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ULTRASONIC TRANSMITTER APPARATUS

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2 Sheets-Sheet 1

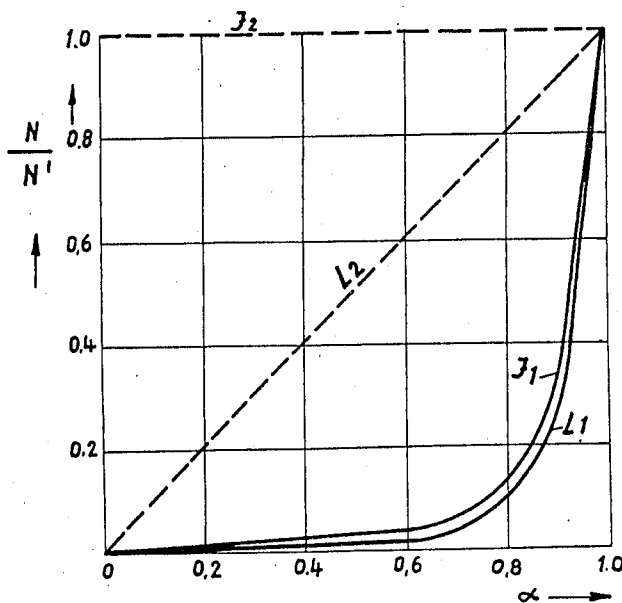


Fig. 1

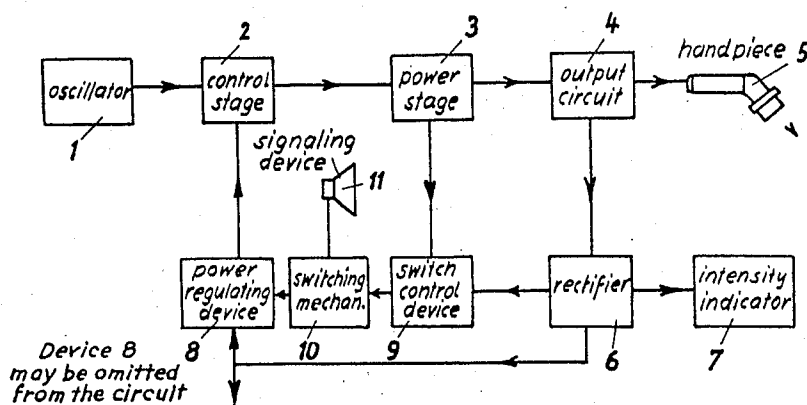


Fig. 2

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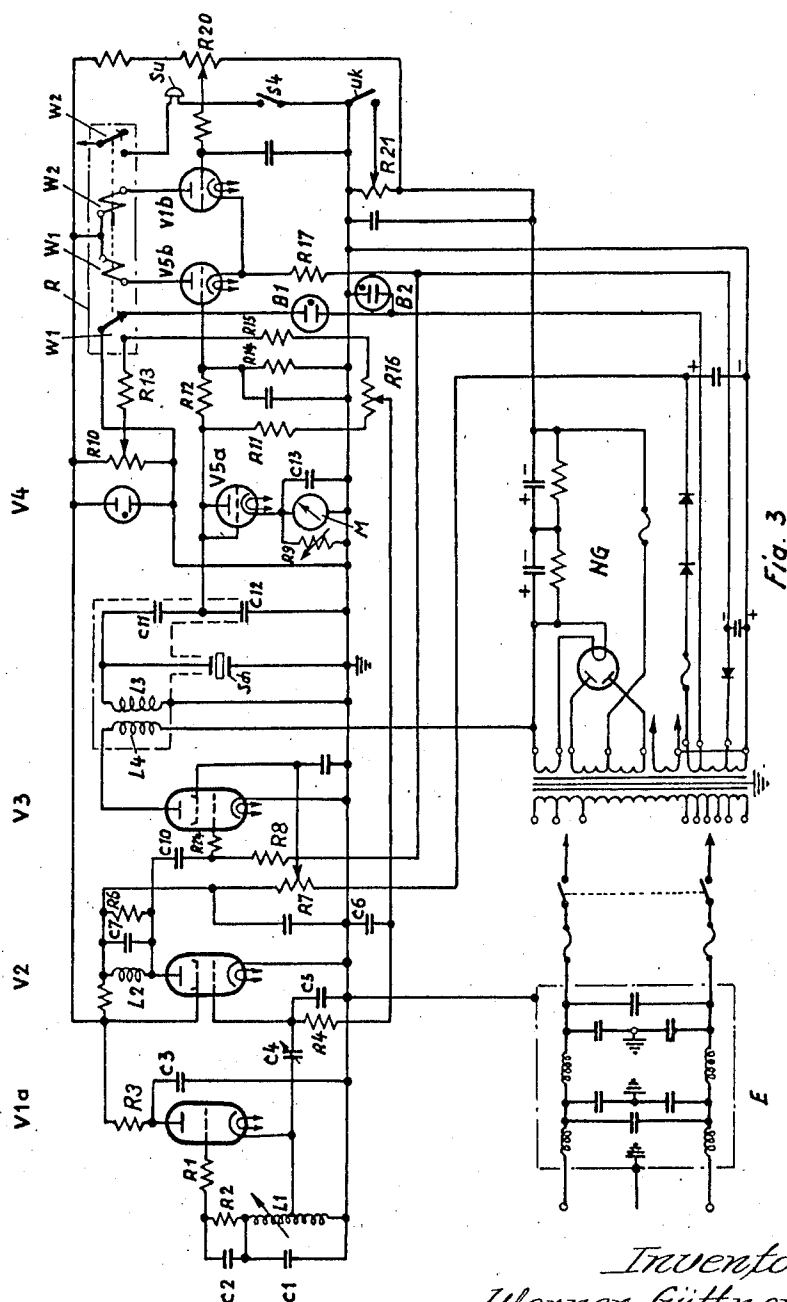
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ULTRASONIC TRANSMITTER APPARATUS

