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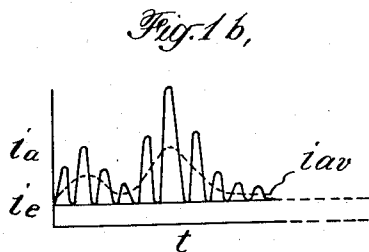
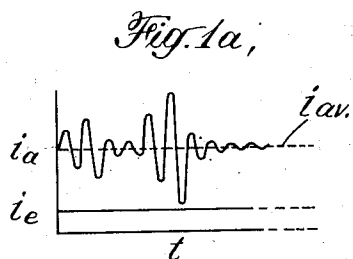
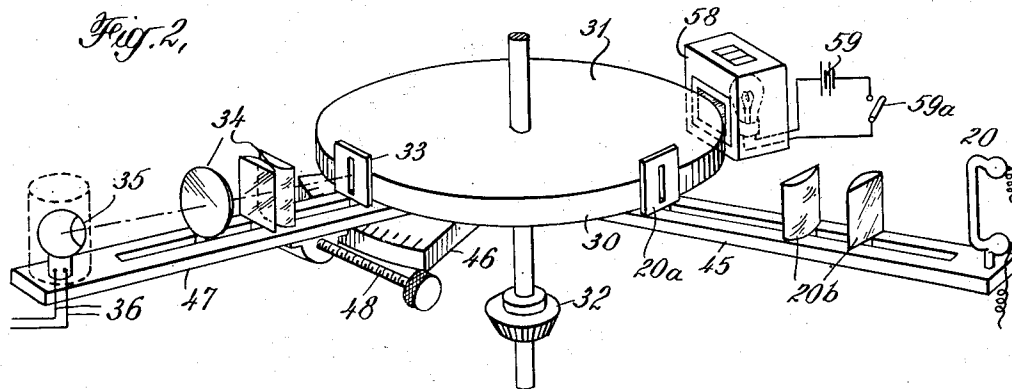
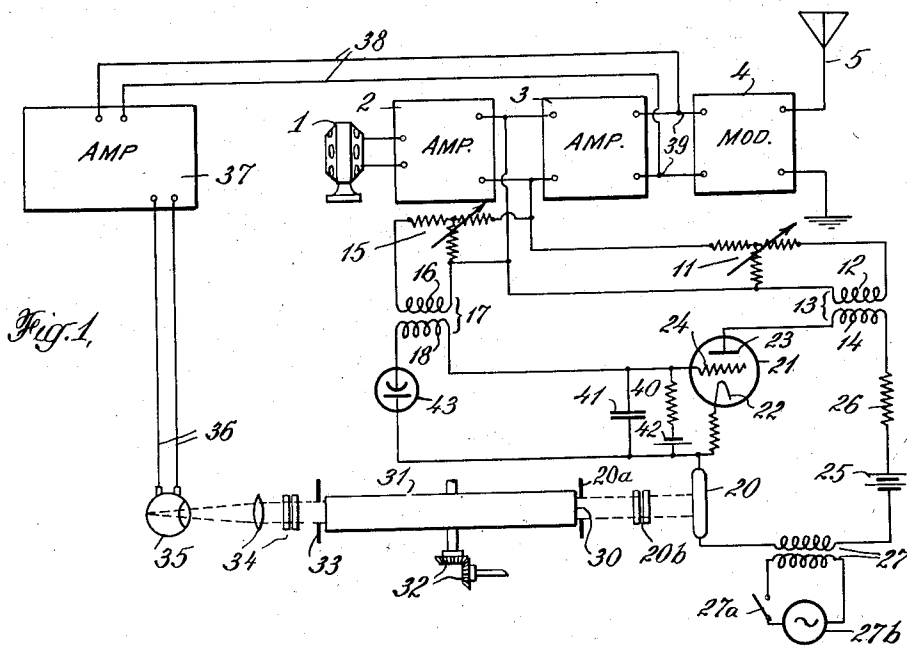
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2,203,353

