Dec. 26, 1933. C. R. HANNA 1,940,858

SOUND RECORDING AND SOUND REPRODUCING SYSTEM

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Fig. 1.

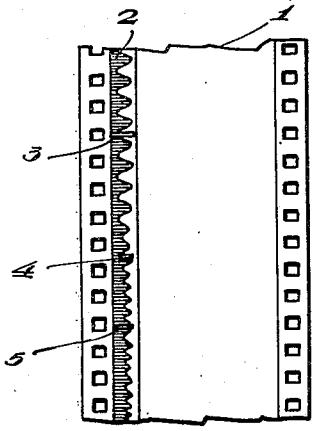


Fig. 2.

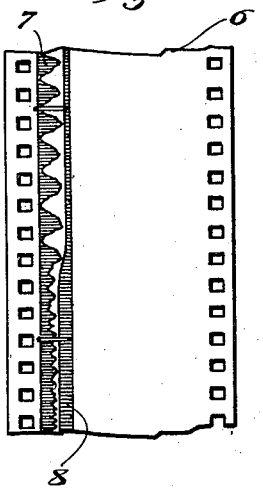


Fig. 3.

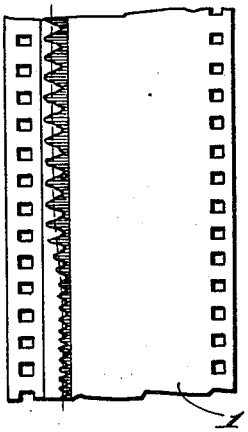


Fig. 4.

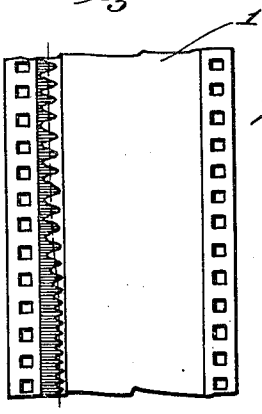


Fig. 5.

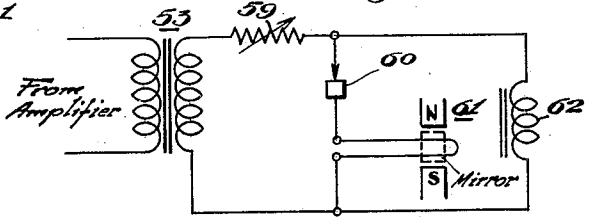


Fig. 6.

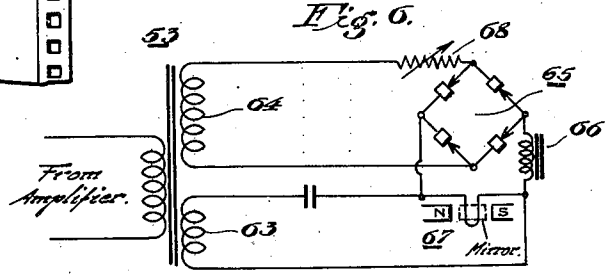
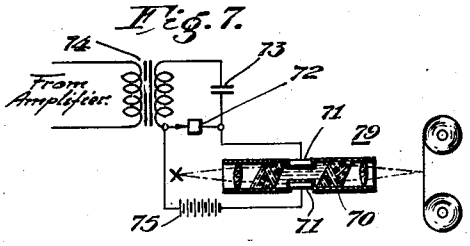


Fig. 7.



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SOUND RECORDING AND SOUND REPRODUCING SYSTEM

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Fig. 8.

