July 21, 1936. O. M. GLUNT 2,048,500

SOUND RECORDING

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FIG. 1

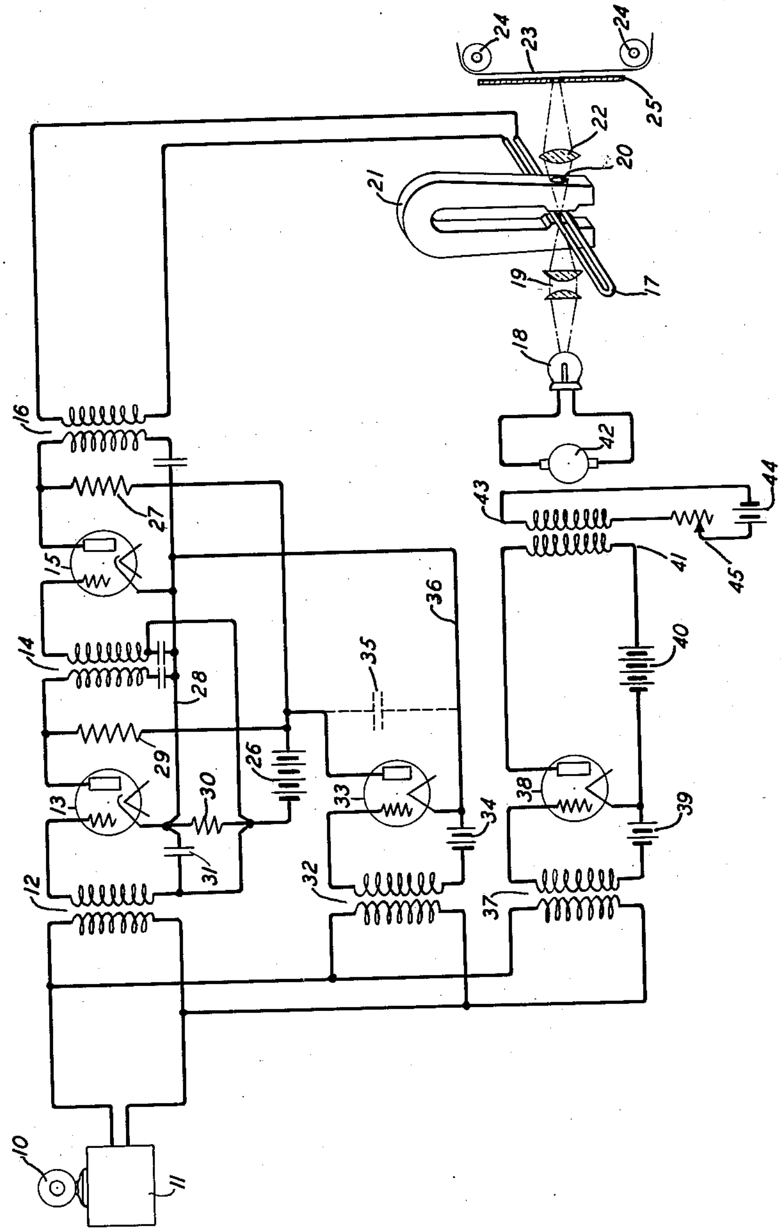

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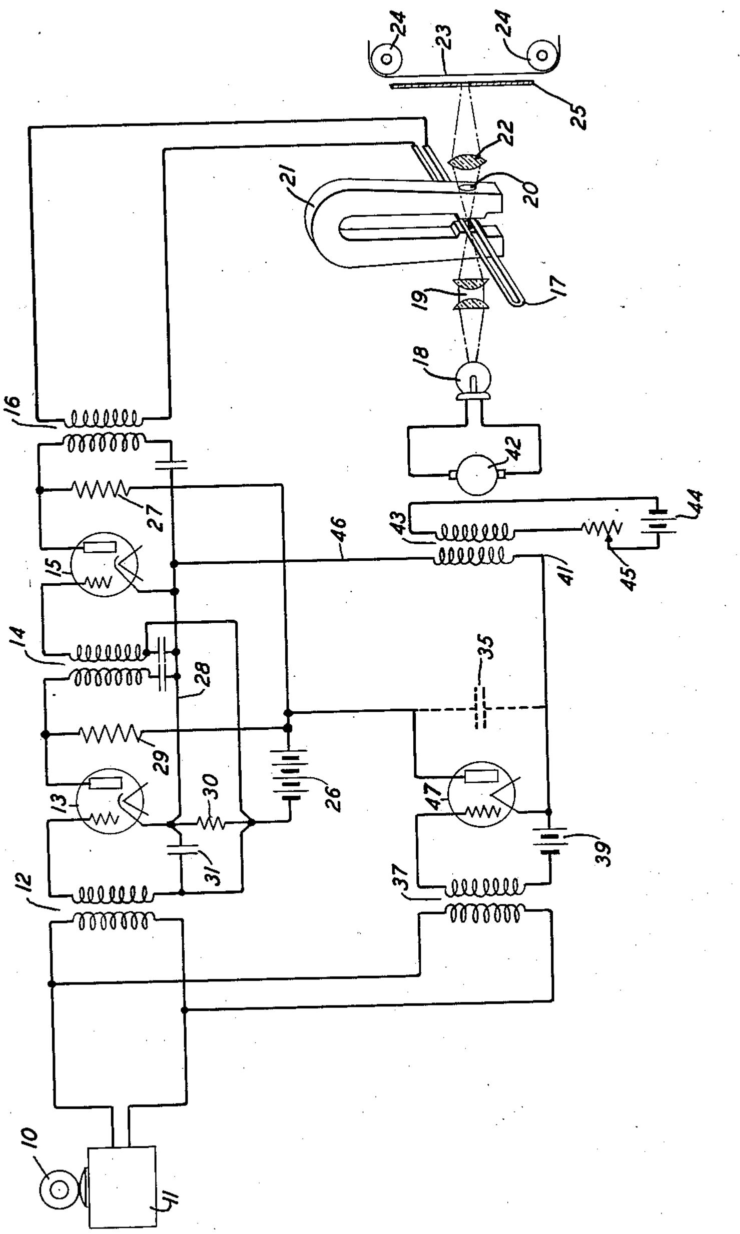
FIG. 2



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Patented July 21, 1936 **2,048,500**

UNITED STATES PATENT OFFICE

2,048,500

SOUND RECORDING

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Application October 1, 1930, Serial No. 485,585
In Great Britain September 4, 1930

3 Claims. (Cl. 179—100.3)

This invention relates to sound recording and particularly to a method of recording by photographic means a wider range of sound volumes than can be recorded by known methods.

The object of this invention is to reduce the volume of noise produced from a photographic sound record during the reproduction of the sound from the record. A reduction in the volume of noise produced from the record will permit smaller volumes of sound to be satisfactorily distinguished from the noise thus increasing the range of volumes of sound which may be recorded. Or, if the increased range is not utilized, the invention will provide a larger ratio between the present minimum volume of sound and the volume of noise produced during the reproduction of the sound and will thus produce a more pleasing result.

A feature of the invention is a method of recording sound by photographic means in which for a given frequency the time of exposure of the negative sound record is constant, but the intensity of the recording light varies directly with the envelope of the volume variations of the sound recorded and the light incident on the film is modulated to a constant degree for all volumes of sound.

Another feature of the invention is a method of producing a negative photographic sound record in which the average opacity of the sound record varies directly with the envelope of the volume variations of the sound and the average opacity for any given volume is modulated to a constant degree.

A further feature of the invention is a device responsive to sound modulated currents which varies the amplification of the recording amplifier inversely in accordance with the envelope of the amplitude variations of the sound modulated currents thus maintaining the output power of the amplifier substantially constant.

