Sept. 14, 1937. W. SIX ET AL 2,093,215

METHOD AND DEVICE FOR RECORDING OSCILLATIONS

Filed March 15, 1935 2 Sheets-Sheet 1

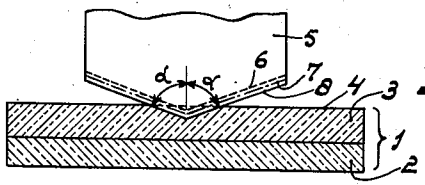


Fig. 1.

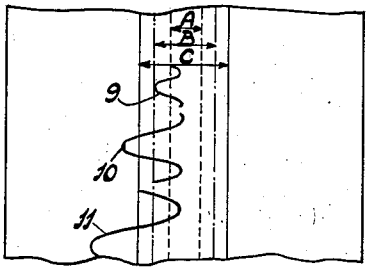
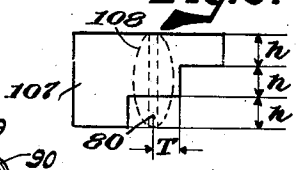


Fig. 2.

Fig. 5.



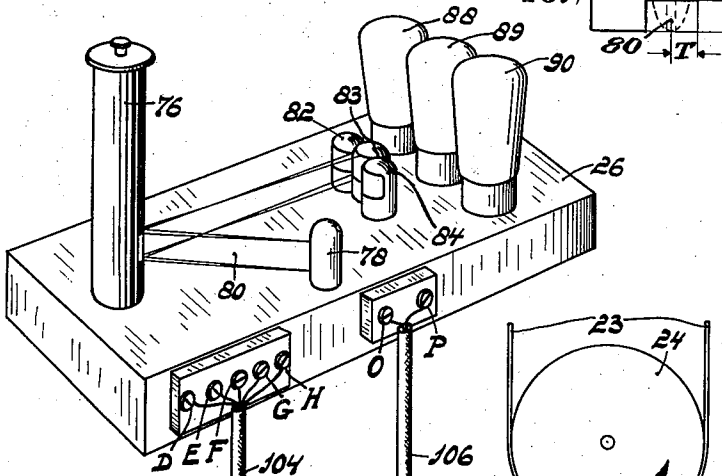
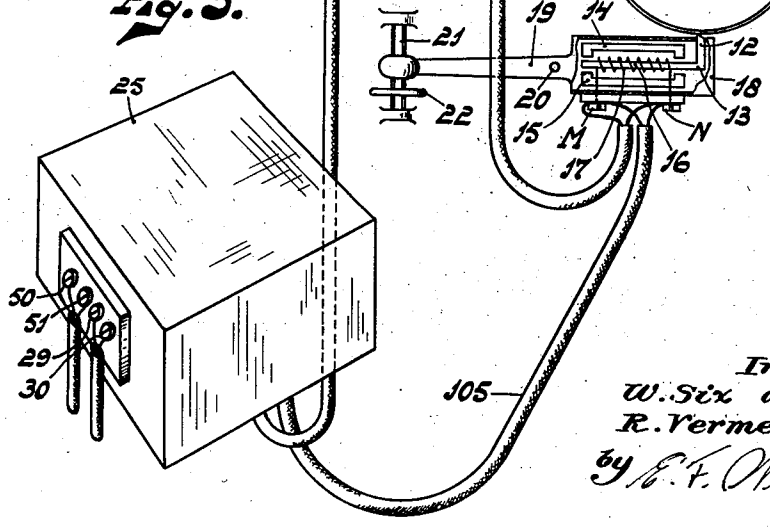


Fig. 3.