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4 Claims. (Cl. 310—8.1)

This invention relates to ultrasonic transmitters of the type in which variations of load occur in the ultrasonic oscillator during transmission of the ultrasonic waves. Such load variations may arise, for example, in medical treatment with ultrasonic vibrations or in ultrasonic material-testing operations if the transducer head engages the object to be treated or tested in a somewhat up-ended or canted manner. This causes undesirable variations in the ultrasonic energy transmitted to the object and in the load on the high-frequency generator forming the source of current for the transducer.

To eliminate these drawbacks of known ultrasonic transmitters it has been attempted to supply the ultrasonic transducer with current from an electric high-frequency generator whose internal resistance is relatively large compared to the magnitude of the fluctuations in radiation resistance in the transducer resulting from load variations. Such operation of the ultrasonic transducer with a constant current, however, has the effect of producing considerable fluctuations in ultrasonic energy radiation into the object upon variations in load, as will now be explained.

A suitable premise for the explanation is to consider a piezo-electric transducer as a multiplicity of individual elements connected in parallel. Upon up-ending of the transducer, even if but a small number of these individual elements border on air, the radiation resistance of these elements is reduced to such a great extent that virtually the entire high-frequency current will flow through these few elements. Consequently, only a relatively small proportion of the current is available for the majority of individual elements, which are still in direct engagement with the object and thus have high radiation resistance. Thus, the energy transmitted by the elements still in engagement with the object becomes exceedingly small.

For example, if but one-tenth of the transducer surface area is separated from the object by an air gap, the intensity of radiation will be reduced to 32 percent and the energy radiated into the object drops to 25 percent. This is apparent from the full-line curves in the diagram of Fig. 1. In this diagram, the abscissae represent the proportion between firmly engaged transducer surface area and total surface area thereof and is expressed as "coupling factor" α , while the ordinates represent the ratio between actual irradiated energy (N) and the energy (N') for which the transducer is intended at 100% coupling factor.

The present invention overcomes the foregoing disadvantage by providing the ultrasonic transmitter with an electrical device which maintains the high-frequency voltage, applied to the ultrasonic transducer head, constant. This is accomplished by having the voltage of the source of current supply for the transducer controlled automatically as a function of an electrical magnitude that varies in response to the high-frequency voltage across the transducer. The conditions thereby created with regard to the ultrasonic intensity at the transducer and with regard to the ultrasonic energy irradiated into the object, is shown in

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the broken-line curves in Fig. 1. As will be seen from these curves, when the transducer is operated in the manner set forth above, the intensity I2 at the transducer remains constant, while the irradiated energy L2 is merely reduced to 90% of maximum if one-tenth of the transducer surface area borders on air.

If it is desired to make the energy output of the ultrasonic transmitter variable, it is merely necessary to vary the value of the electric magnitude, utilized for maintaining the transducer voltage constant, in accordance with the desired energy output.

In high-power ultrasonic transmitters it will be necessary, as a rule, to avoid idling or no-load operation of the transducer, such as would result from complete removal of the radiating surface of the transducer from the object under treatment. This may be done by providing additional damping means for the transducer, which may, for example, be built into the transducer head itself.