In any known method of recording sound the range of volumes of sound which may be recorded satisfactorily will be limited by the properties of the recording medium used and the handling which the completed record receives. The least volume of sound which is of interest in recording is the volume of sound which in reproduction may be satisfactorily distinguished above the noise produced by irregularities in the structure of the mediums used in recording and reproducing and the dirt, scratches, etc. which collect on the record during its useful life. Recent experiments have shown that the volume of noise produced during the reproduction of a film sound record is approximately proportional to the average transmission of the positive sound record. The average transmission of the sound record may be considered to be equal to the transmission of the unmodulated portions of the sound record. The transmission of a photographic medium is defined as the ratio of the light transmitted through the medium divided by the light incident on the medium and for convenience is commonly expressed as a percentage of the incident light. The opacity of the medium is defined as the reciprocal of the transmission.

If the transmission of the positive sound record is at all times as small as possible the noise will then be a minimum. It may be shown, however, that the volume of the reproduced sound is proportional to the product of the average transmission of the positive sound record multiplied by the percentage modulation of this average transmission due to the record of the sound. Thus, in order to avoid distortion of the volume of sound if the average transmission of the positive sound record is reduced the percentage modulation of this transmission must be inversely increased. Obviously if the percentage modulation is at all times as large as possible and the volume of sound is not distorted the average transmission and the noise will be a minimum. For convenience of description the percentage modulation has been assumed to be maintained as nearly 100% as may be practical though any other percentage may be used if desired.

As a photographic positive is an inverse copy of the photographic negative from which the positive was printed, in order for the positive to have a small transmission, the negative must have a large transmission or a small opacity. It is well known that the opacity of a photographic negative is directly proportional to the exposure when the exposure lies within certain limits, and that the exposure is proportional to the product of the intensity of the light incident on the negative multiplied by the time during which the negative is subjected to the light. Thus assuming that the photographic processes are controlled so that no distortion is produced, the transmission of the positive sound record will be proportional to the exposure of the negative sound record. Accordingly, to produce a positive sound record having a small average transmission the exposure of the negative sound record must be correspondingly small. In accordance with the invention the intensity of the recording light is reduced in accordance with the envelope of the volume of sound recorded to produce a negative sound record having a large average transmission or a small average opacity for small volumes of sound.

In the present systems of sound recording the gain of the amplifier supplying the recording device is usually adjusted so that the loudest sound to be recorded will produce substantially complete modulation of the recording light. The intensity of the recording light is then adjusted so that the exposure produced by the unmodulated light is in the center of the allowable range of exposures for the photographic emulsion used. After the sound is recorded and the negative sound record developed, positive prints are made from the negative sound record using a printing light having the intensity adjusted to produce an average transmission of about 40% for the positive sound record. In accordance with the present invention the gain of the amplifier supplying energy to the recording device is automatically varied in accordance with the envelope of the volume variations of the sound being recorded to produce a constant percentage of modulation of the light incident on the film for all volumes of sound recorded and the intensity of the recording light is varied inversely to the variation in the gain of the recording amplifier.

Consider three volumes of sound such that under the present method one volume produces 100% modulation of the light incident on the negative film, a second volume produces 10% modulation and a third volume produces 1% modulation, and that the undesired noise produced in reproduction is equal to the third volume of sound. Assume also that the printing light is adjusted so that the average transmission of the unmodulated sound track of the positive print is 40%. Let S=the light energy passing through the negative for any given volume of sound. Then the light energy passing through the positive will be 40% of this value, that is

$$S\times\frac{40}{100}$$

As the modulation of this energy is assumed to be 100%, that is

$$\frac{100}{100}$$

in the first case, the useful sound reproduced will be proportional to

$$S\times\frac{40}{100}\times\frac{100}{100}=\frac{4S}{10}$$

In the second case the modulation is only 10%, that is

$$\frac{10}{100}$$

thus the useful sound reproduced will be proportional to

$$S\times\frac{40}{100}\times\frac{10}{100}=\frac{4S}{100}$$

Similarly, in the third case the useful sound will be proportional to

$$S\times\frac{40}{100}\times\frac{1}{100}=\frac{4S}{1000}$$

and the noise produced in reproduction will also be proportional to

$$\frac{4S}{1000}$$

Thus the volume of the noise is equal to 1% of the volume of the loudest useful sound, 10% of the volume of the second sound and is equal to the volume of the faintest sound.