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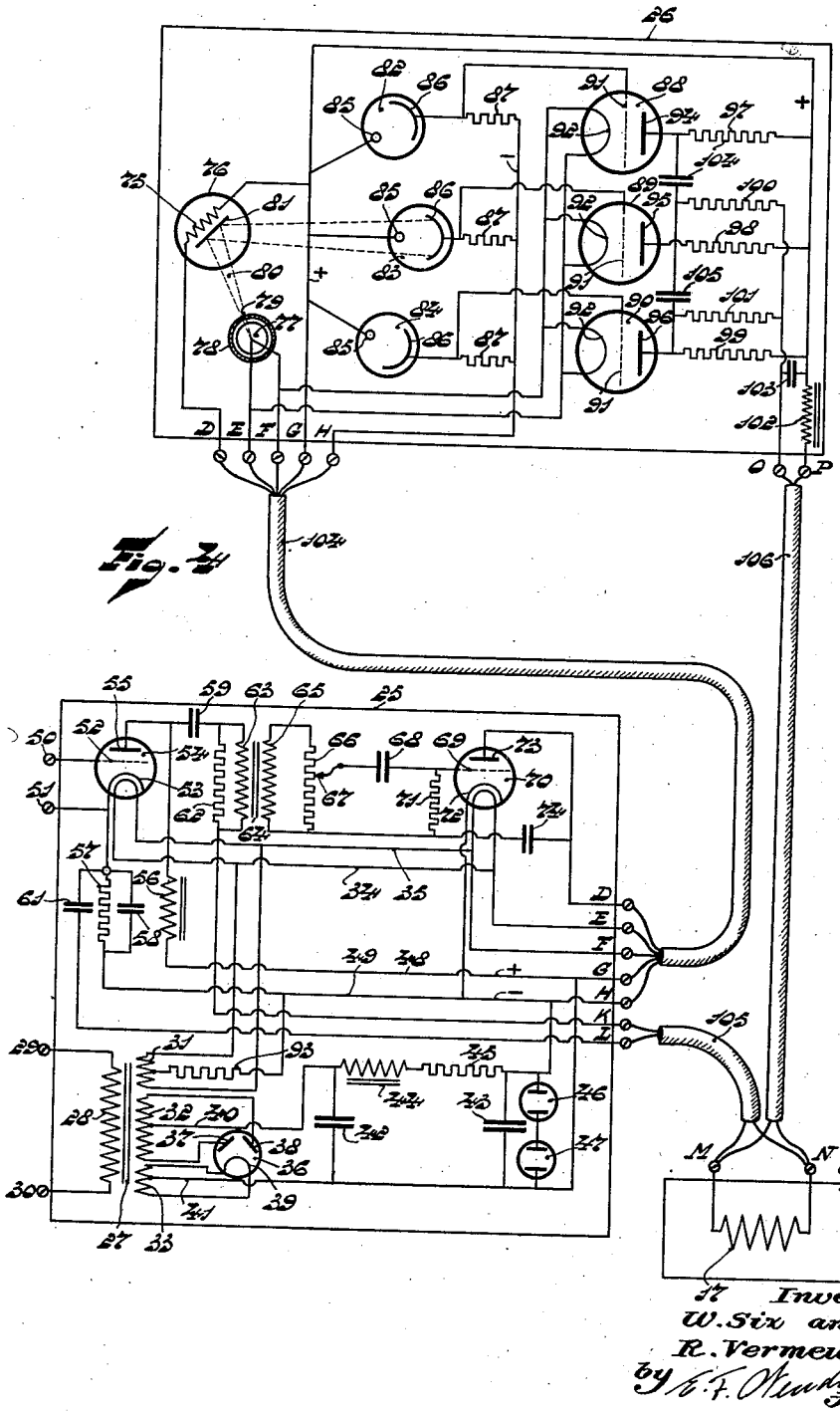


Fig. 4

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METHOD AND DEVICE FOR RECORDING OSCILLATIONS

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Application March 15, 1935, Serial No. 11,371
In Germany March 26, 1934

14 Claims. (Cl. 179—100.4)

This invention relates to a device for and a method of recording oscillations or vibrations on a carrier, and is especially useful in connection with mechanically-recorded and electro-optically reproducible sound vibrations, for example for the sound record of motion picture films, and we shall describe it primarily in connection therewith. Our invention, however, can be also advantageously used for optically recorded sound records.

Methods of mechanically recording sound are known in which a vibration track is cut into a carrier, for example a film, by means of a cutting tool, for instance by means of a chisel or burin, which tool is vibrated in accordance with the vibrations of the sounds to be recorded; such a method being, for example, described in U. S. Patent 1,919,116 to J. A. Miller.

