March 14, 1939. F. OFFNER 2,150,729

POTENTIAL RECORDING MARKER

Filed Aug. 29, 1936 2 Sheets-Sheet 1

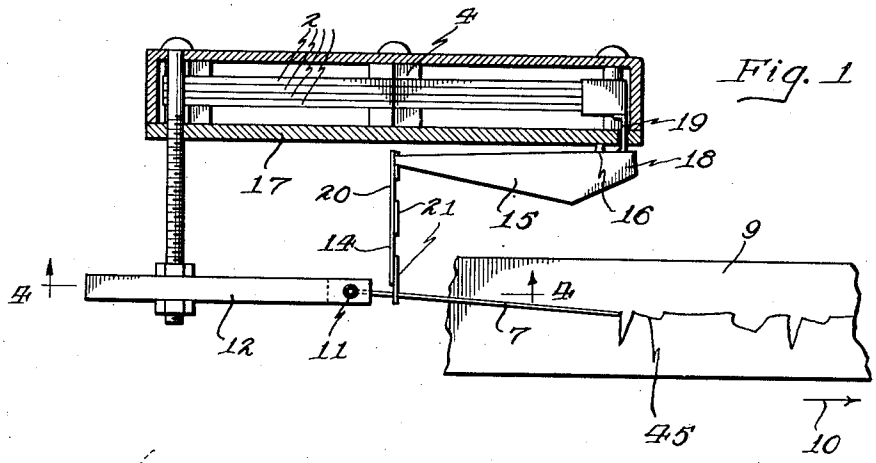


Fig. 1

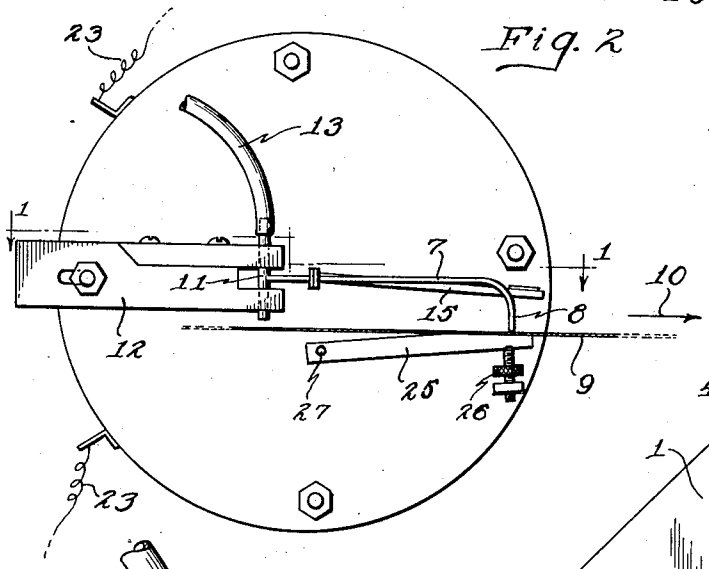


Fig. 2

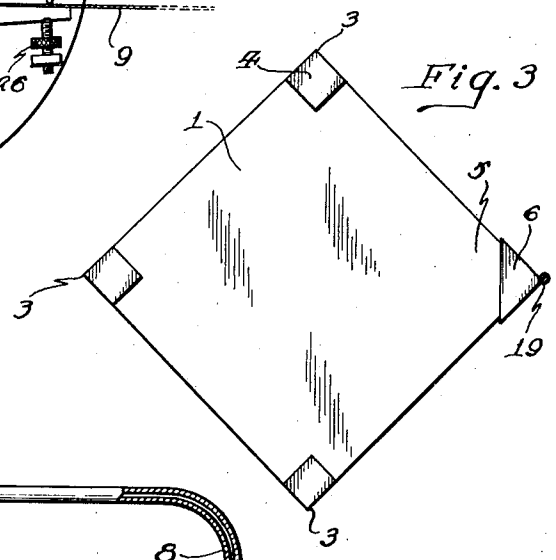


Fig. 3

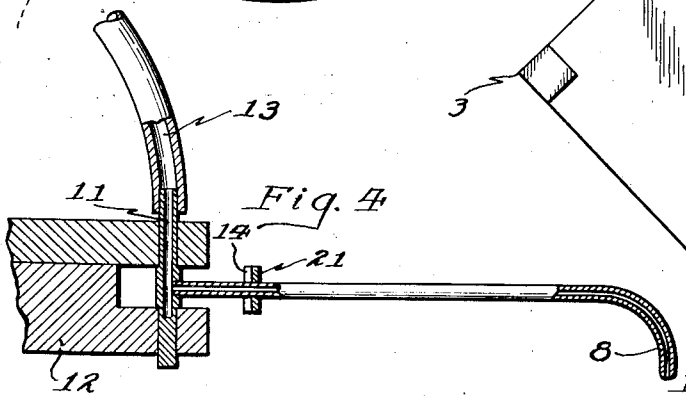


Fig. 4

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March 14, 1939. F. OFFNER 2,150,729