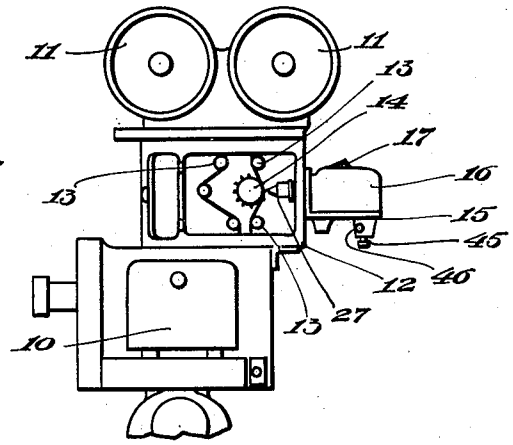
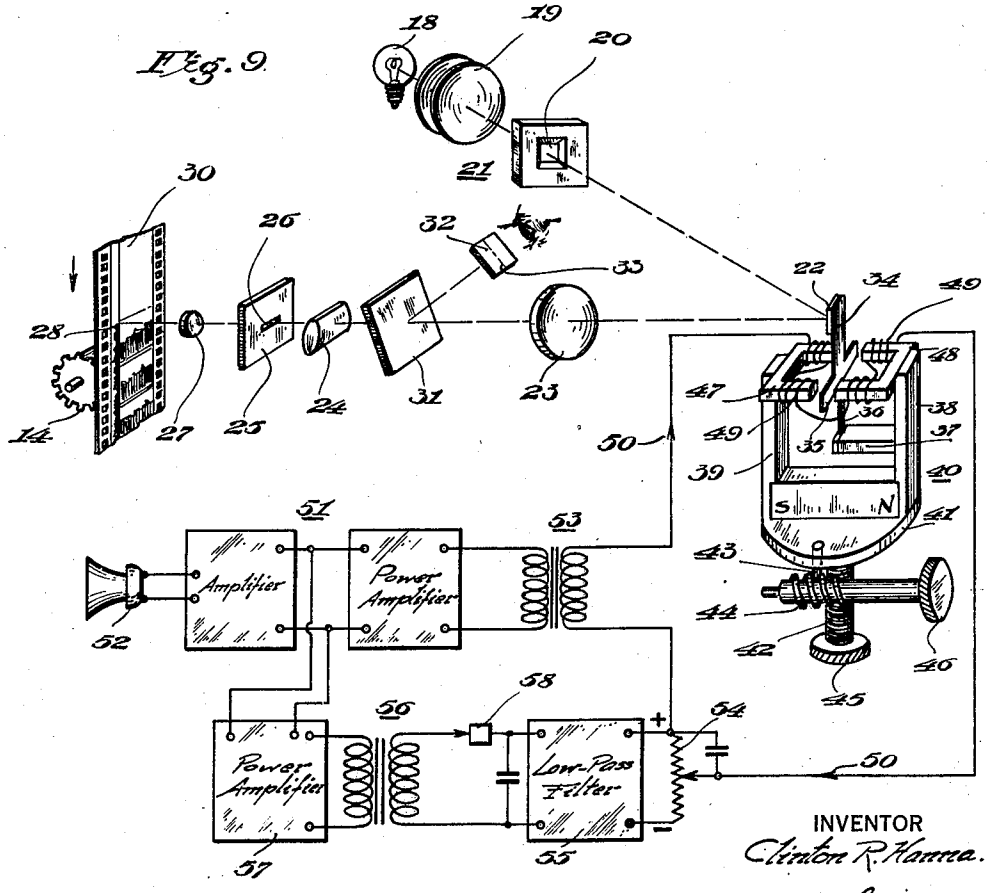


Fig. 9.



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UNITED STATES PATENT OFFICE

1,940,858

SOUND RECORDING AND SOUND REPRODUCING SYSTEM

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Application July 25, 1929. Serial No. 380,841

7 Claims. (Cl. 179—100.3)

My invention relates to sound-recording and sound-reproducing systems and it has particular relation to systems wherein the sound-records are in the form of linear films.

Photographic sound-records, in the form of linear films may be divided into two general classes, in accordance with the methods used in their manufacture, i. e., variable-density records, such as are made through the agency of a glow-tube, a Kerr-cell, or the like, and variable-area records made by causing the film to be more or less exposed, transversely thereof, to light from a fixed source.

In my copending application, Serial No. 321,365, filed November 23, 1928, matured into Patent No. 1,888,724, Nov. 22, 1932, for an improvement in Sound recording and reproducing systems, I have disclosed an invention in which the undesirable effects of ground-tone are minified by automatically controlling the degree of amplification. In the present application I disclose means for obtaining similar results and other desirable results, as well, by automatically controlling certain other factors and leaving the amplification free to be independently controlled.