METHOD AND APPARATUS FOR SIGNAL TRANSLATION

Filed June 30, 1938

5 Sheets-Sheet 1



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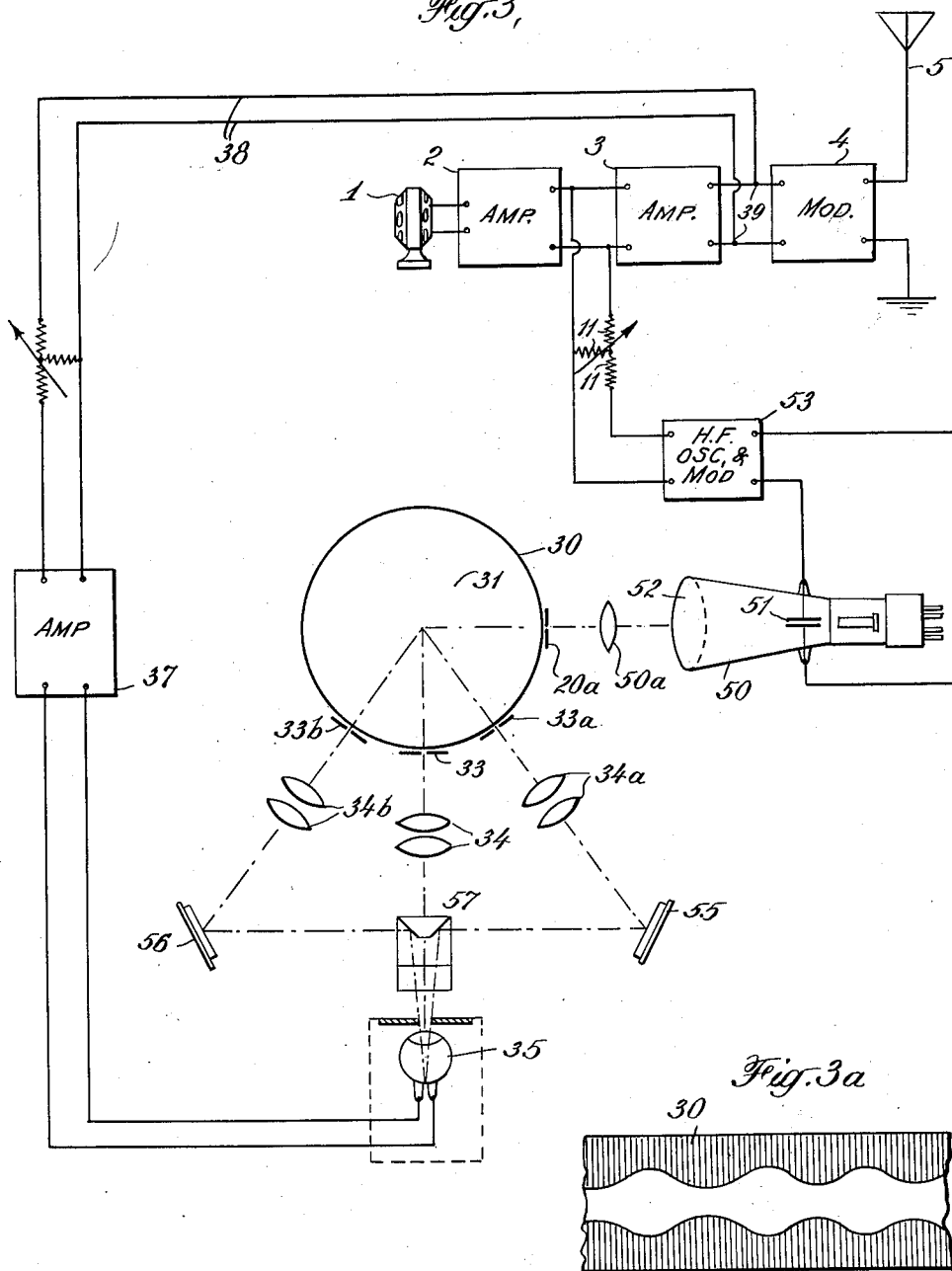
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METHOD AND APPARATUS FOR SIGNAL TRANSLATION

