

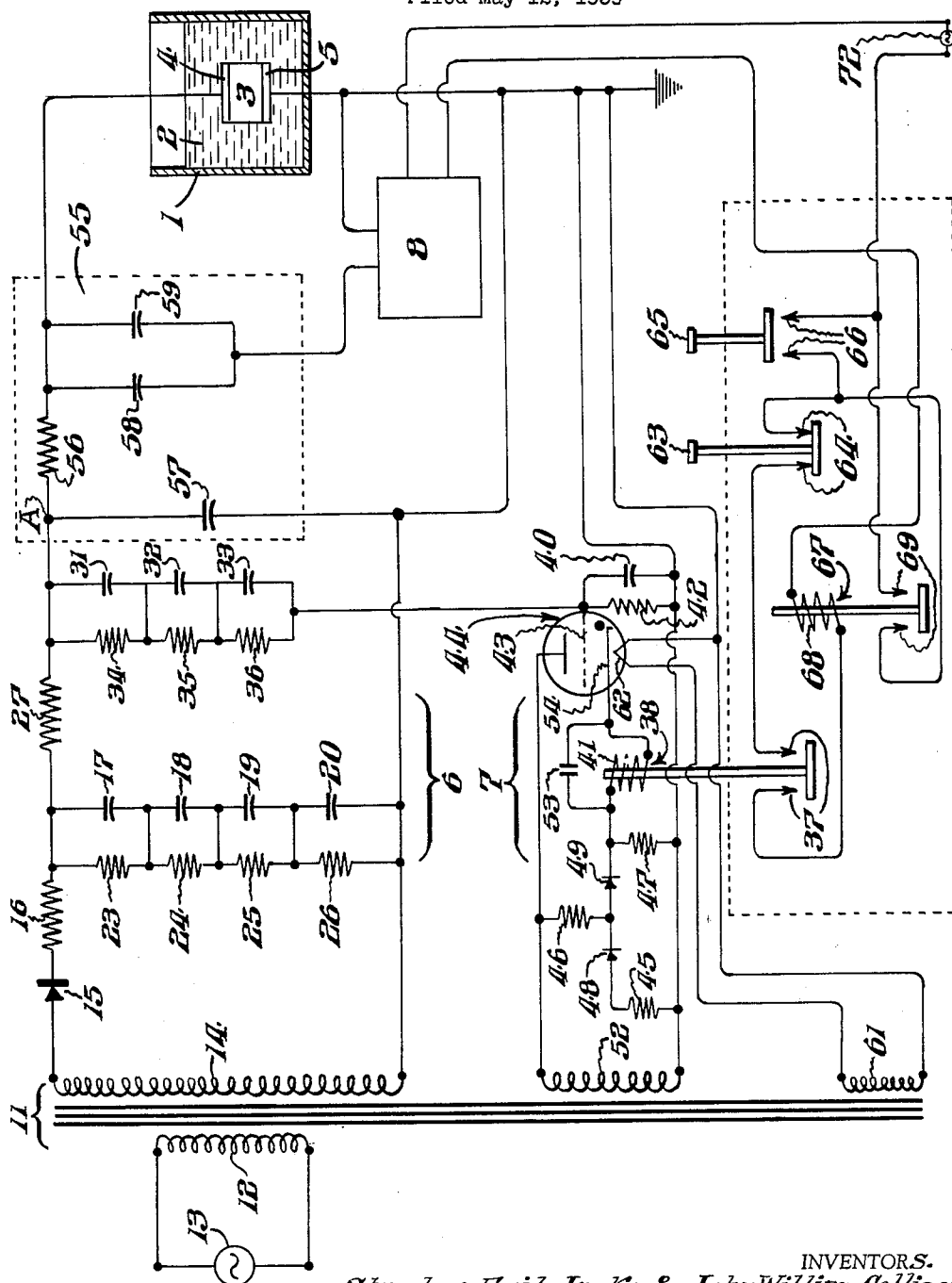
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ULTRASONIC CLEANING APPARATUS

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ULTRASONIC CLEANING APPARATUS

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This invention relates to improvements in ultrasonic cleaning apparatus, and more particularly concerns degreasing apparatus utilizing a ferroelectric transducer submerged in a bath of liquid chlorinated hydrocarbon solvent such as trichlorethylene.

In certain cleaning and degreasing applications, it is desirable to utilize high temperatures in the ultrasonic bath of liquid chlorinated hydrocarbon solvent. However, high temperatures adversely affect the piezoelectric transducer (which may be made of barium titanate) so that the transducer depolarizes when the temperature exceeds the Curie point of the material from which the transducer is made. Under such conditions, the expensive transducer is destroyed.