Although I have found my invention to be useful in the making of sound-records of both types, its application to a sound-recording system wherein the record is of the variable-area type has been chosen for purposes of illustration and explanation. Such a system, preferably, comprises a constant source of light, a lens for focusing the light upon a slotted diaphragm, or mask, an oscillatory mirror for causing an image of the slot to move transversely of the film in its travel, and a lens-system for reducing the size of the image upon the film. It is also customary to so orient the mirror that one end of the image of the slot falls upon the film midway of the space allotted to the sound-record, when no sounds are being recorded, whereby the crests and valleys of the record are substantially symmetrically disposed with respect to the median line of the said space and the average amount of exposed film is constant.

When a negative sound-record, of the type described, or a positive record printed therefrom is caused to move, longitudinally, between a fixed light source and a photoelectric cell, the dust, oil, and dirt adhering to the transparent portions thereof modulate the light sufficiently to give rise to a phenomenon known as "background noise" or "ground-tone". The texture of the film and the grain of the emulsion also contribute, somewhat, to the generation of ground-tone, although I have established, by experiment, that their effect is much less objectionable than the effect of dust and dirt.

The absolute intensity of the ground-tone is substantially constant throughout the length of any particular portion of film, since the average transparency thereof is relatively constant, but it is much more noticeable and unpleasant during periods when no sounds, or faint sounds, are being reproduced.

It is, accordingly, an object of my invention to provide a sound-recording system whereby a photographic sound-record may be made that is reproducible without an objectionable amount of ground-tone.

Another object of my invention is to provide a photographic sound-record that shall be capable of being reproduced, in substantially any well known device adapted to that purpose, without the presence of unpleasant ground-tone.

According to my invention, the aforesaid objects and other objects appurtenant thereto, are attained by so controlling the transparency of a sound record that the average amount of light from the exciting source that reaches the photo-electric cell, during the reproduction of sound from sections of the record representing weak modulation, is greatly reduced. I can obtain this result, during the reproduction of sounds from variable-area records of the usual type, by so automatically or manually controlling the width of the light-image, falling upon the film in its travel between the light-source and the photo-electric cell, that the said image is made shorter during periods of weak modulation and longer during periods of strong modulation.

I prefer, however, to automatically accomplish the necessary modification during the sound-recording process and, accordingly, I provide, in a recording system of the type hereinbefore described, means for normally maintaining the zero-position of the end of the image of the illuminated slot closely adjacent to one edge of the sound-track area during intervals when sounds are not being recorded, and additional means for shifting the said zero-position toward the median line of the sound-track area a distance proportional to the loudness of the sound.

The zero-shifting means, preferably, comprises a rectifier, upon which is impressed a portion of the sound currents delivered by an amplifier, and a biasing-coil associated with the electromagnetic actuating means for the armature that supports the oscillatory mirror, through which coil the rectified currents are caused to

flow. The actuating and biasing coils may be combined, if desirable, as will, hereinafter, be explained in detail.

In order that the shifting of the zero-position shall not interfere with the proper rendition of crescendo and diminuendo passages I have found it expedient to interpose a low-pass filter between the rectifier, that supplies the bias-current, and the bias-coil.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of certain specific embodiments, when read in connection with the accompanying drawings, in which:

Figs. 1 and 2 are views of sections of positive film, carrying photographic sound record, illustrating the application of my invention to the reproduction of sound from records of the types heretofore used.

Figs. 3 and 4 are view of sections of negative and positive film, respectively, made by sound-recording apparatus comprising a preferred embodiment of my invention.

Fig. 5 is a diagrammatic view of a circuit comprising a preferred embodiment of my invention.

Fig. 6 is a diagrammatic view of a circuit comprising a modification of my invention.

Fig. 7 is a diagrammatic view of a sound-recording system comprising a further modification of my invention.

Fig. 8 is a generalized view of a motion-picture camera equipped with a sound-recorder constructed according to my invention, and

Fig. 9 is a view, partly in schematic perspective and partly diagrammatic, illustrating certain essential elements of the sound-recorder, shown in Fig. 8, and the accompanying electrical apparatus.

As hereinbefore stated, the underlying principle of my invention may be utilized in the reproduction of sound, from photographic records of the variable-area type, by automatically or manually correlating the width of the light-beam, falling on the sound-track, to the amplitude of the crests and valleys of the blackened area thereof.

