Aug. 28, 1951 P. F. STILL 2,565,996

COLD CATHODE GAS FILLED TRANSDUCER DEVICE

Filed Feb. 10, 1948

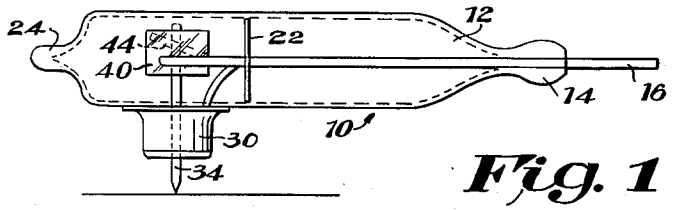

Fig. 1

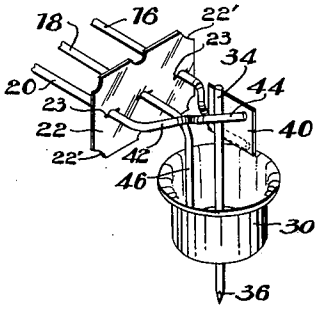

Fig. 2

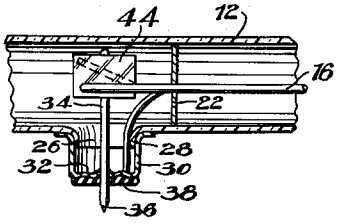

Fig. 3

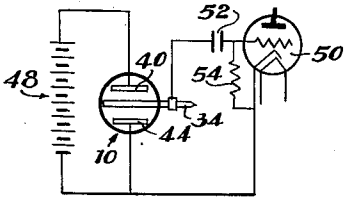

Fig. 4

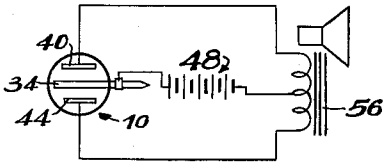

Fig. 5

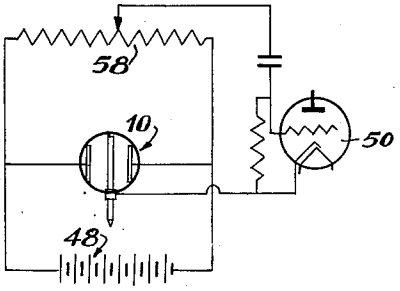

Fig. 6

Paul F. Still,
Inventor

By Homer R. Montague
ATTORNEY

Patented Aug. 28, 1951

2,565,996

UNITED STATES PATENT OFFICE

2,565,996

COLD CATHODE GAS-FILLED TRANSDUCER DEVICE

Paul F. Still, Los Angeles, Calif., assignor to John Steere-Paul Still, Incorporated, Hollywood, Calif., a corporation of California

Application February 10, 1948, Serial No. 7,500

7 Claims. (Cl. 179—100.41)

1

This invention relates to electrical apparatus, and particularly to an improved form of electrical transducer for the conversion of mechanical energy into electrical impulses, or into variations in an electrical current.

It is a principal object of the invention to provide a transducer of extremely simple and economical construction, yet which will be capable of providing a relatively large electrical output or variation in response to mechanical movements of a very small order. As such, the device is particularly well adapted for use as a phonograph pick-up or microphone element, as the driving power required is very small indeed, so that operation at acoustical frequencies without undesirable damping of the higher frequencies is facilitated.

Another object of the invention is to provide a transducer of this type embodying a sealed container of a suitable gaseous medium, for example one of the noble gases or a mixture thereof with other gases, and which does not depend for its operation upon the existence of thermions within the envelope. In other words, as compared with hot-cathode types of transducers, the present invention requires no power supply for the production of thermions, which not only increases its power efficiency, but greatly simplifies the construction of apparatus, for example, sound reproducers, which are driven by the transducer. Thus, the invention provides a transducer which is capable of replacing existing types, for example of the magnetic or piezo-electric types, with a minimum of redesign or reconstruction of the auxiliary apparatus.