To successfully carry out such methods of mechanical recording, it is necessary that the cutting edge of the cutting tool be clean and highly polished, as otherwise the resulting vibration track becomes distorted and blurred.

Furthermore, as the cutting tools used for this purpose are generally of very small size and made of a very hard and brittle material, as a diamond or sapphire, the cutting edges break off rather easily, and therefore great care has to be taken to minimize, during recording, the strain on the cutting edge.

At the same time it is advisable to provide means to minimize background noises whether the optically-reproduced sound records are optically or mechanically recorded; such noises being due to various causes, for instance to the presence of particles of dirt or scratches on the transparent portions of the record, and interfere with the quality of reproduction.

In the optical recording of sound such background noises are usually reduced by the provision of means which alter during the recording the central or neutral position of the recording member, in accordance with the amplitudes of the sound currents. This is effected by rectifying and smoothing a portion of these currents and using this rectified and smoothed current to control the central position of the recording member.

In the above method the central position of the recording member is thereby continually changed in accordance with the changes in the amplitudes of the sound currents. Thus whenever the amplitudes of the sound currents increase or decrease, a movement of the recording member into a different neutral position takes place. This method has the drawback that whenever the amplitudes of the sound currents suddenly change from a small value to a comparatively large value, and the recording device correspondingly assumes a new central position, the inertia of the control system is liable to cause, during the transition from one to another central position, the cutting off of the peaks of the large amplitudes. This is a rather frequent occurrence and deleteriously affects the quality of reproduction.

We have found that the above difficulties can be overcome and special advantages obtained, which are especially marked in the case of mechanical recording of optically-reproducible sound records, by providing instead of a continuous variation of the central position of the recording member, a stepwise variation of the central position; this control or determination of the central position of the recording member being effected by means of a direct current the value of which depends upon the amplitudes of the recorded sound currents. For this purpose we prefer to use controlling means in which a light-valve so biases one or more direct current circuits that the current or currents in such circuits causes a stepwise displacement of the central position of the recording member.

An arrangement in which a light beam is controlled by electrical means is usually referred to as a "light-valve", and this term will be hereafter used in the specification and claims.

Our invention has various important advantages, some of which apply equally well, whether the record is optically or mechanically recorded, while other advantages are particular to mechanical recording.

One of the advantages of the method according to the invention is that the control operates with a smaller expenditure of energy than has been required heretofore, whereby, for instance, with a power of the order of only a few milliwatts highly satisfactory results can be obtained.

Furthermore, when optically reproducing the record—this irrespective of whether the record has been mechanically or optically recorded—a stepwise variation in the central position of the recording member has the advantage over the continuous variation of this position that the cutting off of the peaks only occurs at those infrequent instances when the central position of the recording member is altered by a stepwise displacement. Thus as long as the small and large amplitudes remain within a given range, they are recorded with the same central position of the recording member, and as the cen-

tral position of the recording member does not change in this case, no cutting off of the peaks can occur. It will thus appear that a partial cutting off of the peaks is limited to the infrequent instances when so large amplitudes which require a change in the central position of the recording member occur suddenly.

While a stepwise control of the central position of the recording member affords slightly less freedom from background noise than does a continuous control, nevertheless because of much less cutting off of peaks, the resulting total distortion is considerably less when our novel method is used than when using the known method.

When used in connection with mechanical recording, the method according to the invention has the further advantage that by the stepwise displacement of the central position of the recording tool, the active portions of the cutting edges or edge of the tool change and thus, instead of a given portion of the tool being subjected to a continuous strain and wear, strain and wear are distributed over different portions of the cutting edge. This not only provides for better heat dissipation, but also materially saves the tool and extends its useful life.

Furthermore, when the cutting tool is in the position to record small amplitudes, it may be partly raised from the cutting layer. This gives a shallower cut, reduces the cutting resistance, and thereby permits a very accurate recording of such small amplitudes.

Further objects and advantages of the invention will appear as the specification progresses.

In order that the invention may be clearly understood and readily carried into effect, it will be more fully explained with reference to the accompanying drawings, in which,

Figure 1 shows a carrier suitable for mechanical recording, according to the method described in the above-mentioned patent, in cross-section and a recording tool according to this method in front view.