One method whereby the proper correlation may be secured, in the reproduction of sound from a record of the variable area type, is illustrated in Fig. 1, which is a view of a portion of a motion-picture film 1, or the like, provided with a photographic sound-record 2 adjacent to one edge thereof. During the reproduction of sounds of large amplitude the light-beam is permitted to extend over the full width of the sound-track, as indicated by a small rectangle 3, in order to include the crests and valleys of all of the waves. If the modulation of the recorded sound is less than full amplitude for a considerable period as, for example, when a violin solo is recorded in the middle of an orchestral piece, the length of the light-beam is caused to decrease, as indicated in Fig. 1 by a rectangle 4, or the illuminated area may be shortened at one end only, as indicated by the lower rectangle 5.

In either event, the shortening of the light-beam on the film during the reproduction of sounds of low amplitude reduces the average percentage of clear film through which light passes to fall upon the photoelectric cell (not shown), with a consequent reduction of the absolute amount of ground-tone produced.

I have not illustrated any means for accomplishing the reduction in length of the light-beam, by manual control, inasmuch as the type of means employed would depend, in large measure, upon the specific apparatus through which the film travels in the sound-reprodution process. In other words, in reproducers of certain types it would be possible to alter, by micrometric adjusting devices, the actual length of an illuminated slot, the image of which falls upon the film while other possible ways of manually controlling the length of the light-beam will be apparent to those skilled in the art and need not be enumerated.

The automatic control of the length of the light-beam may be accomplished by exposing the film, just previous to its passage past the light-source and the photoelectric cell utilized for the reproduction of the recorded sound, to an additional light source and cell, and by employing the output-current from the last-mentioned cell to actuate a magnetically-controlled device, such as a shutter or the like, so interposed in the path of the light-beam as to cause it to lengthen or shorten in a direction transverse to the travel of the film. As one example of the manner in which the length of the light-beam could be altered, attention is called to the patent to Bell et al., No. 341,213. In Fig. 9 of the said patent is shown a sound-responsive shutter for changing the length of a light-beam in recording. A similar shutter could be used in reproducing the sound record, to attain the results discussed in connection with Fig. 1 of this application, by arranging it to be controlled by the output of the second photoelectric cell mentioned above.

My invention may also be practiced, in the preparation of photographic sound records of the usual variable-width type, by so blackening the positive film by photographic, or other means, that the width of the transparent area is reduced in the portions where the modulation is weak. A section of a film, so prepared, is illustrated in Fig. 2, which shows a positive film 6 having a sound-record 7 adjacent to one edge thereof, and being further provided with a blackened area 8 that closely follows the crests of the waves and reduces the transparent area accompanying the record of the weaker sounds.

From a consideration of the foregoing it will be seen that the essential element of my invention resides in the provision of means for obtaining a diminution of the transparent area of the sound-record during the reproduction of sounds of low amplitude and, furthermore, that my invention is as equally well applicable to the making of the sound-record as to the reproduction of sound therefrom. The manual or automatic control of the light-beam during reproduction and the blackening of the positive described in connection with Fig. 2 are, however, not commercially desirable and, for that reason, I have devised the system illustrated in Figs. 8 and 9 for automatically controlling the average percentage of the transparent areas of the sound-record during the recording process.

The apparatus shown in Fig. 8 comprises a housing 10 wherein are disposed the usual mechanical elements constituting a motion-picture camera, a plurality of film-magazines 11, and a housing 12 interposed between the camera proper and the film-magazines. The housing 12 is provided with a plurality of rotatable film-guiding

rollers 13 and a toothed, positively driven roller 14 over which the film passes in its travel between the two magazines.

A plate 15 is affixed to the end of the housing 12 adjacent to the film-advancing roller 14 for the purpose of removably supporting the optical portions of the sound-recorder.

A cover 16 preferably encloses the apparatus mounted on the supporting plate, to protect it against dirt and moisture. The cover is provided with an observation opening 17.

The optical apparatus mounted on the plate 15, is illustrated in Fig. 9 and comprises a light source 18 and lens system 19, for concentrating the light upon an opening 20, in a masking device 21, an oscillatory mirror 22 on which an image of the illuminated opening falls, a plurality of lenses 23 and 24 for directing light from the mirror onto a second mask 25, having a narrow opening 26 therethrough, and an objective lens 27 for reducing the image of the opening in the last-mentioned masking device and concentrating it as a narrow line 28 upon a film 30 where it passes over the roller 14.