Alternatively, and as a further feature of the present invention, no-load operation may be avoided by maintaining the voltage across the transducer constant, only until no-load operation has been approached to a point at which the transducer would be endangered by the excessive amplitudes of vibration. This may be achieved by providing means which will reduce the voltage across the transducer when critical load conditions arise that would endanger the operation of the transducer; and by controlling these means in response to a—preferably adjustable—electric magnitude or value that varies both in response to the electric high-frequency current passing through the transducer and also in response to the variable energy output of the source of high-frequency current supply for the transducer. An electric magnitude or value of this nature will vary in response to the radiation resistance of the transducer. Preferably, these means are so adjusted that reduction of the voltage across the transducer will set in, at least, when more than 30% of the transducer surface borders on air.

In accordance with a further aspect of the present invention it is possible to provide means which emit an audible or optical signal whenever critical conditions of load arise that would endanger the operation of the transducer or that are equivalent to an interruption in the treatment. These means must be controlled in the same manner as the means for automatically reducing the voltage across the transducer. Therefore, if such means for reducing the voltage are provided, they may be used at the same time for controlling the emission of the signals.

The invention will now be described with reference to the accompanying drawings in which—

Fig. 1 is a graph representing the variation in ultrasonic energy transmitted to a body with changes in loading;

Fig. 2 is a block diagram illustrating the principles of construction of an ultrasonic transmitter incorporating the invention; and

Fig. 3 is a circuit diagram illustrating the specific circuit scheme of an embodiment of the invention.

Referring first to Fig. 2, there is diagrammatically illustrated an oscillator 1, generating high-frequency currents which are transmitted over a control stage 2 to a power stage 3. Between the latter and the hand piece 5, containing the transducer, there is inserted the output circuit 4 in which the transducer is attuned to the power stage 3. Part of the high-frequency voltage applied to the transducer is transmitted to a rectifier 6. The voltage rectified in the latter is transmitted, on the one hand, to an intensity indicator 7, and on the other hand as a negative control voltage to the control stage 2. The path for this last-mentioned transmission, which serves for maintaining the voltage constant, may be either direct, as indicated by the broken line in Fig. 2, or it may include the power regulating device 8. This device is required only if the

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energy output of the ultrasonic transmitter is to be variable notwithstanding constancy of the voltage. This is so because the energy output can be regulated by merely varying the magnitude of the control voltage derived from the rectifier 6, for example by connecting an adjustable positive voltage in opposition to the negative control voltage. Finally, the rectifier 6 controls a further switch control device 9 which receives from the power stage 3 a voltage that is responsive to the anode current of this stage. In this device 9, the electrical magnitudes supplied to it are used to create an electrical magnitude or value that is proportional to the radiation resistance of the transducer. When this resistance reaches a value critical to the operation of the transducer, the last-mentioned magnitude causes operation of a switching mechanism 10 which, over device 8, acts upon control stage 2 in a manner causing reduction of the voltage across the transducer. Also, when the resistance reaches a value equivalent to interruption of the treatment, this electrical magnitude, again acting over switching mechanism 10, operates a signaling device 11.

As the high-frequency voltage across the transducer is maintained constant, the intensity of ultrasonic radiation will also be largely independent of fluctuations in the local current supply lines. Thus, there is no need for providing the ultrasonic transmitter with extraneously operable means for compensating for such line voltage fluctuations.

Referring now to Fig. 3, V1a designates the oscillator tube which, together with the tank circuit elements L1, C1 and with the grid circuit elements R2, C2, forms a so-called RCO oscillator. The insertion of resistor R1 in the grid circuit serves to prevent excessive oscillation. The high-frequency component of the anode voltage of tube V1a is connected to zero potential over capacitor C3; the D. C. component of this anode voltage is supplied over resistor R3.

The high-frequency voltage generated in oscillator tube V1a is transmitted to control stage tube V2 over the capacitive voltage divider C4, C5, of which the element C4 is variable and may be an adjustable capacitor. The anode circuit of this tube V2, comprising tank circuit elements L2, C7, has a shunt resistor R6 connected thereacross, whereby this circuit is damped to such an extent as to prevent auto-energization of power stage tube V3.

Coupling circuit elements C10 and R24 transmit the high-frequency voltage derived from control stage V2 to power stage tube V3. The latter receives its negative grid bias over resistor R8. The screen grid potential of this tube is adjustable at resistor R7. This adjustment need be effected but once; its purpose is to provide means for compensating for differences in tube characteristics when exchanging tube V3 for a new one.