Figure 2 shows the carrier of Fig. 1 in top view.

Figure 3 is a schematic perspective view of an arrangement in accordance with the invention;

Figure 4 is the wiring-diagram of the arrangement according to Fig. 3.

Figure 5 is a diagrammatic view of a screen having stepwise recesses, as used in connection with a modified embodiment of the invention.

In the drawings same references relate to corresponding parts.

In Figure 1, **1** is a carrier suitable for mechanically recording a vibration track according to the method described in the Miller Patent 1,919,116. The carrier as designed is in the form of a film-strip and consists of three superimposed layers, of which **2** is a base or supporting layer, preferably made from celluloid, **3** is the so-called cutting layer, and preferably made from gelatin, whereas **4** is a very thin opaque covering layer. The recording tool **5**, shown in front view is shaped as a small chisel having a V-shaped cutting edge with a very large top angle, (2α) e. g. about 174°. During recording the chisel has an oscillatory movement in a direction perpendicular to the surface of the carrier. For clearness sake the figure does not show real proportion; the top angle of the chisel being chosen somewhat smaller and consequently the thickness of the carrier layers having a thickness a little out of proportion. Without these deformations the situation could not be clearly shown in a drawing.

According to the invention the chisel has several central positions. In Figs. 1 and 2 an embodiment is shown in which the chisel has three central positions indicated by **6**, **7**, and **8**. If the chisel does not oscillate in the subsequent positions the track A, bordered by the dotted lines, the track B bordered by the dot and dash lines and the track C bordered by the full lines, are cut. By the double arrows the subsequent widths of the tracks are indicated. In the central position **6** a maximum amplitude **9** can be recorded, in the central position **7** amplitudes between those shown by **10** and **9**, and in the central position **8** amplitudes between those shown by **11** and **10** can be recorded.

In connection with Figures 3 and 4 we will set out now how we can obtain the steplike recording in practice applicated to the Miller-recording method.

In Figure 3, reference numeral **12** indicates the cutting member corresponding to the chisel **5** shown on an enlarged scale in Fig. 1. This member is solidly fixed to the ferromagnetic armature **13** forming part of the magnetic system, comprising substantially the ⊓ shaped pole-shoes **14** and **15** magnetized by a permanent magnet (not shown) in such a way that each pole shoe has like poles, an armature **16** and a coil **17**. The magnetic system is mounted in a casing **18** forming one part with the arm **19**, the latter being rotatably mounted at **20** and adjustable by the screw **21**, with milled adjusting disc **22**, the screw being axially fixed. The carrier for the record is in the form of a film **23**, carried in the direction of the arrow by a driven roller **24** beneath the recording tool **12**.

Furthermore in Figure 3 two apparatus **25** and **26** are shown, the operation of which will be explained in connection with Figures 3 and 4, the last figure showing the wiring diagram of the installation according to Fig. 1.

The casing of apparatus **25** contains a rectifier for the anode and grid tensions, required by the applicated electron tubes, an amplifier for the sound currents, and a rectifier for a part of the sound currents.

The rectifier for the desired tensions consists of a transformer **27**, comprising a primary winding **28** connected to the terminals **29** and **30**, and three secondary windings **31**, **32**, and **33**. The winding **31** feeds the heating filaments of the several electron tubes, both ends being connected for this purpose to the mains **34** and **35** and further to the terminals E and F. The ends of the winding **32** are each connected to an anode of the full-wave rectifying tube **36**, the anodes being numbered **37** and **38**. The winding **33** supplies the heating current for the cathode **39** of the tube **36**. Both windings **32** and **33** have a midpoint tap **40** and **41** respectively, forming the negative and positive pole of the rectifier. For smoothing the pulsations in the direct current the condensers **42** and **43** in combination with the choke **44** and resistance **45** are arranged. In order to keep the produced tension independent of the load, the direct current source is continuously loaded by the glowing discharge tubes **46** and **47**. The terminals of the rectifier are further connected to the mains **48** and **49** and the latter in turn with the terminals C and H. In order to make the diagram more readily understandable the conductors, which are directly connected to

the mains 48 and 49 are provided with the marks + and −.