Now in accordance with this invention, let the gain of the recording amplifier be adjusted to produce substantially complete modulation of the recording light for all volumes of sound recorded and let the average intensity of the recording light be adjusted inversely to the adjustment of the gain of the amplifier. Assume also that the printing light is adjusted so that the average transmission of the unmodulated sound track of the loudest sound on the positive print is 40%. For the loudest sound the useful sound reproduced will now be proportional as before to

$$S\times\frac{40}{100}\times\frac{100}{100}=\frac{4S}{10}$$

In the second case the intensity of the recording light is reduced to

$$\frac{1}{10}$$

of its original value. Thus the light energy passing through the positive is now

$$S\times\frac{40}{100}\times\frac{1}{10}=S\times\frac{40}{1000}$$

while the modulation is 10 times its original value, that is

$$\frac{100}{100}$$

The useful sound reproduced will now be proportional to

$$S\times\frac{40}{1000}\times\frac{100}{100}=\frac{4S}{100}$$

In the third case, the intensity of the recording lamp is reduced to

$$\frac{1}{100}$$

of its original value and the modulation is increased to 100%, thus the useful sound reproduced is now proportional to

$$S\times\frac{40}{100}\times\frac{1}{100}\times\frac{1}{100}\times100=\frac{4S}{1000}$$

The light energy passing through the positive in the third case is the light energy effective in causing noise and this energy is now reduced to

$$S\times\frac{40}{100}\times\frac{1}{100}$$

The modulation due to the noise is unchanged, however, as it is due to the structure of the film thus the noise produced in reproduction is now proportional to

$$S\times\frac{40}{100}\times\frac{1}{100}\times\frac{1}{100}=\frac{4S}{100,000}$$

Thus the volume of the noise produced during reproduction is now reduced to 1% of the volume of the faintest sound; that is, the ratio between the faintest sound and the noise has been increased one hundredfold.

It will be appreciated that the numerical values used in the above explanation are illustrative only of the order of the advantage which may be secured by this invention and are not to be construed as limiting this invention in any way to the exact values of the quantities assumed.

In the drawings:

Fig. 1 represents in schematic form a film sound recording system embodying one form of the invention.

Fig. 2 represents in schematic form a film sound recording system embodying another form of the invention.

Sound waves are detected by a known type of microphone 10, and the resulting sound modulated currents may be amplified, if desired, in a suitable amplifier 11 known in the art. A part of the amplifier currents are applied through a transformer 12 to the input circuit of an amplifying device 13. The output of the device 13 is applied through a transformer 14 to the input circuit of a second amplifying device 15. The output of the device 15 is applied through a transformer 16 to the movable elements 17 of a light valve. It will be understood that more or less than two amplifying devices in cascade may be used, and that other known systems of coupling these devices may replace the transformer coupling shown.

For convenience of description, the light valve is shown as a modification of the light valve disclosed in U. S. Patent 1,638,555 August 9, 1927 to E. C. Wente. An image of the filament of a suitable lamp 18 is formed by the lens system 19 on the small slot defined by the movable elements 17 in the orifice 20 pierced in the pole pieces of a permanent magnet 21. Suitable pole faces concentrate the magnetic field of the magnet 21 to form a uniform magnetic field in which the movable elements 17 are immersed. The movable elements 17 are mechanically mounted and spaced to define a small light transmitting slot in the orifice 20. An electric current flowing in the movable elements 17 will cause the elements to be displaced by the reaction of the magnetic field due to the current and the uniform field due to the magnet 21 and thus to vary the height of the slot. An image of the slot is formed by an optical system 22 on a photographic film 23 moved in a known manner by the sprockets 24, 24 at uniform speed past the point of exposure. An aperture plate 25 holds the film smooth at the point of exposure and prevents diffused light from fogging the record formed on the film.