Accordingly, it has been a problem to discover means whereby an ultrasonic bath could be operated at high temperatures and yet not destroy the transducer by depolarization. It has been a problem to operate at high temperatures without destroying the transducer, and also to provide fail-safe means whereby if the system fails, the transducer is protected. It has also been a problem to provide means whereby high voltage and current may be used across the transducer, and at the same time to provide means whereby a person who may accidentally come in contact with such high voltages and currents is prevented from being electrocuted.

Accordingly, it is an object of this invention to provide ultrasonic cleaning apparatus which solves the foregoing problems.

It is another object of this invention to provide ultrasonic cleaning apparatus which operates safely and efficiently at elevated temperatures above the normal Curie point of the material of which the transducer is made without causing depolarization of the transducer.

It is another object of this invention to provide ultrasonic cleaning apparatus wherein high voltages and currents are used, and to provide means for preventing the electrocution of a person who may accidentally come in contact with said voltages and currents.

Other objects and advantages of this invention, including its simplicity and economy, as well as the ease with which it may be adapted to existing equipment, will further become apparent hereinafter and in the drawing.

The drawing is a diagrammatic view of ultrasonic cleaning apparatus constructed in accordance with this invention.

Although specific terms are used in the following description for clarity, these terms are intended to refer only to the structure shown in the drawings and are not intended to define or limit the scope of the invention.

Turning now to the specific embodiment of the invention selected for illustration in the drawing, there is shown ultrasonic cleaning apparatus including a well 1 containing a liquid chlorinated hydrocarbon solvent 2 such as trichlorethylene, perchlorethylene, or methylene chloride. Positioned in the liquid of the well is an ultrasonic transducer 3 which may be made of barium titanate or other ferroelectric transducer material. Transducer 3 may be constructed in accordance with the disclosure in U.S. Patent No. 2,802,476 which issued to T. J. Kearney on August 13, 1957.

Silvered electrodes 4 and 5 of transducer 3 are con-

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nected in an electrical circuit with a biasing supply circuit 6 and a generator control circuit 7 which is actuated by the biasing supply circuit 6 to control a radio frequency generator 8. Biasing supply circuit 6 impresses a D.C. voltage bias across ultrasonic transducer 3 to enable transducer 3 to operate at elevated temperatures above the normal Curie point of the material from which transducer 3 is made without causing depolarization and deterioration of the expensive transducer. Generator 8 impresses an A.C. voltage on transducer 3 to generate ultrasonic waves which are useful in cleaning and degreasing operations. Generator control circuit 7 operates to shut off generator 8 when the biasing supply circuit 6 fails. If the radio frequency generator 8 were to continue its operation without the D.C. bias supplied by the biasing circuit 6, transducer 3 would depolarize, deteriorate, and be destroyed.

Biasing supply circuit 6 includes a transformer 11 having a primary winding 12 connected to a source of power 13, and a secondary winding 14. Secondary winding 14 supplies approximately 3000 volts, 60 cycle, A.C. to a selenium rectifier 15 which supplies pulsating D.C. to the filter network of resistor 16 and capacitors 17-20 which smooth the pulsating D.C. Resistors 23-26 form part of a divider network to divide the voltage evenly across the four filter capacitors 17-20 and thereby permit the use of less expensive elements. The effective filter capacity is one quarter of the value of capacitor 17 which is large enough to provide relatively good filtering but is not so large that the time required to charge the bank of capacitors 17-20 through the resistor 16 becomes too great when the power is turned on.

A resistor 27 is used to provide the system with poor voltage regulation in order to cause the output voltage to drop to a very low value if a person should accidentally come in contact with the connections to transducer 3. With transducer 3 connected in the circuit and no short circuits in the system, the voltage drop across resistor 27 is negligible. Resistor 27 acts as a series A.C. filter and prevents excessive alternating current from flowing through a bank of capacitors 31-33 instead of through the bank of capacitors 17-20. The resistors 34-36 divide the D.C. voltage evenly across each of the capacitors 31-33.

When power is first turned on, the bank of capacitors 31-33 permit high enough direct current to flow at the outset to close contacts 37 of an under voltage relay 38.

If the capacitors 17-20 are much larger than four microfarads, the bank of capacitors 31-33 charge up at a slower rate so that the under voltage relay 38 is not energized. The value of the resistors 34-36 are set so that when the voltage from a point A to ground is above nine hundred volts, enough direct current flows through coil 41 of under voltage relay 38 to keep the relay 38 energized (contacts closed). If the voltage drops below nine hundred volts D.C., under voltage relay 38 opens and contacts 37 are opened.

Resistors 34-36 and resistor 42 form a voltage divider to supply a small positive potential to the grid 43 of a thyratron tube 44 which is preferably a 2D21. As long as the proper bias potential exists between point A and ground, thyratron 44 conducts and keeps the relay 38 energized. The contacts 37 of under voltage relay 38 are in the holding circuit of the generator control circuit 7, and resistor 42 is provided with a capacitor 40 (preferably .001 microfarad) in parallel therewith.