A small section of plain glass 31 is interposed between the lens 23 and the mask 25, adjacent to the film roller, and it is so angularly disposed with respect to the path of the reflected ray from the mirror that an image of the illuminated slot 20 is cast upon a ground-glass screen 32 for observation purposes. The screen is provided with a fiduciary mark 33 corresponding to the inner border of the area on the film allotted to the sound-record.

The optical system is preferably so adjusted that an image of one edge of the opening 20 in the mask nearest the light source is thrown upon the film, the chosen edge being indicated by cross hatching on the drawing.

The oscillatory mirror 22 is mounted upon an extension 34 of a cross-shape magnetic armature 35, the lower end 36 of which is affixed to a non-magnetic element 37 which extends inwardly between the poles 38 and 39 of a permanent magnet structure 40. The permanent magnet is, preferably, mounted upon a table 41 that is pivoted to the upper end of an adjusting screw 42 in order that the mirror may be adjusted vertically. Angular movement of the mirror is permitted by the pivotal connection of the table with the screw 42, a small depending abutment 43 on the said table being operatively associated with a worm 44, whereby micrometric angular adjustments may be made.

The screw 42 is provided with a knurled knob 45 and the worm 44 is provided with a similar knob 46, both knobs being disposed within easy reach of the operator of the camera.

The magnetic structure is provided with a plurality of U-shaped pole-pieces 47 and 48. The pole pieces project toward each other to define two air-gaps in which are disposed the cross bars of the armature. The pole pieces are, further, provided with a plurality of windings 49 adapted to carry sound-currents, the direction of the windings being so chosen that, if direct current is caused to pass therethrough in the direction of the arrows 50, the mirror will turn in a counterclockwise direction, as viewed from above, through an angle proportional to the current.

The oscillatory mirror and the associated magnetic means for causing it to move in response to sound-currents will, hereinafter, be designated as a "galvanometer" or an "oscillograph".

The windings 49 are energized from an amplifier system 51 associated with a microphone 52, the energizing circuit including the secondary winding of an output transformer 53 and a variable resistor 54.

The resistor 54 is also included in the output circuit of a low-pass filter 55. The input-circuit of the low pass filter includes the secondary winding of a transformer 56 associated with a power-amplifier 57, that is also energized from the microphone 52, and a rectifying device 58.

In the operation of the recording system illustrated, the sound-currents cause the armature supporting the mirror to oscillate about its vertical axis, thus causing the end of the image of the illuminated slot 20 to move from side to side, transversely of the film, during its passage over the roller 14. The normal, or zero position for the end of the light beam corresponding to the darkened edge of the slot nearest the light source is closely adjacent to the inner margin of the sound-track area. This position can be easily fixed by manipulation of the adjusting knob 46.

When sounds of low amplitude are being recorded, the end of the light-beam moves from side to side transversely of the film about a zero-line which is spaced only a sufficient amount from the edge of the sound-track area to permit the recording of the crests and valleys of the waves.

As the amplitude of the sound increases, the potentials impressed across the rectifier 58 rise and an increasing amount of direct current flows in the windings 49 by reason of their connection, in series, with the output resistor 54 associated with the low-pass filter 55.

As the sound increases in loudness the potential impressed across the rectifier 58 rises, proportionally thereto, and an increasing amount of direct current flows in the windings by reason of their connection, in series, with the output resistor 54 associated with the low-pass filter 55. The increased direct current, or biasing current, as it will, hereinafter, be styled, biases the armature in a counter-clockwise direction and causes the reflected beam of light, thereupon, to oscillate about a zero-line on the film that is shifted toward the center of the sound-track area an amount approximately equal to the amplitude of its swing corresponding to the louder sound.

By properly proportioning the windings 49, the magnitude of the resistance included in circuit with the windings, the constants of the low-pass filter 55. etc., the amount by which the end of the light-beam is shifted toward the center of the sound-record area on the film is so controlled that, at all times, irrespective of the amplitude of the oscillation of the light-beam on the film, the valleys of the waves remain substantially equidistant from the inner margin of the said area.

A portion of a negative sound-record made by my improved system is illustrated in Figure 3, the shifting of the zero-position of the light-beam being indicated therein by a dotted line.