Plate current is supplied from a battery 26 through a coupling resistor 27 to the amplifying device 15, and flows through the device to wire 28. Plate current is similarly supplied from the battery 26 through resistor 29 to the device 13. The combined plate currents flow through resistor 30 back to the battery 26. A condenser 31 bridged across the resistor 30 prevents sound modulated voltages from being developed between the ends of the resistor 30. When no sound modulated currents are applied to the amplifier, the bias voltage applied to the control elements of the amplifying devices 13 and 15 is determined by the magnitude of the potential drop in the resistor 30 due to the combined plate currents.

Referring now more particularly to Fig. 1 a portion of the sound modulated current is applied through a transformer 32 to a detector 33, which may be a thermionic triode. A battery 34 impresses on the control electrode of the triode a potential of such magnitude that the output current of the triode varies with the envelope of the amplitude variations of the sound modulated currents. A condenser 35, shown in dotted lines in Figs. 1 and 2 may be used to aid the detector action of the triode. Current from the battery 26 passes through the triode 33, wires 36 and 28, and resistor 30 to the battery 26. A potential drop is developed across the resistor 30 by the pulsating current flowing through the detector 33, and this potential drop varies the bias applied to the grids of the amplifying devices 13 and 15.

It is well known that when the output of a detector energized by sound modulated currents varies the grid bias of an amplifier amplifying the same currents, by a suitable choice of the constants of the circuit, the gain of the amplifier may be caused to vary inversely with the envelope of the amplitude variations of the sound modulated currents and the output power of the amplifier maintained substantially constant for a wide range of amplitudes. The amplitude of vibration of the movable elements 17 will thus be approximately constant, and, by suitable design of the amplifier, the amplitude of vibration may be made of such magnitude as to produce substantially complete modulation of the light incident on the film 23 for all volumes of sound. The period of the vibration of the movable elements 17 however will vary with the frequency of the sound modulated currents. Thus the action of the light valve may be considered to be the production of a latent image in the emulsion of the film which is a pattern of the frequency variations of the sound reduced to a constant amplitude. While it may be true that this latent image possibly has no physical existence, it is believed that the use of this idea is justified by the aid it gives in obtaining a clear understanding of the processes involved.

A portion of the sound modulated current is applied through a transformer 37 to a detector 38, which may be a thermionic triode similar to detector 33. A battery 39 impresses on the control electrode of the triode a potential of such magnitude that the output current of the triode is a pulsating current varying with the amplitude of the sound modulated currents. Current flows from the battery 40 through the winding 41 to the output circuit of the detector 38 and through the detector 38 to the battery 40.

The filament of the lamp 18 is supplied with current from the armature 42 of a generator which is driven by a suitable motor, not shown. The generator is excited by a field winding 43 supplied with current from a battery 44 through a variable resistor 45. The current in the exciting field 43 may be adjusted so that, in the absence of sound modulated currents, the voltage generated by the armature is of such value that the current flowing in the filament of the lamp 18 is large enough to heat the filament but not large enough to cause the filament to emit light rays which will cause a record on the film 23. When sound modulated currents are applied to the detector 38, a current varying with the amplitude of the sound modulated currents flows in the regulating field winding 41 and increases the voltage generated by the armature 42. An increased current thus flows in the filament of the lamp 18 and causes the light emitted by the lamp to vary with the current flowing in the winding 41. Due to the electrical and magnetic inertia of the exchange of power and the thermal lag of the filament, the light will not vary with the instantaneous variations of the sound modulated currents, but rather with the envelope of the amplitude variations of the sound modulated currents.