The terminals 50 and 51 are connected to the grid 52 and cathode 53 respectively of the amplifying tube 54 and serve for the sound current supply. The anode 55 of this tube receives its positive potential via the choke 56. The cathode 53 receives automatically a negative potential from the resistance 57, shunted by the condenser 58. The amplified sound currents pass through the condenser 59 the terminals K and N to the recording device 60, of which only the coil 17 is shown, and there via the terminals M and L and the condenser 61 to the cathode 53 of the amplifying tube 54. In the drawings the amplifier for the sound currents consists of one step only. This however, is not essential. Without any difficulties a multi-step amplifier, if desired, can be used.

By the insertion of the resistance 62 in the amplified sound current circuit, a part of this current is tapped off and led to the primary winding 63 of the transformer 64. The secondary winding 65 of this transformer is shunted by the potentiometer 66. By the adjustable contact 67 an arbitrary alternating tension is tapped off and lead via the condenser 68 to the grid 69 of the electron tube 70, acting as a grid detector, reference numeral 71 indicating a leakage resistance connecting the grid with the cathode 72. The anode lead of the detector valve 70 goes from the anode 73 via the terminals D—D to the coil 75 of the mirror galvanometer 76 and from there to the positive main. By this arrangement the position of the mirror galvanometer is determined by the intensity of the sound.

The light source 77, being surrounded by an opaque casing 78 having a light slit 79, throws a light beam 80 of fixed dimensions upon mirror 81 of the mirror galvanometer. Dependent upon the position of the mirror the beam is reflected to one of the photocells 82, 83, 84. Each photocell has an anode 85 and a cathode 86, the anodes being directly connected to the positive main, and the cathodes being connected through the resistances 87 to the negative main. The cathodes 86 of the several photocells are furthermore each connected to the grid 91 of corresponding gasfilled discharge tubes 88, 89 and 90, commonly called Thyratrons, and having directly heated cathodes 92. In order to obtain the required negative grid potential, the midpoint of the winding 31 of the transformer 27 is connected to the negative main 49 through the resistance 93, the potential of the heating wires of the indirectly heated tubes 54 and 70 being of no importance for the good working of these tubes. The anodes 94, 95, and 96 of the gas-filled discharge tubes 88, 89, and 90 are connected through resistances 97, 98, and 99 respectively to the positive main. Furthermore the anode 95 of tube 89 and the anode 96 of tube 90 are connected through resistances 100 and 101 respectively to the terminal O and from there via the terminal M and through the recorder coil 17 via the terminals N and P connected to the positive main.

It must well be noticed that the recorder coil receives no potential from the device 25. No direct tension can reach the recorder from that side, because of the complete insulation by the condensers 59 and 61. Only alternating currents can be imparted from this side. The terminal P being connected to the positive main gives the coil 17 a positive direct tension. The choke 102 and the condenser 103 form a smoothing arrangement in order to prevent the sound currents from entering the device 26.

The condensers 104 and 105 couple the anodes of the tubes 88, 89, and 90, in order to ensure that only one tube can work at the same time.

The installation operates as follows.

Assuming the light source 77 is not illuminated, the photocells will have a very great resistance and no current will pass them and the resistances 87, so that the grids 91 of the gas-filled discharge tubes will have the potential of the negative main.

Suppose now the light source 77 is switched on and no sound is being recorded, the mirror 81 reflects the lightbeam onto the first photocell, i. e. 82. With this illumination the resistance decreases considerably and a current passes from the positive main, the anode 85, the cathode 86 and the resistance 87, all belonging to the photocell 82, to the negative main. By this current the potential of the anode 86 will strongly increase as will the potential of the grid 91 of the discharge tube 88. As a result, this tube will be ignited and a direct current will flow from the positive main through the resistance 97, the discharge tube 88, the winding 31 of the transformer 27 and the resistance 93 to the negative main, the intensity of this current being substantially determined by the ohmic resistance of the resistance 97. This current thus does not pass through the coil 17 of the recorder. One of the discharge tubes being in operation all tubes receive automatically a negative grid potential by the resistance 93 and consequently are checked.