A positive sound record, corresponding to the negative record illustrated in Figure 3, is shown in Figure 4, wherein it will be noted that the percentage of translucent film accompanying a record of faint sounds is much less than the percentage accompanying the record of louder sounds.

I have also found it expedient to dispense with the separate power amplifier illustrated in Fig. 9 and to include a rectifying device directly in

series with the winding which actuates the armature in response to sound frequencies.

A sound recording system of such modified type is illustrated in Fig. 5 and preferably comprises a resistor 59, a rectifying device 60 and an oscillograph element 61, connected directly in series with the secondary winding of the output transformer 53. A choke-coil 62 is connected in shunt to the rectifying device and the galvanometer and is so proportioned that, when potentials representative of the sounds to be recorded are impressed across the network including it, the rectifying device and the conductors constituting the oscillograph, a circulatory current is set up, which current has an amplitude approximately equivalent to the crest amplitude of the said sound currents.

As is apparent from the arrangement of the circuit, after the transient period, a substantially constant current is maintained by the inductance 62 in a counter-clockwise direction around the network comprising the inductance, the rectifier 60 and the coil of the galvanometer 61. In detail, the action of the system may be related as follows:

For purposes of simplicity, it is assumed that the first pulse of current is in a clockwise direction in the network comprising the secondary of the transformer 53, the resistance 59, the rectifier 60, and the coil of the galvanometer 61. Since the rectifier and the galvanometer coil may be regarded as substantially short-circuiting the coil 62, the pulse of current will flow in the network including the rectifier, and little current will flow in the network including the coil 62.

The pulse in the reverse direction (i. e., in the counter-clockwise direction), however, flows principally in the coil 62 and tends to maintain itself by reason of the high inductance of the coil. The result is that a direct current substantially equivalent in magnitude to the peak current of the waves introduced into the transformer is set up in the network of the rectifier 60, the galvanometer coil, and the inductor 62. The pulsations introduced by the sound into the transformer are now superimposed on the direct current, and the total current is in such a direction as to pass through the rectifier and produce vibrations in the movable element of the galvanometer.

It is, furthermore, to be noted that the time constant of the circuit including the coil 62 is determined by the ratio of the inductance of the coil 62 to the resistance in the circuit, that is to say, to the resistance of the galvanometer coil. By making the inductance sufficiently great, relative to the resistance, the ripples in the direct current set up in the circuit may be substantially eliminated. I have found that it is possible to so regulate the time constant that comparatively low frequencies may be recorded with considerable fidelity. The time constant, of course, also dominates the dissipation of the current maintained by the inductor 62 and, consequently, controls the rate of drop in the biasing current.

Moreover, the resistor 59 not only takes care of the non-linearity characteristic of the rectifier but may also be utilized to regulate the time constant of the network including the inductance 62 and the secondary of the transformer 53. That is to say, the ratio of inductance of the coil 62 to the resistance of the element 59 determines how quickly or how slowly the direct-current bias impressed on the coil of the galvanometer rises to its peak value. I have found that a certain compromise must be reached in this connection for, if the rise is rapid, an undesirable sound is introduced in the reproduction of the record when the shift occurs, and, on the other hand, if the rise is slow, the peaks of the waves are cut off.

As has been explained hereinabove, the impedances and the resistances of the circuit illustrated in Fig. 5 are so arranged that the pulsations of the direct-current bias and, in addition, the fall of the bias values are regulated independently of the rise of the bias values. It is to be noted that a similar effect is attained in the circuit illustrated in Fig. 6 by the coaction of the coil 66 with the resistor 68.

The resistor 59, that is included in the circuit over which potentials are impressed on the rectifying device, and is given such a magnitude that the non-linear characteristic of the said rectifier does not appreciably alter the wave-form of the sound-currents which flow through the oscillograph element simultaneously with the direct current.

Although not so shown in Fig. 5, the relation of the mirror, comprised in the oscillograph, to the optical system is so chosen that the direct current biases it, with respect to a film, in the same direction as the mirror is biased in the apparatus illustrated in Fig. 9. The modified system, therefore, functions, in every essential respect, the same as the recording system hereinbefore described in detail.