The output circuit of power stage V3 (designated by numeral 4 in Fig. 2) includes the inductance L4 in the anode circuit of tube V3, and the inductance L3 coupled therewith and connected in parallel with the transducer Sch. Also connected in parallel with the transducer Sch is the capacitive voltage divider C11, C12.

A fractional voltage taken off from this voltage divider is applied to the rectifier tube V5a (designated 6 in Fig. 2). The cathode circuit of this tube includes a measuring instrument M, serving as the intensity indicator designated 7 in Fig. 2. A steadying capacitor C13 and a variable resistor R9 are connected in parallel with the measuring instrument M and serve for calibration of the latter. The anode of tube V5a is connected over resistor R11 to one terminal of a potentiometer R16. The other terminal thereof is connected over resistors R15 and R13 to the movable contact of the power-controlling potentiometer R10. The movable contact of potentiometer R16 is connected over resistor R4 to the grid of control stage V2. Capacitor C6 merely serves for uncoupling.

At a predetermined voltage, adjustable at potentiometer R10, there will be across potentiometer R16 a potential difference which results from the negative voltage

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proportional to the voltage across the transducer, on the one hand, and from the opposed, positive voltage taken off at potentiometer R10, on the other hand. The resultant voltage acts upon control stage V2 so that a corresponding high-frequency voltage arises at the transducer and remains constant as long as the adjustment of the power-controlling potentiometer R10 (corresponding to device 8 of Fig. 2) remains unchanged.

Tubes V5b and V1b are associated with the switch control device designated 9 in Fig. 2, serving to establish an electric magnitude or value proportional to the radiation resistance of transducer Sch. The grid of tube V5b receives a slight negative D. C. potential from the voltage divider R12, R14 connected to rectifier tube V5a. This D. C. potential is proportional to the high-frequency voltage applied to transducer Sch. On the other hand, the potential of the grid of tube V1b is dependent upon the D. C. anode current of power tube V3, and with proper selection of the grid bias and control voltage for this tube, this D. C. anode current is proportional to the high-frequency current passing through the transducer. The cathodes of tubes V5b and V1b are connected to a negative potential over the common cathode resistor R17.

The anodes of the tubes V5b and V1b are each connected by a relay winding, W1 and W2 respectively, of a polarized differential relay R with the positive voltage terminal of the source of anode voltage. The associated control potentiometers R21 and R20 are so adjusted that when the radiating surface of the transducer Sch fully engages the object being treated, a relatively large anode current will flow through tube V1b, and a relatively small anode current will flow through tube V5b. In this case, relay contacts w1 and w2 will occupy the position illustrated in Fig. 3.

If the engagement of the transducer surface with the object under treatment becomes inadequate, or if the transducer is lifted completely off this object, the anode current in the power tube will rise. As this current flows through potentiometer R21, there will then be a relatively large negative potential drop across this potentiometer. This potential drop will override the positive grid bias of tube V1b, adjustable at potentiometer R20, and will block this tube. Consequently, tube V5b will then carry the greater anode current. Relay R will shift its contact w1 and will thereby short-circuit the positive voltage adjusted at power-control potentiometer R10. This shift of contact w1 also opens the circuit of a signal lamp B1. At the same time, contact w2 operates a buzzer Su. Short-circuiting of the positive voltage applied to the movable contact of potentiometer R10 has the result that the voltage drop across potentiometer R16 now comprises only the relatively high negative D. C. voltage of tube V5a. This D. C. voltage adjusts control tube V2 to such a low value that only a relatively small voltage lies across the transducer Sch; but this voltage is sufficient so that if the radiating surface of the transducer is again applied more firmly to the object under treatment, the reverse operation will be initiated. In this reverse operation, the tube V1b will again receive such a small negative (or even a positive) grid bias as to cause the larger current to flow through tube V1b again. The relay contacts w1 and w2 will thereby be returned to their operative positions as illustrated. The corresponding constant high-frequency voltage as regulated at power control potentiometer R10, will then be applied again to the transducer Sch.

The stabilizer V4 insures that the voltage applied to the power-control potentiometer R10 will be independent of line voltage within wide limits. In this manner, the transducer Sch is enabled to radiate constant ultrasonic energy even with relatively substantial line voltage fluctuations. The stabilizer V4 also serves to maintain constant the anode voltage of tube V1a and the screen grid voltage of tube V2.