Resistors 45-47, diodes 48, 49, secondary winding 52 and capacitor 53 (preferably ten microfarads) provide a positive potential for the cathode 54 of thyratron 44 so that the thyratron 44 cuts off from conduction when the

transducer biasing potential from point A to ground falls below a predetermined value.

Located near the output of generator 8 is a blocking network 55 which passes the radio frequency energy from generator 8 toward the transducer 3 but blocks it toward biasing supply circuit 6, and which passes the D.C. voltage from the biasing supply circuit 6 toward the transducer 3 but blocks it from the generator 8. Blocking network 55 includes a resistor 56 and capacitors 57-59. Capacitors 58, 59 block the D.C. bias voltage from flowing toward generator 8, and resistor 56 and capacitor 57 block the radio frequency energy from flowing toward the biasing supply circuit 6.

Capacitor 57 is a radio frequency bypass and is not critical in value. Resistor 56 and capacitor 57 form RF filter (L section) to keep the radio frequency energy generated by generator 8 from flowing back into the divider networks. Capacitors 58, 59 are coupling capacitors to keep the D.C. bias from flowing toward generator 8 and for allowing the radio frequency to flow toward transducer 3. These capacitors should be .01 microfarad each or larger to keep the capacitive reactance at this point relatively small.

Also provided is a heater circuit which includes secondary winding 61 and heater element 62.

Contacts 37 of under voltage relay 38 are in the circuit which includes stop button 63 with its contacts 64, start button 65 with its contacts 66, control relay 67 with its coil 68 and contacts 69, and a source of power 72.

In operation, the D.C. bias across transducer 3 is above nine hundred volts, thyatron tube 44 is conducting, under voltage relay 38 is energized so that its contacts 37 are closed, coil 68 of control relay 67 is energized so that its contacts 69 are closed so that power is supplied to generator 8 which puts A.C. energy across transducer 3 to generate ultrasonic waves.

If the biasing voltage should fall below nine hundred volts (or other predetermined value), thyatron tube 44 stops conducting which de-energizes the coil 41 of under voltage relay 38 to open contacts 37. This de-energizes coil 68 of control relay 67 to open contacts 69 to cut off the power to generator 8 and thereby shut down the generator.

The system is operated very satisfactorily where resistor 16 is 200K, resistors 23-26 are each 72K, resistor 27 is 1K, resistors 34-36 are each 120K, resistor 56 is 10K, capacitors 17-20 are each 4 microfarads, 450 volt electrolytic, capacitors 31-33 are each 8 microfarads, 450 volt electrolytic, and capacitor 57 is a .0047 microfarad, 3 kv., disc ceramic.

It is to be understood that the form of the invention herewith shown and described is to be taken as a preferred embodiment. Various changes may be made in the shape, size, and arrangement of parts. For example, equivalent elements may be substituted for those illustrated and 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 or scope of the invention as defined in the subjoined claims.

Having thus described our invention, we claim:

1. In ultrasonic cleaning apparatus having a well, a liquid chlorinated hydrocarbon solvent contained within

said well, a piezoelectric transducer submerged in the solvent of the well, and means for applying a high-frequency voltage across said transducer to vibrate said transducer and to generate ultrasonic waves in said solvent; means for operating said transducer at high temperatures exceeding the otherwise safe temperature limits of said transducer material, said lastnamed means comprising means for applying a high direct-current biasing voltage across said transducer; and control means coupled both to said direct-current biasing voltage means and also to said high-frequency voltage means for preventing the application of said high-frequency voltage across said transducer unless said direct-current biasing voltage exceeds a selected minimum value and for removing said high-frequency voltage from said transducer when said direct-current biasing voltage falls below a selected minimum value.

2. Apparatus adapted for operating piezoelectric transducers at high temperatures exceeding the Curie point of the piezoelectric material, said apparatus comprising: a well adapted to contain a high-temperature liquid chlorinated hydrocarbon solvent; a piezoelectric transducer in said well; a radio-frequency generator; means coupling the output terminals of said radio-frequency generator across said transducer; a direct-current generator for developing a high biasing voltage; means for applying said high biasing voltage across said transducer; a relay having a winding and contacts; means, including the contacts of said relay, for coupling a source of alternating current power to the input terminals of said radio-frequency generator for operating said generator; an electronic switch in series with the winding of said relay for controlling the flow of current through said winding; means coupling said electronic switch to output terminals of said direct-current generator for controlling the state of said switch according to the magnitude of the direct-current biasing voltage, said electronic switch being adapted to open the series circuit through said relay winding when the direct-current voltage applied to said switch is less than a selected minimum.

3. Apparatus as claimed in claim 2 characterized in that said electronic switch comprises a thyatron tube and means for applying a portion of said direct-current biasing voltage across the input electrodes of said thyatron for biasing said tube into conduction when said direct-current biasing voltage is above said selected minimum value.

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