A further modification of the recording system, illustrated in Fig. 6, comprises an output transformer 53 having a plurality of secondary windings 63 and 64. The terminals of the windings 64 are connected to the input terminals of a rectifier bridge 65, the output terminals of which are connected in series with a choke coil 66 and a galvanometer element 67. The purpose of the winding 64 and the rectifier bridge is to supply biasing current to the galvanometer, the constants of the choke coil 66 being so chosen as to maintain substantial continuity of direct current between cycles of the currents representative of sounds at low frequencies, this coil being equivalent to the coil 62 in Fig. 5.

A resistor 68 is included in circuit between the secondary winding 64 and the rectifier bridge, this resistor being chosen large enough to prevent the curvature of the rectifier volt-ampere characteristics from introducing a harmonic voltage which would appear in the winding 63. The resistor has the further function of determining the rate of current rise in the inductor 66, and is equivalent to the resistor 59 in Fig. 5.

Although not self-evident from the above description of a sound-recording system adapted to make records of the variable-area type, my invention is equally well applicable to variable-density recording by current-responsive light-valves. In such event the galvanometers shown in the various figures of the drawings may be replaced by suitable current-actuated light-valves analogous to the valve shown in the patent to Wente, 1,638,555, and the direction of the biasing current is so chosen that, during recording, the average amount of light permitted to pass through the light valve, is small during periods when faint sounds are recorded and large during the recording of loud sounds. On printing, the average density, or capacity, of the positive will, accordingly, be greater for those portions of the record corresponding to faint sounds than the portions cor-

responding to loud sounds, with consequent small average transmission of light to the photo-cell during the reproduction of the said faint sounds. Dirt particles on the film will, therefore, have a lessened effect in producing ground-tone during the reproduction of faint sounds from my improved positive than from positives of the usual variable-density type.

It can be demonstrated that the hereinbefore described recording process in no way weakens the reproduction of the faint sounds themselves since the absolute magnitude of the variable component of the light is not reduced, either in the recording or the reproduction of the said sounds.

My invention is also applicable to the making of variable-density sound records by light-valves of the potential-responsive type, such as Kerr-cells. Attention is called to the patent to Hartley No. 1,565,566, the British patent to Karolus, No. 235,857, and the patent to Kruh, No. 968,484, as illustrative of various types of light-valves that may be so utilized in the production of photographic sound-records of the variable-density type.

Referring specifically to Figure 7 of the drawings, a variable-density sound-recording system comprising my invention may be constituted by a Kerr-cell 70, such as the cell 1 of the British patent, together with means for impressing sound-potentials across the electrodes 71 thereof and means for also impressing a direct-current biasing potential, derived from the sound-potentials, across the said electrodes. The bias-potential deriving-means, preferably, comprises a rectifier 72 and a condenser 73 connected in series with the secondary winding of a transformer 74 energized from an audio-frequency amplifier (not shown), the electrodes of the Kerr-cell being connected in shunt to the rectifier.

The presence of the rectifier and the condenser do not interfere with the application of alternating sound-current potentials to the Kerr-cell simultaneously with the application thereto of the biasing potential.

In the operation of a sound-recording system such as is indicated in Figure 7, a potential source 75 is utilized to so initially bias the Kerr cell that it operates at the lower end of the straight portion of its characteristic curve. The Kerr cell shown is so adjusted that, when zero potential is applied across the electrodes, no light passes. In the actual operation of the device, however, sufficient bias is applied to the electodes, from the source 75, to permit a small amount of light to pass, this bias being necessarily chosen such that the cell operates at the beginning of the straight portion of its characteristic curve. When potentials representative of sounds appear across the secondary of the transformer 74 they also appear across the electrodes of the Kerr-cell and an additional steady potential, representative of the crest potential at the secondary, is applied to the Kerr-cell electrodes through the action of the rectifier 72 and the condenser 73. The steady potential is in such direction as to add to the bias from the source 75, thus permitting the average amount of light passing through the Kerr cell to increase with increase in the loudness of the sounds. The size of the condenser is so chosen, with respect to the backward resistance of the rectifier 72 that the steady potential is substantially maintained between successive cycles of potentials representing sounds at low frequencies.

It will be seen, from a consideration of the above, that the average amount of light passed by the Kerr cell is maintained proportional to the loudness of the sounds, and that substantially 100% modulation of this average is approached. A positive record, therefore, when printed from a negative produced by my improved recording process, has greater average density in those portions corresponding to faint sounds than in the portions corresponding to loud sounds, with a consequent reduction of ground-tone during the process of reproducing the sounds therefrom.