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Filed Aug. 29, 1936 2 Sheets-Sheet 2

Fig. 5

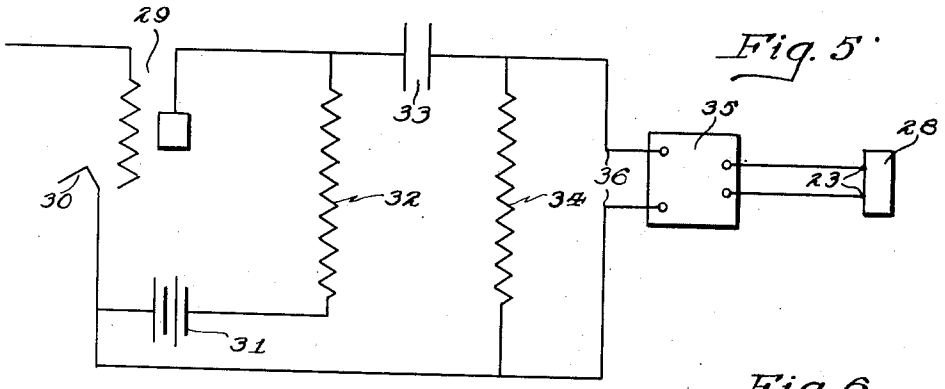
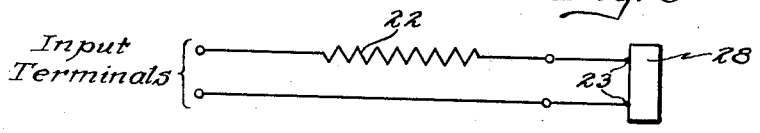


Fig. 6



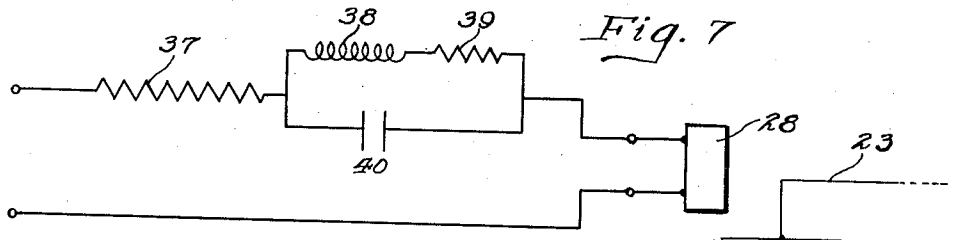


Fig. 7

Fig. 8

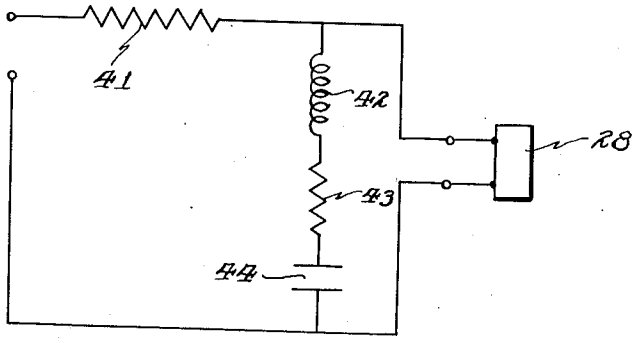
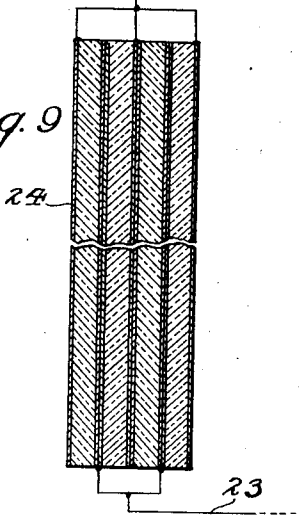


Fig. 9



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UNITED STATES PATENT OFFICE

2,150,729

POTENTIAL RECORDING MARKER

Franklin Offner, Chicago, Ill.