Still another object of the invention is to provide such a transducer which is very small and compact, and which may readily take the form of a capsule or cartridge that may easily be connected with and disconnected from its auxiliary apparatus, so that replacement is facilitated and made more economical than is possible with existing types of transducer cartridges.

A further object of the invention is to provide a transducer of the above type which will be impervious to climatic conditions such as high or low temperatures or humidities, as compared with existing types, many of which are permanently injured by exposure to conditions which are common in many parts of the world. The unit of the present invention is capable of operation independently of humidity and altitude, for example, and insofar as temperature is concerned, requires merely the existence of a temperature greater than a certain minimum which may

2

be extended downward almost indefinitely by the proper selection of the gaseous medium and the other components of the device.

Still a further object of the invention is to provide a device of this type whose output characteristic, in terms of amplitude at various frequencies of energization, may be varied almost without limit in order to provide a frequency response best suited to a particular application, or for use with given auxiliary equipment such as reproducers, amplifiers and the like.

An additional object of the invention is to provide a transducer having the movable, or mechanically driven, portion of its mass so light and small that the inertia of this portion does not operate to limit the speed of response to an appreciable extent, within audio frequency ranges. Moreover, the device does not require for its operation any permanent magnets or the like such as are used in certain other types of transducers, whereby the total mass of the whole element or cartridge is maintained as small as possible.

The above and other objects and advantages of the invention are obtained by a construction which is extremely rugged and immune to mechanical shocks such as often occur in service conditions, and yet which is well adapted to large-scale production upon existing machinery, so that the cost per unit may be made to compare favorably with known devices intended for the same purposes, but which are incapable of the performance obtained with the present unit.

The invention will best be understood by reference to the following detailed specification of a preferred embodiment thereof, taken in connection with the accompanying drawings, in which

Fig. 1 is a side elevation of one form of the invention, as embodied in a phonograph pick-up cartridge;

Fig. 2 is a perspective view of the arrangement of the electrodes within the envelope of Fig. 1;

Fig. 3 is a fragmentary sectional view of a portion of Fig. 1, illustrating the manner of sealing the motion-transmitting element to the envelope in a gas-tight manner;

Fig. 4 is a schematic view of a possible circuit diagram for the utilization of the output of the unit of Figs. 1 to 3;

Fig. 5 is a similar diagram of another method of utilizing the output of such a unit, and

Fig. 6 is still another diagram of a modified form of circuit for the device.

In the following specification, the invention is shown as embodied in a particular form of transducer useful as a phonograph pick-up or re-

producer cartridge, but it is to be understood that the principles of the invention are in no way limited to such application, and may be utilized as well in microphones, vibrations or pressure and motion pick-ups, stethophones or similar devices, by the application of means well known to the skilled worker in this general field. Also, the disclosure of certain preferred circuits for utilizing the output of the transducer is not to be taken as a limitation on the circuits which can be employed, since these also are capable of wide variation without departing from the spirit of the invention. All such changes and modifications as come within the scope of the claims appended hereto, are deemed to be covered by this application.

In general, the invention depends for its operation upon the fact that there exists a potential gradient along any electrically ionized column of gas, and hence that the potential of an electrode lying in such a column may be varied by moving the electrode along the column. It is, of course, known that the conversion of mechanical variations into electrical can be accomplished by the movement of one or the other of the electrodes of a hot-cathode type of vacuum tube, most often the control grid of such a tube, but all such proposals have been rendered impractical either by the complexity or instability of the necessary electrode assembly, or by the excessive cost of manufacture, or other factors. In accordance with the present invention, the number of component parts of the transducer has been reduced to a minimum, without sacrificing any of the inherent sensitivity of such a device. Moreover, prior art hot-cathode types of transducers have always depended for their operation upon the control of the number of thermions which reach a collector plate from a heated cathode, which number is very far from being a simple function of the position of the control grid. The result has always been non-linearity of response, and the output of such devices has therefore been rich in harmonics and distortion of various kinds, even with simple forms of mechanical motions.