The light emitted by the filament of the lamp 18 will thus be small for small volumes of sound and will vary directly with the envelope of the volume variations of the sound. Thus the action of the lamp 18 may be considered to be the production of a latent image in the emulsion of the film which varies with the envelope of the volume variations of the sound and which is superimposed on the latent image of the frequency variations to produce one composite image which is an undistorted record of the sound.

Considered from another viewpoint, the intensity of the recording light is varied directly with the envelope of the volume variations of the sound to be recorded. The average opacity of the impression in the medium will vary with the intensity of the light. The light incident on the film is simultaneously modulated by the light valve. The modulation of the light is substantially complete for all volumes of sound. The time of exposure of the film is varied by the light valve in accordance with the frequency pattern of the sound.

While a preferred form of control of the intensity of the recording light has been disclosed, it will be obvious to those skilled in the art that many modifications of this control may be made. For example, a lamp having a reasonably thin filament may be used and the filament kept warm by an auxiliary battery. The rectified sound modulated currents may then be applied directly to the filament or a suitable amplifier may be used to amplify the rectified currents to such value that the amplified currents will directly vary the intensity of the light.

In Fig 2 the circuit elements which have the same function and operate in the same manner as the corresponding elements in Fig. 1 have been correspondingly numbered. As the operation of these elements has been given in detail in the description of Fig. 1, only the elements in Fig. 2 which operate in a new manner need be described.

A portion of the sound modulated currents from the amplifier **11** is applied through the transformer **37** to the input circuit of a detector **47**. A battery **39** maintains the control electrode of the detector **47** at such a potential that the output current of the detector **47** is a pulsating current varying with the amplitude of the sound modulated currents. Current is supplied by the battery **26** to the output circuit of the detector **47**, and flows through the detector **47**, winding **41**, wire **46** wire **28**, resistor **30** to battery **26**. The rectified sound modulated currents flowing in the winding **41** will control the intensity of the lamp, and the same currents flowing in the resistor **30** will control the gain of the amplifier as described in detail under Fig. 1. The single detector **47** combines the functions of the two detectors **33** and **38** and the system shown in Fig. 2 will in general operate in the same manner as the system shown in Fig. 1. In some cases, practical advantages are gained by the use of separate detectors and control circuits. The filaments of the detectors **33**, **38** and **47** and the cathode heaters of the amplifiers **13** and **15** are supplied with suitable power in a manner well known in the art.

What is claimed is:

1. In a system for recording sound on a photographic medium, in combination, a source of light, a light valve having at least one movable element vibrating in the direction of motion of said medium and controlling the transmission of light from said source to the full effective width of said medium, a source of sound modulated currents vibrating said movable elements, means for controlling the power delivered to said elements by said source to maintain substantially constant the amplitude of vibration of said elements for all volumes of sound and a control circuit energized by sound modulated currents to vary the intensity of said source of light in accordance with the envelope of the sound modulated currents.

2. In a system for recording sound on a photographic medium, in combination, a source of sound modulated currents, an amplifier supplied with said currents, a source of light, a light valve having at least one movable element vibrated in the direction of motion of said medium by the output of said amplifier and controlling the transmission of light from said source to the full effective width of said medium, a device responsive to said sound modulated currents for regulating the gain of said amplifier to maintain substantially constant the amplitude of vibration of said elements for all volumes of sound and a control circuit energized by sound modulated currents to vary the intensity of said source of light in accordance with the envelope of said sound modulated currents.

3. In a system for recording sound on a photographic medium, in combination, a source of sound modulated currents, an amplifier supplied with said currents, a device responsive to said sound modulated currents for maintaining the output of said amplifier substantially constant, an electric lamp, a recording device energized by the output of said amplifier and producing substantially complete modulation of the light from said lamp incident on said medium, an electric generator supplying energy to said lamp and having a regulating winding, and a control circuit energizing said regulating winding in accordance with the envelope of said sound modulated currents.

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