wired" to the transducer. The user is thereby able to freely rotate and/or remove the cuvette from the test instrument without having to remove or disengage wires or electrical connectors. In the context of the turbidimeter referenced above, it is also important for the user to periodically index the cuvette within the turbidimeter by axially turning the tubular glassware. Such indexing allows the turbidimeter to obtain the cleanest and most accurate readings through the glassware. The glassware also must be removed each time recalibration of the instrument is required. Because the cleaning system of the present invention is not hard wired, performing the necessary indexing (rotation) and glassware removal (for re-calibration) are facilitated considerably. When the glassware is indexed, the spring contacts simply slide across and remain in unbroken contact with the transducer. Removing the glassware disengages the contacts from the transducer and replacing the glassware after in the instrument is calibrated automatically re-engages the spring contacts with the transducer. No wiring or connectors must be manipulated for either procedure.

[**0038**] From the foregoing it may be seen that the apparatus of this invention provides for a system that automatically and continuously inhibits the buildup and growth of organic and inorganic particulates on optical test equipment glassware so that more reliable readings may be taken with reduced interruption of service. While this detailed description has set forth particularly preferred embodiments of the apparatus of this invention, numerous modifications and variations of the structure of this invention, all within the scope of the invention, will readily occur to those skilled in the art. Accordingly, it is understood that this description is illustrative only of the principles of the invention and is not limitative thereof.

[**0039**] Although specific features of the invention are shown in some of the drawings and not others, this is for convenience only, as each feature may be combined with any and all of the other features in accordance with this invention.

[**0040**] Other embodiments will occur to those skilled in the art and are within the following claims:

What is claimed is:

**1**. A system for ultrasonically cleaning glassware in optical water testing equipment, said system comprising:

an ultrasonic transducer for securing to the glassware to be cleaned, said transducer including material that vibrates when a selected voltage is applied to said transducer;

a connector for establishing electrical contact with said transducer; and

an ultrasonic control circuit for delivering an electrical signal with the selected voltage through said connector to said transducer such that said transducer vibrates to dislodge particulate matter from the glassware and prevent particulate matter from collecting on the surface of the glassware.

**2**. The system of claim 1 in which said transducer including a piezoelectric disk and an aluminum disk juxtaposed against and secured to said piezoelectric disk.

**3**. The system of claim 2 in which an upper surface of said aluminum disk is attachable to the glassware, said piezoelectric disk being secured to an opposite, lower surface of said aluminum disk.

**4**. The system of claim 3 in which said transducer is attachable to the glassware by an adhesive.

**5**. The system of claim 1 in which said connector includes a connector cap comprising a plurality of contacts for energizing said transducer.

**6**. The system of claim 5 in which said contacts are slidably engagable with said transducer to maintain electrical contact with said transducer when said transducer and the glassware are adjusted in the testing equipment.

**7**. The system of claim 5 in which said contacts comprise spring contacts carried by an upper portion of said cap for electrically engaging said transducer.

**8**. The system of claim 7 in which said springs are longitudinally retractable within said cap.

**9**. The system of claim 8 in which said spring contacts comprise coil spring contacts.

**10**. The system of claim 2 in which said connector includes an outer coil spring contact that is interengagable with said aluminum disk and a second inner coil spring contact that is interengagable with said piezoelectric disk.

**11**. The system of claim 5 in which said cap includes an annular wall surrounding said contacts for receiving said transducer and an attached lower end of the glassware, said wall for holding the glassware in place with said transducer engaging said contacts.

**12**. The system of claim 7 in which lower ends of said spring contacts are electrically connected to said ultrasonic control circuit.

**13**. The system of claim 1 in which said control circuit includes an ultrasonic printed circuit board for operably mounting to a printed circuit board that controls operation of the water testing equipment, said control circuit for being electrically powered by an operating circuit of the test equipment.

**14**. The system of claim 1 in which said control circuit generates signals having a series of frequencies, including the resonant frequency of said transducer and glassware to which said transducer is attached such that said transducer and glassware vibrate sufficiently to maintain the surface of the glassware substantially free of particulate build-up.

**15**. The system of claim 14 in which said control circuit continuously and repeatedly sweeps through a predetermined series of frequencies.

**16**. The system of claim 1 in which said selected signal includes the resonant frequency of the transducer and glassware to which said transducer is secured.

* * * * *