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5 Sheets-Sheet 2

Fig. 3,



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METHOD AND APPARATUS FOR SIGNAL TRANSLATION

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5 Sheets-Sheet 3

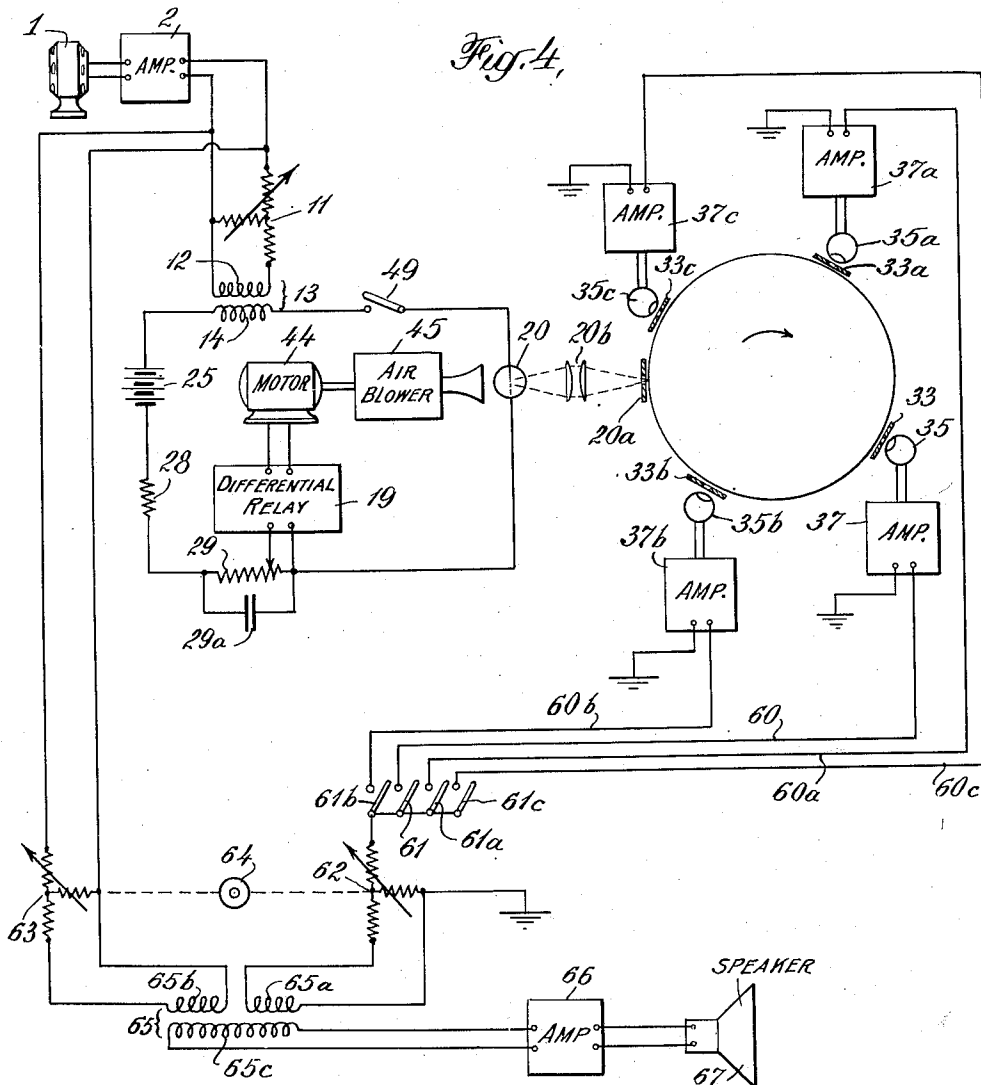
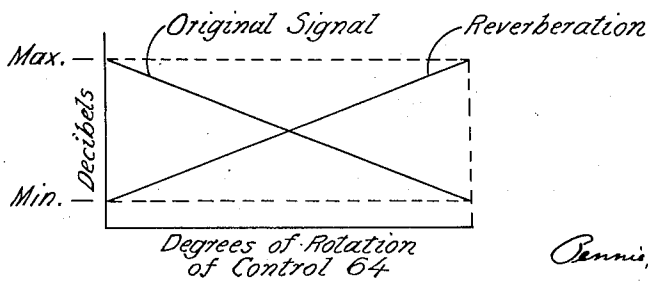