If now sound is recorded and the intensity of the sound surpasses a certain level (which can be adjusted by the movable contact 67 of the potentiometer 66) the lightbeam 80 is reflected to the second photocell, i. e. 83. The grid of the corresponding discharge tube 89 becomes positive with respect to the cathode and the tube "gets on", but because of the small internal resistance of a gasfilled discharge tube in operation, the potential of the anode of this tube falls suddenly down nearly to the cathode potential. At the same time the condenser 104 is discharged and during a very short period of time the potential of the anode 94 of the tube 88 decreases by nearly the same amount as the anode of the tube 88. The anode potential of this tube becomes much less than the cathode potential and at the same moment the tube 89 is ignited the discharge in the tube 88 is checked. When the illumination of the photocell 82 ceases, the grid potential of the tube 88 is negative with respect to the cathode potential and no re-ignition takes place.

Upon ignition of the tube 89, a direct current flows from the positive main partly through the resistance 98 and partly through the recorder coil 17 and the resistance 100 to the anode of the tube 89 and further through the tube etc., as described in the former case.

As the sound intensity surpasses a second level, the photocell 84 is illuminated and according to the above description now the tube 90 is ignited, whereas the tube 89 is extinguished.

The values of the ohmic resistances of the resistances 100 and 101 are so chosen, that during operation of the tube 90 a current of higher intensity passes through the coil 17 of the recorder. Furthermore the substitute values of the parallel resistances 98—100 and 99—101 are such that they are practically equal to that of the resistance 97 alone, so that no load variations occur for the rectifier and the negative grid tension of the grids 91 does not vary.

It must be noted that only by ignition of another tube is a tube in operation extinguished. It is necessary therefore that the illumination of the corresponding photocell is over, because if this were not the case reignition would take place. An interruption in the illumination of the photocell corresponding to a gasfilled discharge tube which is in operation does not influence this operation, the latter being insensible to potential variations of the grid. The only way to extinguish a tube of the type used, is to decrease the anode tension a sufficient amount.

In the case the sound decreases under the predetermined levels the same performances take place as described above for an increasing sound intensity, so that further consideration thereof seems to be superfluous.

The several wires connected to the devices **25**, **26**, and **60** are formed into cables **104**, **105**, and **106**.

It will be noted that in the above arrangement the discharge tubes **82**, **83**, and **84** act as direct-current relays, whose action is initiated by their respective photocell. Instead of using such discharge tubes as relays, mechanical or electromagnetic relays may be used, which are so interlocked that only one of the relays, namely the relay whose corresponding photoelectric cell is struck by light is operated at a time. Through the closed contacts of the relays are supplied direct currents of different values to coil **17** in the same manner as has been described in connection with the discharge tube currents. However, we prefer to use the discharge tube relays, as generally these tubes can be reliably actuated by using the weak voltages generated in the photo-electric cells as grid bias of these tubes. In addition, the illumination of these discharge tubes gives a convenient check as to the proper operation of the control device.

According to a further embodiment of the invention, the light beam **80** instead of being reflected towards the photocells by a mirror is projected directly towards the photocells, but the light beam is intercepted by a small stepped screen of the type shown in Fig. 5, which screen may be connected to a galvanometer coil and moves laterally with regard to the light beam **80**, in accordance with the intensity of the sound to be recorded.

The screen **107** is stepwise recessed, for example if a three-step screen is used, as shown in Fig. 5, the height h of each of the three steps may be one-third of the total height of the screen. At the rear of the screen is placed, for example, a large photocell, as indicated by dotted lines as **108**, whose active surface corresponds to the cross-section of the light beam **80**. When the screen **107** is in the position shown only a small portion of the active surface of the photocell **108** is struck by light. As is well known, the current generated or transmitted by a photocell depends upon the active area of the photocell struck by light and, corresponding to the illuminated portion of the photocell, as shown in Fig. 5, a small current is generated in the photocell, which current may be used to bias the grid of a triode so that corresponding to this bias a current passes through the triode and is led to the actuating coil **6**.