Referring now to the device shown in Figs. 1 to 3 of the drawings, numeral **10** designates generally a transducer element in the form of a phonograph pick-up cartridge, by way of example, which may be mounted at the free end of any well-known form of pick-up arm; said element comprising an envelope **12** preferably formed of glass within which is provided an atmosphere of a suitable ionizable gas, neon being preferred, although many other gases or mixtures thereof could be used. The pressure of the gas, within envelope **12**, may be varied within wide limits in accordance with the electrode construction and the applied voltage, but a pressure within the range of 15 to 30 millimeters of mercury has been found to produce good results. At one end of the envelope **12** its walls are sealed together in a typical form of press **14** through which pass three conductors **16**, **18** and **20** (see Fig. 2) whose outer ends may serve as contact pins for the connection of the device to the external circuit, and whose inner ends constitute, or are electrically connected with, the electrodes of the unit.

The material of which the conductors **16**, **18** and **20** are formed is subject to wide variation, the principal requirement being that it form a gas-tight and structurally rugged seal to the glass of the envelope. Where the envelope is formed of a soft glass of the composition of Corning G–1 or G–12, the conductors may desirably be formed of a special alloy known to the trade as "Sylvania #4," a stainless steel alloy which may be sealed hermetically to glass either by flame, radio-frequency heating or by other methods. Alternatively, such metals as "Kovar," "Fernico" or the like may be employed.

In the construction shown in Figs. 1 to 3, the three conductors **16**, **18** and **20** lie in substantially the same horizontal plane throughout most of their length, and are supported within envelope **12** by a supporting plate **22** of mica or other suitable insulating material, beyond which the conductors diverge in a manner to be described below. That end of envelope **12** opposite to the press **14** may be provided with a sealed-off tip **24** resulting from the evacuation and filling of the envelope in a manner so well known in the vacuum tube art that it need not be here described. As best shown in Fig. 3, the under surface of envelope **12**, adjacent the electrode end thereof, is provided with an aperture **26** surrounded by an external lip or ring **28** to which is secured a cup **30** which may be of the same material as conductors **16** to **20** and sealed to the envelope by the application of heat. The bottom surface of cup **30**, which is designated by numeral **32**, is preferably annularly corrugated to increase its flexibility, and constitutes a diaphragm through which is passed a metallic movable-electrode control rod **34**, the latter being welded or soldered to the diaphragm **32** in any desired gas-tight manner. Rod **34** is here shown for simplicity as terminating in a stylus point **36**, but it may equally well be provided with a socket to receive a separate needle or stylus as is well known in the pick-up art. In order to provide a controlled degree of damping of the motion of rod **34** in response to mechanical motions or vibrations of its stylus end **36**, a layer **38** of vinyl plastic or similar resilient material having a suitable damping coefficient is secured as by cementing to the under side of diaphragm **32**, and apertured so as to pass around the rod **34**.

Support plate **22**, as best shown in Fig. 2, may have peripheral cut-outs **22'**, and the holes which pass the conductors **16** to **20** may be intersected by slots **23** to provide free passage of ionized (luminous) gas throughout the length of the envelope **12**.

The thickness of the material constituting cup **30**, and particularly the thickness of that portion thereof forming the diaphragm **32**, is made as small as possible consistent with adequate mechanical strength, and may be of the order of .001 to .003 inch, in order to provide a minimum of inertia and hence an extended upper frequency-response characteristic. Such a thickness has been found suitable for a device intended as a phonograph pick-up, but obviously the figures given may be varied to suit other requirements or applications.