Fig. 4a,



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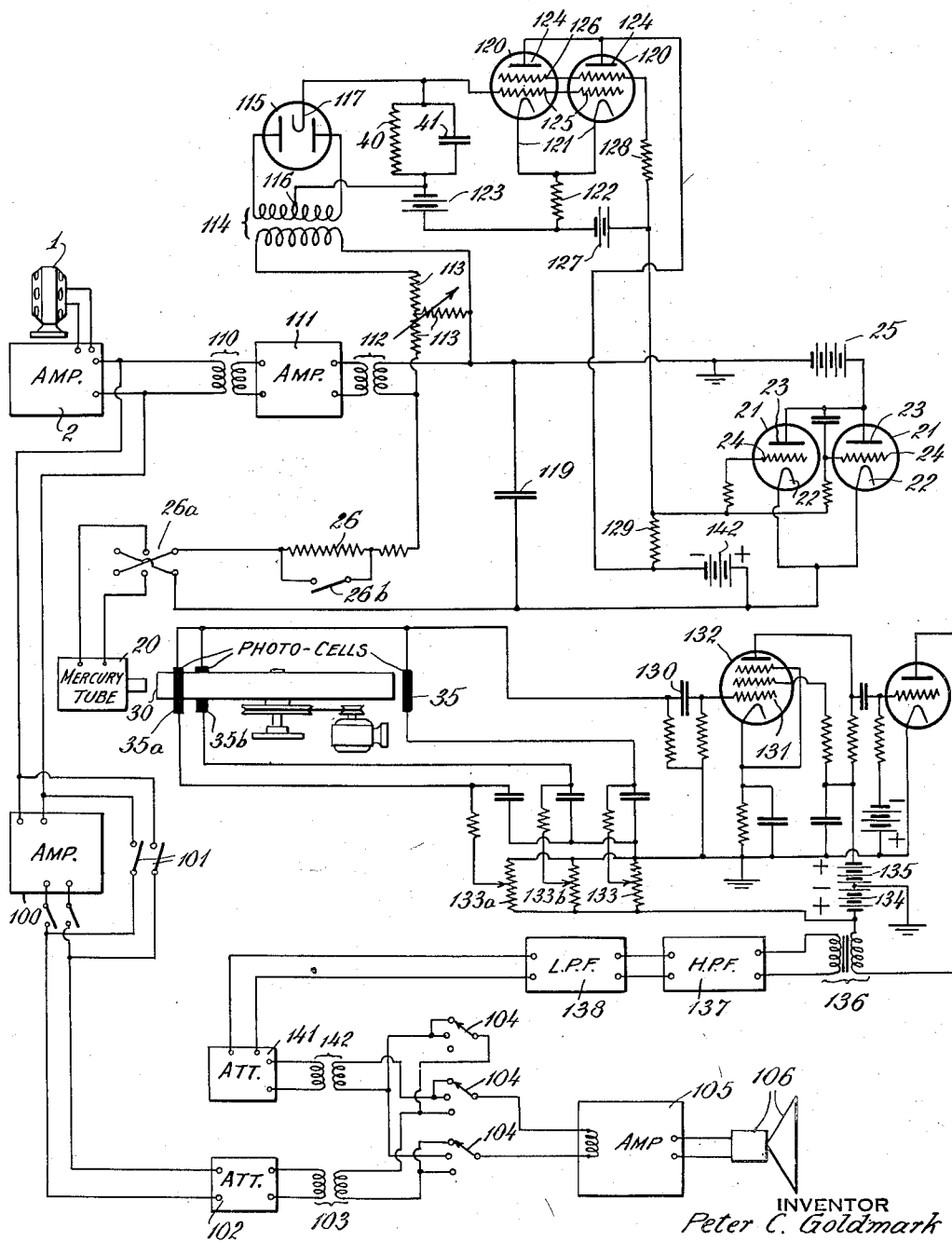
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METHOD AND APPARATUS FOR SIGNAL TRANSLATION