If the amplitudes of the sound currents are increased the screen moves towards the left, but this does not increase the illuminated surface of the photocell until such movement of the screen exceeds a distance T. When such displacement of the screen has taken place, the light beam **80** strikes twice as large active portion of the photo-electric cell, and the photo-electric cell supplies twice as large grid voltage to the triode, which step causes a stepwise movement of the central position of the cutting tool.

In the same way, a further leftward movement of the screen corresponding to still larger amplitudes of the sound currents will cause a third portion of the photocell to be struck by light, and correspondingly a further stepwise increase of the biasing voltage will result, which in turn causes a further stepwise movement of the central position of the recording tool.

Instead of using a single large photocell, three individual photocells may be disposed above each other. In this case, instead of using a single triode, a plurality of electron tubes can be used—one for each of the photocells—the photocells causing the biasing of the grid circuits of their corresponding electron tubes, thereby permitting them to pass current. In this arrangement, however, the electron tubes, instead of being connected, as discussed in connection with Figures 3 and 4, are so arranged that their currents are additive. Thus the same result is obtained as if a single photocell were used.

While we have described our invention in connection with specific embodiments, it is obvious that various modifications may suggest themselves to one skilled in the art; for example, the number of photocells, or similarly the number of steps of the screen of Fig. 5, may be varied. Also various mechanical recording devices can be used, or instead of mechanical recording, optical recording can be employed. Therefore, we do not wish to be limited to the specific examples and applications given herein, but desire the appended claims to be construed as broadly as permissible in view of the prior art.

What we claim is:

1. In the recording of oscillations on a carrier, the process which comprises, controlling a light-valve in accordance with the amplitudes of the oscillations to be recorded, and actuating a device by said light-valve to place the recording member in one of several predetermined positions with respect to the carrier and to maintain said member in each position while the amplitudes are within a predetermined range.

2. In mechanically recording an optically-reproducible sound track upon a carrier, the process which comprises, controlling a light-valve in accordance with the amplitudes of the sound vibrations to be recorded, and actuating a device by said light-valve to locate the central position of the recording member at one of several predetermined distances from the carrier and to maintain same at each distance while the amplitudes remain within a predetermined range.

3. In the recording of oscillations on a carrier, the steps which comprise, controlling a light-valve in accordance with the amplitudes of the oscillations, actuating by said light-valve a device to alter the value of the current in a direct-current circuit between several predetermined values and to maintain the current at each value while the amplitudes remain within a predetermined range, and changing the central position of the recording member with respect to the carrier in accordance with said values.

4. The method of recording oscillations on a carrier, comprising the steps of vibrating a recording member in accordance with the oscillation currents to be recorded, feeding a portion

of the oscillation currents through a circuit, controlling a light-valve in accordance with the amplitudes of the oscillation currents, altering by said light-valve the current in a direct-current circuit between several predetermined values and maintaining the current at each value while the amplitudes are within a predetermined range, and changing, in accordance with said direct-current values, the central position of the recording member with respect to the carrier.

5. In the recording of sound oscillations on a carrier, the process which comprises, vibrating a recording member in accordance with the oscillations of the sound currents, projecting a light beam on a photo-electric surface, intercepting said light beam by a stepped screen, changing the position of said screen with regard to the beam and said photo-electric surface in accordance with the amplitudes of the recorded sound oscillations to selectively expose several predetermined portions of the photo-active surface and to maintain the exposure of each portion while the amplitudes of the oscillations remain within a predetermined range, and stepwise displacing the recording member by means of a direct current whose value depends upon the exposed photo-electric surface to cause said member to assume one of several predetermined central positions.

6. In the mechanical recording of optically-reproducible sound oscillations on a film, the process which comprises, dividing the sound-modulated currents to be recorded into two portions, passing one portion through an actuating coil to vibrate a recording member in accordance with the sound oscillations and to cut on a film a corresponding sound track, rectifying the smaller portion of said currents and passing this portion through a second coil, controlling the position of a mirror by the current through said second coil, projecting on said mirror a light-beam, reflecting said light-beam by said mirror in the direction of a plurality of photocells, selectively activating said photocells in accordance with the position of said mirror to maintain each photocell active while the amplitudes of the oscillations remain within a predetermined range, aud causing by said activation direct currents of predetermined values to flow through said actuating coil and to cause the central position of said member to selectively assume predetermined distances from the film and to retain each position while the amplitudes are within a predetermined range.