Application August 29, 1936, Serial No. 98,594

3 Claims. (Cl. 234—5.5)

This invention is in that general class wherein electrically deformable dielectric materials are used for recording variations in electric potential. In the past such uses included the deflection of light in oscillographs, and use in phonograph recorder. The present application of such a dielectric is intended mainly for work in medical research but has numerous other applications in chemistry, physics, and engineering. In physiological work, for example, in recording the precise nature of electrical variations in heart action or muscle contractions, it has been customary to make use of a beam of light deflected or produced in oscillographs and recorded on a moving photographic surface.

The present invention is the outcome of an attempt to avoid the delays, expense and inconvenience of photographic technique, and with that end in view it was found that a recording pen could be actuated directly by the motion occurring in a dielectric upon a change of potential, provided the dielectric is of proper form and composition and is properly mounted for the intended work and in mass and structure is balanced with the electrical impedance arrangement of the circuit within which it is placed. The mechanical and electrical characteristics of the assembly are such as to minimize the effect of the natural resonances of the electro-mechanical circuit.

Previous attempts to make marked oscillograph records directly on moving paper, so far as known, have made use of electromagnetically actuated pens which had numerous inherent defects, particularly that of a rather low maximum response frequency. Now, by the use of an electrically deformable dielectric, the maximum response frequency of the pen is increased to about three times that of the electromagnetic pens and renders the instrument much more useful for physiological studies. It is also highly efficient as only a minute driving power is required. The high impedance of the dielectric driver allows it to be effectively coupled to the output of most ordinary vacuum tubes with good impedance match.

In magnetic driving systems the situation is entirely different as there is difficulty in obtaining sufficient current to actuate the pen except by the use of more or less complicated circuits using a multitude of large tubes to get sufficient power. Also its low impedance makes the magnetic drive impractical to couple into the output of a vacuum tube through a condenser of any convenient size, for the purpose of blocking out the direct current component of the output.

The high impedance of the dielectric driver allows for coupling to the output of any vacuum tube supplying sufficient voltage at the required power (about one-half watt) through a moderately sized condenser, and resistance; and no polarizing current or voltage is required in addition to the impressed signal. The response amplitude is practically independent of frequency up to about 200 cycles per second. Thus, with a frequency range greater than that of the string galvanometer as ordinarily used it is possible to obtain satisfactory marked records within the range required for biological work. This also renders the instrument useful in many other sciences; for example, in recording number and amplitude of Geiger counter discharges.

The purpose of the invention may be accomplished by means of a construction and the circuit arrangement illustrated in the accompanying drawings in which:

Fig. 1 is a fragmentary plan view showing the crystal, its holder in section, and the pen and recording tape.

Fig. 2 is a side view of the construction shown in Fig. 1.

Fig. 3 is a plan view of the crystal indicating three corner insulating fixed supports for the crystal and one corner for transmitting motion to the pen.

Fig. 4 is an enlarged sectional detail of the pen.

Fig. 5 is a diagram of an actuating circuit for the crystal in which 35 is an impedance device and 20 is the crystal and pen assemblies, as shown in Figs. 1 and 2.

Figs. 6, 7, and 8 are diagrams showing optional forms of the impedance device as connected to the pen operating assembly.

Fig. 9 is an enlarged sectional detail of the dielectric unit.

In carrying out the invention as before outlined, the best dielectric substances now available for the purpose are of the Rochelle salt type laminated to provide a plurality of crystal plates combined to form a compact block. A particularly suitable form is composed of four plates each cut with parallel faces properly oriented with the crystallographic axes of the crystals. The electrodes which carry to the crystal the electro-motive force needed to produce a mechanical motion for operating the pen are applied in good electric contact to the opposite faces of the block. There are also thin metallic contact elements between the opposed faces of the plates forming the block. One manner in which the

crystal block may be formed is that described in Patent No. 1,803,275.

In the drawings the crystal is shown as a rectangular block 1 composed of four plates 2. The crystal block is supported at the three corners 3 on fixed insulating blocks 4. The remaining corner 5 of the crystal carries a metal attachment 6 by which motion of this free end of the crystal is transmitted to a recording pen. The pen 7 is a fine capillary tube having a downwardly bent end 8 bearing on a strip of paper tape 9. The paper is fed, for example, in a longitudinal direction as indicated by the arrow 10 Fig. 2 by an electric motor drive equipped with a standard variable speed drive not shown.