A switch S4, incorporated in the circuit for buzzer Su, may be advantageously built into the hand piece containing the transducer. When the hand piece is replaced upon a support, for example upon a suitable hook on the apparatus casing, this switch S4 disconnects the buzzer Su.

The apparatus preferably has a clock incorporated therein to indicate the treating time. After the interval for which this clock has been set, has elapsed, the clock opens a contact uk which is closed during use of the apparatus. Opening of contact uk causes the partial short-circuiting of potentiometer R21 to be interrupted so that the negative potential drop across this potentiometer is increased. This causes blocking of tube V1b in the manner described above and thereby reduces the high-frequency voltage across the transducer Sch.

The device NG is provided for supplying the necessary direct and alternating voltages. Between the terminals of the local alternating current source and the device NG is disposed the anti-distortion element E.

What is believed to be new and desired to have protected by Letters Patent is defined in the appended claims.

We claim:

1. In an ultrasonic treatment apparatus having a generator for producing high-frequency oscillations and a transducer adapted for physical contact with a body to be treated and having a feed circuit for said transducer for supplying said high-frequency oscillations thereto for the purpose of transmitting ultrasonic energy to said body, varying physical contact between said transducer and said body during transmission of ultrasonic energy causing variable loading of said transducer and consequent variations of the high-frequency voltage flowing therethrough; a regulating device comprising means connected with said feed circuit for deriving therefrom an electrical value which changes in accordance with variations of the high-frequency voltage flowing through said transducer responsive to varying physical contact thereof with said body, control means for reducing the high-frequency voltage flowing through said transducer, regulating means controlled by said derived electrical value for automatically regulating the operation of said generator so as to maintain substantially constant the high-frequency voltage supplied to said transducer in the presence of variable loading thereof, and means also governed by said derived electrical value for actuating said control means at times when the magnitude of the current flowing through said transducer approaches a predetermined critical value.

2. In an ultrasonic treatment apparatus having a generator for producing high-frequency oscillations and a transducer adapted for physical contact with a body to be treated and having a feed circuit for said transducer for supplying said high-frequency oscillations thereto for the purpose of transmitting ultrasonic energy to said body, varying physical contact between said transducer and said body during transmission of ultrasonic energy causing variable loading of said transducer and consequent variations of the high-frequency voltage flowing therethrough; a regulating device comprising means connected with said feed circuit for deriving therefrom an electrical value which changes in accordance with variations of the high-frequency voltage flowing through said transducer responsive to varying physical contact thereof with said body, means for adjusting the magnitude of the

voltage of the high-frequency oscillations supplied to said feed circuit, means for deriving a control voltage from said feed circuit, means for rectifying said control voltage, means for deriving from said adjusting means a direct current component which is proportional to the magnitude of the adjusted high-frequency voltage, means for utilizing said direct current component in opposition to said rectified control voltage for feeding to said transducer a high-frequency voltage of predetermined magnitude, and regulating means controlled by said derived electrical value for automatically regulating the operation of said generator so as to maintain substantially constant the high-frequency voltage supplied to said transducer in the presence of variable loading thereof.

3. An apparatus and cooperation of parts as specified in claim 1, comprising a generator having an output stage including an electronic tube, means for adjusting the magnitude of the voltage of the high-frequency oscillations supplied to said transducer, means for deriving a control voltage from said feed circuit, means for rectifying said control voltage, means for deriving from said adjusting means a direct current component which is proportional to the magnitude of the adjusted high-frequency voltage, means for utilizing said direct current component in opposition to said rectified control voltage for feeding to said transducer a high-frequency voltage of predetermined magnitude, and a device for controlling the reduction of the high-frequency voltage flowing through said transducer, said device comprising two grid controlled electronic tubes and a differential relay having winding respectively disposed in the plate circuits of said tubes, the control grid of one of said tubes being governed by an electrical value derived from the high-frequency voltage fed to said transducer, the control grid of the other one of said tubes being governed by an electrical value derived from the plate current of the electronic tube included in said output stage, and contact means controlled by said relays for shunting the direct current component derived from said adjusting means which is utilized in opposition to said rectified control voltage.

4. An apparatus and cooperation of parts as specified in claim 1, comprising manually controlled means for adjusting the magnitude of the high-frequency current supplied by said generator, means respectively associated with said adjusting means and with said feed circuit for deriving an electrical control value which changes with alterations in the magnitude of the high-frequency current flowing through said transducer and with the magnitude of the current supplied thereto by said generator, and signal means actuated by said electrical control value responsive to reduction of the high-frequency voltage flowing through said transducer.

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