7. In a device for recording oscillations on a carrier, in combination a recording member, a direct-current circuit to control the distance between the central position of said member and the carrier, and photo-electric means to produce in said circuit direct currents of several values each corresponding to a predetermined range of amplitudes of the oscillations being recorded, said member being selectively placed into one of several predetermined positions by said direct currents and maintained in the selected position while the amplitudes are within a predetermined range.

8. In a device for recording oscillations on a carrier, a recording member, a light-valve governed by the amplitudes of the recorded oscillations and comprising a plurality of photocells selectively illuminated, a direct-current circuit, means including said light-valve to selectively produce in said circuit direct current of several predetermined values and to maintain said current at each value while the amplitudes remain within a predetermined range, and means to change the distance between the central position of said member and the carrier in accordance with the values of the direct current.

9. In a device for recording oscillations on a carrier, a recording member, a light-beam, and a photo-electrically active surface, means to selectively direct the light-beam on several predetermined portions of said surface and to maintain the light-beam directed upon each portion while the amplitudes of the oscillations to be recorded remain within a predetermined range, and means to stepwise alter the central position of the recording member in accordance with the extent of the selectively activated surface.

10. In a device for recording oscillations on a carrier, a recording member, a light-valve adjusted in accordance with the amplitudes of the recorded oscillations and comprising a plurality of photocells, means to selectively illuminate said photocells in accordance with predetermined ranges of the amplitudes, and a direct current circuit, means to produce in said circuit currents of definite values corresponding to the photocell illuminated, and means to vary the distance between the carrier and the central position of the recording member in accordance with the value of the direct current.

11. In a device for recording oscillations on a carrier, a recording member, a light-beam and a photo-electrically active surface, a stepwise recessed screen interposed between the light beam and the active surface, and means to alter the position of the screen with regard to the light-beam to expose to light one of several predetermined portions of said surface and to maintain each portion exposed while the amplitudes of the oscillations are within a predetermined range, a coil to actuate said recording member, and means to produce in said coil direct currents of definite values corresponding to the portions of the active surface exposed to light and to vary the distance between the carrier and the central position of the recording member in accordance with the value of said direct currents.

12. In a sound recording apparatus, a device to alter the central position of the recording member with respect to a carrier, said device comprising an actuating coil for the recording member, a direct current circuit for said coil, and means to change between several predetermined values the direct current flowing through said coil, each of said values corresponding to a predetermined range of the amplitudes to be recorded.

13. In a device for recording optically-reproducible oscillations on a carrier in combination, a rectifier for rectifying a portion of the oscillation current, a mirror galvanometer actuated by the rectified current produced by said rectifier, a light source directing a light beam upon the mirror of said galvanometer, a plurality of photocells selectively illuminated by the light reflected by said mirror, each photo-cell being illuminated while the amplitudes of the oscilllations are within a predetermined range, an electric circuit for each photocell, recording means including a recording member and a coil connected to all of said circuits, illumination of either of said photocells causing the flow of a predetermined current through said coil and the placement of the recording member in a predetermined central position, and coupling means between said cir-

cuits to prevent the simultaneous flow of current in any two of said circuits.

14. In a device for recording optically-reproducible oscillations on a carrier in combination, a rectifier for rectifying a portion of the oscillation currents, a mirror galvanometer actuated by the rectified current produced by said rectifier, a plurality of photocells each having a cathode, a light source directing upon the mirror of said galvanometer a light beam reflected from said mirror toward said photocells to selectively illuminate same in accordance with the amplitudes being recorded, a circuit for each photocell including a gas-filled discharge tube having an anode and a grid connected to the cathode of the corresponding photocell, an ohmic resistance connected in series with each photo-cell, means to apply a constant potential across the series connection of photocell and resistance, condensers connected between the anodes of said discharge tube, and a recording device comprising a recording member and an actuating coil therefor, said coil being connected to said circuits, the distance between the carrier and the central position of said recording member assuming one of several predetermined values and remaining at each value while the amplitudes of the oscillations are within a predetermined range.

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