The pen element 7 is attached to a perpendicular, tubular pivot support 11 which passes through a fixed arm 12 forming bearings for the pen. The tubular element 11 is plugged at its lower end and at its upper end fits a flexible tube 13 which serves to conduct ink from a supply not shown, to the pen. As appears in Fig. 1, the pen passes through a link 14 by which the pen is connected to a multiplying lever 15. The latter is fulcrumed at 16 to the casing 17 for the crystal block 2. The shorter arm 18 of lever 15 is secured to a flexible bar 19 connecting the lever with element 6. The link 14 is composed of a flexible portion 20 and more rigid reinforcement elements 21.

This specific link provides the necessary freedom of motion without the use of loose connections and yet is sufficiently rigid to transmit vibrations without loss.

The electrical connections for the crystal blocks are indicated at 23 in Fig. 2. From Fig. 9 it may be seen that the separate crystal plates forming block 1 have affixed electrodes 24 which may be tin foil and these are alternately connected in parallel to the conductors 23.

The paper tape 9 is supported under the pen 7 by a guide plate 25. The position of the plate 25 with respect to the pen 7 is controllable by a screw adjustment 26 which controls the height of one end of the plate 25, while the other remains fixed at pivot 27. The adjustability of the paper tape 9 with respect to the pen 7 allows the pressure with which the pen bears upon the tape to be readily controllable. This pressure is adjusted to give proper damping of the motion of the pen. This mechanical damping of the pen in combination with electrical circuits of Figs. 6, 7, or 8 is adjusted to give a response amplitude substantially independent of frequency over as large a range as possible.

In Fig. 5 is shown a circuit by which the crystal may be actuated by a vacuum tube amplifier. The crystal and pen assembly is shown symbolically at 28. 29 is a thermionic vacuum tube which may represent the last vacuum tube in a series of cascaded stages in an amplifier. The input circuit of the vacuum tube 29 is not shown nor is the circuit for heating the filament 30 of said vacuum tube. 31 is the plate supply battery for 29, and 32, the plate resistor.

A blocking condenser 33 is used to allow the output of 29 to be obtained without the direct potential from 31. A high resistance 34 is shunted from the output of 33 to the filament 30, to by pass any small direct potential which might leak across 33. At 35 is shown symbolically an impedance device interposed between the output terminals 36 of the amplifier and the input terminals 23 of the crystal 1 of the crystal and pen assembly 28. The purpose of the impedance device 35 is, with the mechanical damping of the pen previously disclosed, to provide as nearly as possible a uniform response amplitude independent of frequency.

At certain frequencies the electro-mechanical system composed of the crystal and pen assemblies 28 will exhibit resonance. The instrument here disclosed will generally be used only up to frequencies slightly higher than the first resonant frequency. Because of the large effective inertia of the pen and associated mechanical linkage system relative to that of the crystal element, this resonant frequency will depend largely upon the mass of the former and only slightly upon that of the latter. Then as this resonant frequency is approached, for a constant applied potential the response amplitude of the pen would normally be considerably greater than the response amplitude at lower frequencies. Similarly the electrical impedance presented at the input terminals 23 will be disproportionately lower than at lower frequencies.

At Fig. 6 is shown a circuit which may be used for the impedance device 35 and which takes advantage of this properly of the crystal. Here a resistor 22 is placed in series between the output terminals 36 of the amplifier and the input terminals 23 of the crystal. Now, as the frequency applied to the input terminals of 35 approaches the resonant frequency of the electro-mechanical system 28, then assuming that the applied potential is constant, the current flowing between the input terminals of 35 will increase and the potential drop in 36 will thus increase, and thus decrease the potential applied to the terminals 23 and consequently decreasing the amplitude of motion of the pen 7. Thus, it may be seen that the interposition of the resistor between the output of the amplifier and the input of the crystal 1 will aid in providing a more nearly uniform frequency response.