Referring now particularly to Fig. 2, the conductor **16** is shown as terminating at its inner end in a portion turned to approach the center-line of the central conductor **18**, and has secured to such in-turned portion an electrode plate **40** constituting the cathode of the electrode system. Conductor **20** terminates at its inner end in a portion **42** also deflected toward the center-line of conductor **18**, and a terminal portion **44** lying parallel to the diagonal of plate **40** but spaced therefrom by a distance which may be of the order of .030 to .060 inch, this terminal portion **44** constituting the anode of the device. Between these terminal portions of conductors **16** and **20**

extends the upper end of the rod 34, substantially midway therebetween when the device is at rest. Central conductor 18 is deflected downward from its center-line as at 46, and is soldered, welded, or otherwise secured to an edge portion of diaphragm 32, or to the inner wall of cup 30 below ring 28. Thus, conductor 18 is in electrical connection with the movable or control electrode constituted by the upper end of rod 34, which rod also constitutes means for varying the position of the movable electrode along the path between electrodes 40 and 44.

It will be observed that the point on rod 34 at which it is connected to the flexible diaphragm 32 is only about one third or one fourth of the distance along rod 34 from its lower end. In this way, a mechanical amplification of the order of three or four times is obtained as regards the relative movements of the electrode end of the rod and the movements of its stylus end 36. Compared to the flexibility of the corrugated diaphragm 32, rod 34 is of course relatively rigid, so that its upper or electrode end faithfully executes movements proportional to the extent to which its lower end 36 is driven, as by the sound groove of a phonograph record or the like.

The actual operation of the device will be made clear by an inspection of Fig. 4, which illustrates a typical operating circuit connected to the device. In this figure, numeral 48 designates a battery or other suitable source of direct or high-frequency alternating current of sufficient voltage to produce ionization, and preferably, a glow discharge, between the anode 44 and cathode 40. Suitable D. C. voltages may range from 100 to 250 volts for a unit of dimensions such as earlier described, and alternating voltages of 70 to 250 volts may be used, depending upon the particular gaseous medium being employed. One side of this current source, herein the negative side, is also connected to the cathode of any suitable form of amplifier tube 50. The movable electrode (rod 34) is connected through a blocking condenser 52 to the grid of the tube 50. Hence, as the electrode 34 moves back and forth along the potential path represented by the discharge between the outer electrodes 40 and 44, the potential of electrode 34 and of the vacuum tube grid will be varied accordingly, and the output of the amplifier will be varied in accordance with the mechanical motion of the stylus end 36. A grid resistor 54 may connect the grid of tube 50 with the cathode in a known manner, but it is to be understood that the variations in the potential of the movable electrode may be utilized in any desired manner without departing from the spirit of the invention.

It will be clear from the above that the output of the device is primarily sensitive only to movement of the electrode 34 in a direction to and from the fixed electrodes, and only to an insignificant degree to motions thereof in a vertical direction, or in a direction perpendicular to the discharge path. This is a desirable feature, since in reproducing a laterally cut phonograph record, for example, it is undesirable that the pick-up device be affected by merely incidental vertical modulation of the groove depth. On the other hand, the transducer of this design can readily be made sensitive to movements in any desired direction, merely by supplying a suitable mechanical linkage to the outer end of the rod 34.

As shown by way of further example in Fig. 5, the output of the transducer may also be utilized directly, without amplification, where the power

output required is not excessive. As there shown, the fixed electrodes 40 and 44 are connected to the opposite ends of the coil of any desired type of sound reproducer, or to an impedance-matching transformer connected thereto, and the movable electrode 34 may be connected through battery 48 or other source of potential to the mid-point of the coil or transformer primary. In Fig. 6, a balanced bridge type of circuit is shown the transducer 10, battery 48 and a center-tapped resistor being connected in parallel, and the movable electrode 34 and the center-tap being connected respectively to the cathode and control grid of the amplifier tube 50. Many other possibilities in the way of circuits will suggest themselves to those skilled in electronics.