It will be apparent, from consideration of the foregoing description, that I have, by my invention, very materially advanced the art of making sound-records by photographic processes and that I have, further, provided an important improvement in the process of reproducing sounds from photographic records of the usual types. By eliminating ground-tone, or back-ground noise, from the sounds accompanying the projection of "talking motion pictures" the naturalness of the performance is greatly enhanced.

In addition, the useful life of films will be lengthened because accumulation of dirt will not increase ground noise to the objectionable point as soon as with ordinary records.

Other advantages of my invention will be apparent to those skilled in the art to which it pertains, as well as many modifications of the means whereby the invention may be practiced. My invention, therefore, is not to be limited except insofar as is necessitated by the prior art or by the spirit of the appended claims.

I claim as my invention:

1. In a recording system of the type including a recording medium, means for impressing a record of a physical disturbance on said medium, and means for shifting the zero boundary of said record in accordance with the amplitude of the impressed disturbance, additional means for regulating the rate of rise of said shift substantially independent of the rate of fall of said shift.

2. In combination with a source of variable alternating current, a galvanometer winding and a rectifier serially connected to said source and an inductance connected in shunt to said galvanometer winding and said rectifier whereby the current transmitted through said galvanometer winding is substantially composed of a direct current component proportional to the peak values of said variable current and an alternating current component substantially proportional to the instantaneous values of said variable current.

3. In combination with a source of variable alternating current, a galvanometer winding and a rectifier serially connected to said source and an inductance connected in shunt to said galvanometer winding and said rectifier, said rectifier being of a type having a counter-electromotive force substantially proportional to the current flowing therethrough whereby the current transmitted through said winding is substantially composed of a direct current component proportional to the peak values of said variable current and an alternating current component substantially proportional to the instantaneous values of said variable current.

4. In combination with a source of variable alternating current, a resistor, a galvanometer winding and a rectifier serially connected to said source and an inductance connected in shunt to said galvanometer winding and said rectifier, said rectifier being of a type having a counter-electromotive force substantially proportional to the current flowing therethrough whereby the cur-

rent transmitted through said winding is substantially composed of a direct current component proportional to the peak values of said variable current and an alternating current component substantially proportional to the instantaneous values of said variable current.

5. In combination with a source of modulated alternating current, a transformer having a primary in series therewith, an indicating instrument, a rectifier of the type having an inverse voltage substantially proportional to the current traversing it, and a variable resistor serially connected with the secondary of said transformer, an inductance shunting said instrument and said rectifier, whereby the current transmitted through said instrument is substantially composed of a direct current component proportional to the peak values of said modulated alternating current and an alternating current component substantially proportional to the instantaneous values of said modulated alternating current and means to produce on a light-sensitive film a light area having a dimension transverse to said film, and measured from a straight longitudinal line thereon, which is proportional to the indication of said instrument.

6. Apparatus for recording a physical disturbance on a radiant-energy-responsive record of the type incorporating means for producing a beam of radiant energy to be projected on said record and voltage responsive means for modifying said beam before it is projected on said record comprising: means for producing a potential microscopically proportional to the magnitude of said disturbance, means for impressing said potential across a rectifier and a capacitor connected in series and means for coupling said voltage-responsive means in parallel with said rectifier whereby the potential impressed across said voltage-responsive means is substantially composed of a direct current component substantially proportional to the peak values of said microscopically-responsive potential and an alternating current component substantially proportional to the instantaneous values of said microscopically responsive potential.

7. Apparatus for recording a physical disturbance on a radiant-energy-responsive record of the type incorporating means for producing a beam of radiant energy to be projected on said record and current-responsive means for modifying said beam before it is projected on said record comprising: means for producing a potential microscopically proportional to the magnitude of said disturbance and means for impressing said potential across a network comprising a rectifier and said current-responsive means connected in one arm thereof and an inductor connected in another arm thereof, said last-named arm being connected in parallel to said first-named arm whereby the current transmitted through said current-responsive means is substantially composed of a direct current component proportional to the peak values of said microscopically-proportional potential and an alternating current component substantially proportional to the instantaneous values of said microscopically-proportional potential.

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