Instead of the simple resistance shown in Fig. 6 more complicated circuits can be used at 35 giving a still more nearly uniform frequency response. In Fig. 7 is shown a resistor 37, a parallel circuit composed of an inductance 38 and a resistor 39 in series, both being shunted by a condenser 40, all being connected in series as shown. The resistor 39 may simply be the inherent resistance of inductance 38. By properly proportioning the components 37, 38, 39 and 40, the desired effect of giving more uniform frequency response may be obtained. In Fig. 8 is shown another circuit for accomplishing the same purpose. 41 is again a resistor, 42 an inductor, 43 is another resistor which again may be the inherent resistance of 42, and a condenser 44. A portion, or all, of the resistances 22, 37, or 41 may be replaced by the plate resistance inherent in the thermionic tube, such as 29, supplying the actuating potential.

While the impedance device 35 is shown in Fig. 5 as interposed between 28 and a particular form of vacuum tube amplifier, it is to be understood that these circuits may be used with amplifiers of other forms and with supplies other than vacuum tube amplifiers.

While as beforementioned, the instrument has numerous uses in electrical and physical fields, that as illustrated is especially useful for work such as diagnosing the condition of the heart. For this work a vacuum tube amplifier of which 29 in Fig. 5 might represent the last tube, is used. The input terminals of this amplifier, which must have a voltage gain of approximately

1,000,000 times, will be placed at two proper points of the subject's body. Then, as the subject's heart passes through one cycle of motion a potential will be developed across these two points of the body. This potential will be amplified by the vacuum tube amplifier and finally applied to the input terminals **23** of the crystal and pen assembly **28**. The motion of the pen **7** is recorded in ink upon the moving tape **9** giving a record on **9** as shown in Fig. 1 at **45**. By the form of this record, which, as it will be seen, is immediately obtained, the condition of the subject's heart may be diagnosed. Previously permanent records have been obtained by comparatively complicated and expensive apparati in which a permanent record is obtained on a moving photographic film which requires photographic processing before it is available for use for diagnostic purposes. The improved method here disclosed provides a means for obtaining a permanent record immediately available by a more economical method.

I claim:

1. In a device for making a directly visible and readable marked record of the wave form of a varying electric potential upon a movable record receiving surface, a movable record marking member having a marking element adapted to move freely laterally over said record receiving surface, actuating means for said marking member comprising a piezo-electric crystal element deformable under the influence of an applied electric field, mechanical connecting means between said crystal element and said marking member for moving the latter as a direct function of the motion of the crystal element, said mechanical connecting means with said marking member having large effective inertia relative to the effective inertia of the crystal, an input circuit to the crystal for applying an electric field of varying potentials and frequencies to said crystal, and a series resistance in said input circuit, said series resistance dissipating the most energy at frequencies approaching the first electromechanical resonant frequency of the crystal system comprising the crystal element and associated marking member and mechanical connections, whereby to obtain substantially true readable reproductions of the wave form of potentials of any frequencies up to and slightly above the said first electromechanical resonant frequency of the crystal system.

2. In a device for making a directly visible and intelligible marked record of the wave form of a varying electrical potential upon a movable record receiving surface, a movable record marking member having a marking element adapted to move freely over said record receiving surface, actuating means for said marking member comprising a piezo-electric crystal element deformable under the influence of an applied electric field, motion multiplying connecting means between said crystal element and said marking member for moving the marking member as a direct function of the motion of the crystal element, said marking member and connecting means providing so great mass loading of the electromechanical system that the first electromechanical resonant frequency of said system is substantially independent of the mass of the crystal element, circuit connections for applying an electric field of varying potentials and frequencies to said crystal element, means in said circuit connections presenting a resistive source of potential to said crystal element said resistive means dissipating the most energy at frequencies approximating the first electromechanical resonant frequency of the system comprising the crystal element and associated marking member and connecting means, whereby the record traced by said marking member is a substantially true recording of the wave form of the said varying potential for all frequencies up to and slightly surpassing the first electromechanical resonant frequency of the system comprising the crystal element and associated marking member and connecting means.

3. In a device for making a directly visible and legible marked record of the wave form of a varying electric potential comprising a movable record marking element, actuating means for said marking element comprising a piezo-electric crystal element deformable under the influence of an applied electric field, motion multiplying means providing a driving connection between said crystal element and said marking element, said motion multiplying means with said marking element having large effective inertia relative to the effective inertia of the crystal element, and means for damping the action of said crystal element, whereby to obtain substantially true readable reproductions of the waveform of potentials of any frequencies up to and slightly surpassing the first electromechanical resonant frequency of the system including the crystal element, the marking element, and motion multiplying means.

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