It will have been noticed that the envelope 12 has been referred to above as formed of glass; while it could equally well be made of a metal, as by the utilization of known techniques for the fabrication of vacuum tubes, there is a considerable advantage in the use of a transparent material. When the device is in operation, and using a gaseous atmosphere such as neon or the mixture of gases known commercially as B–10, the glow discharge is, of course, visible, and provides a visual indication that the device is in operative condition. Thus, the unit is in a measure self-testing, since the presence or absence of the glow when the device is energized to some extent indicates whether the envelope has been damaged or has developed leaks, and whether energizing potential is being received at the device. Moreover, the glow discharge serves the function of a pilot or indicator light for the energization circuit, and greatly contributes to the aesthetic appearance of the unit and its associated equipment.

The current flow through the transducer under the conditions of operation stated above as exemplary only, may range from 0.5 to as much as 15 milliamperes, and of course much larger current flows could be obtained by suitable design of the electrode areas and spacing. Useful output voltages ranging from 0.1 to 1.0 volt have been obtained under actual operating conditions, which compares favorably with existing types of transducers operating on dynamic or piezo-electric principles.

It will be seen from the above description that there has been provided a transducer element of perfectly general application, in that any sort of motion-transmitting connection can be coupled to the movable electrode exteriorly of the envelope 12, so that the device can be used not only for microphones, phono pick-ups and similar audio frequency appliances, but can be operated by much slower impulses, such as might be produced by gauges, indicators or the like. In this connection, it is to be noted that the potential output of the device depends upon the position of the movable electrode with respect to the fixed electrodes, and not upon the existence of a certain velocity of travel of the movable element. Moreover, since the potential drop across the ionized column of gas is substantially independent of the supply voltage, the output is relatively stable with reference to minor variations in the supply.

While there have been disclosed herein certain preferred details of an exemplary embodiment of the invention, and the best method known for practicing the same, it is to be understood that many changes and modifications may be made in the device itself, and in its application, without

departing from the spirit of the invention as defined in the following claims.

I claim:

1. A transducer for converting mechanical movements into electrical variations, comprising a sealed envelope, an ionizable gas in said envelope, electrodes in said envelope for establishing a potential gradient therebetween sufficient to ionize said gas, a potential sensing electrode mounted in said envelope for movement along the path of said gradient, and a single electrically conductive support element mounting said last named electrode and extending through said envelope for conducting the potential of said electrode to an external circuit.

2. In combination, a transducer for converting mechanical movements into electrical variations, comprising a sealed envelope containing an ionizable gas, a pair of fixed electrodes in said envelope, a movable electrode located between said fixed electrodes, an electrically conductive connecting element extending outside said envelope for moving said movable electrode with respect to said fixed electrodes, a source of ionizing potential connected across said fixed electrodes, and an output utilization circuit connected to said movable electrodes and at least one of said fixed electrodes.

3. A transducer for converting mechanical energy to electrical energy, comprising an elongated sealed envelope containing an ionizable gas, conductors passing lengthwise of said envelope and having their inner ends deflected towards one another to provide fixed electrodes for ionizing a column of gas therebetween, an aperture in a lateral wall of said envelope opposite to the inner ends of said conductors, a

flexible diaphragm sealed to said envelope about the said aperture, and a rigid conducting element passing through said diaphragm and sealed thereto, said element extending to a point between the deflected ends of said conductors.

4. The invention in accordance with claim 3, and a support member fitted within the profile of said envelope and supporting said conductors in spaced relationship.

5. The invention in accordance with claim 4, in which said support member has cut-out portions to provide free passage along said envelope for said ionizable gas.

6. The invention in accordance with claim 3, in which said diaphragm is of metal, and a conductor secured to the inner surface of a peripheral portion thereof and passing out of said envelope.

7. A transducer for converting mechanical energy to electrical energy, comprising an envelope containing an ionizable gas, means for maintaining an arc in said ionizable gas, a movable electrode in the path of said arc, and means extending outside said envelope and connected to said movable electrode for receiving mechanical energy to vary the position of said movable electrode.

PAUL F. STILL.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,157,719	Pulaski	May 9, 1939
2,440,565	Antalek	Apr. 27, 1948