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Fig. 6,



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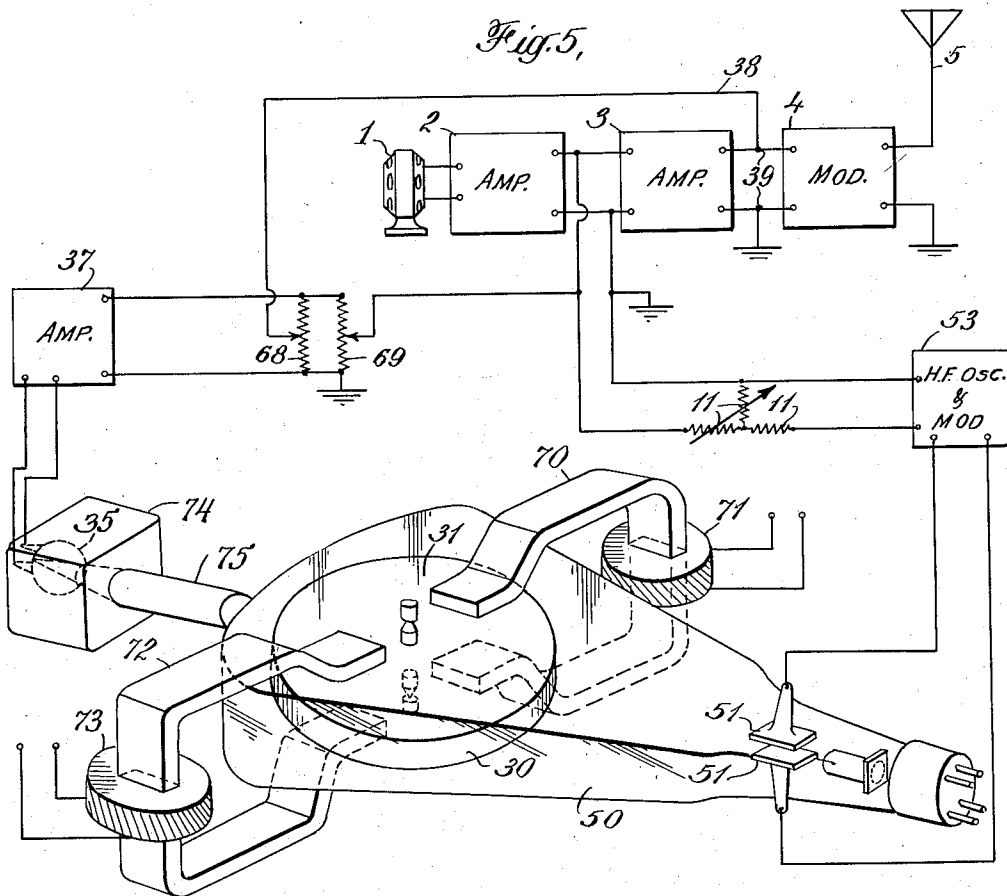
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METHOD AND APPARATUS FOR SIGNAL TRANSLATION

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Fig. 5,



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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR SIGNAL
TRANSLATION

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Application June 30, 1938, Serial No. 216,735

43 Claims. (Cl. 179-1)

This invention relates generally to a method and apparatus for signal translation which is particularly useful for modifying signal voltages and for adding thereto, after a time interval, secondary voltages modified or unmodified, derived from the original signal voltages.

It has for its principal objects the provision of an improved method and apparatus whereby from original signal voltages there may be derived secondary signal voltages which are delayed, attenuated, or otherwise modified to an extent which is controllable within wide limits. The secondary signal voltages may be utilized directly in lieu of the original signal voltages, or the secondary voltages may be electrically combined with the original signal voltages to produce a variety of desired effects.

Broadly speaking, the invention employs a fugitively image-retaining surface, for example, a phosphorescent surface, on which a transient image of a primary signal is recorded. Secondary signals are then derived from the transient image record by a suitable pickup or signal-translating device. The transient image is one which tends, of itself, to decay in time after the recording stimulus is removed.

In my copending application Serial No. 116,601, filed December 18, 1936, I have disclosed a method and apparatus having these several features. The present invention is directed toward an improved method and apparatus similar in certain respects to that disclosed in my previous application.

My invention offers advantages in many branches of the signalling art, not the least of which is the art of producing and transmitting music or speech signals, whether by radio or by telephone. In this art, it frequently happens that the amount of reverberation desired to be introduced for its effect upon the listener is markedly greater than the amount which arises due to the acoustic characteristics of the studio or auditorium in which the performers are located. It is often desirable to locate the performers engaged in a broadcast or the making of a record in a small room or studio. The acoustical characteristics of a small room are essentially different from those of a large auditorium. Attempts to build up natural reverberation in a small room usually result in a confusion of tones rather than a pleasantly blended rendering. Furthermore, musical artists can frequently give better performances in a room having relatively low reverberation, whereas from the standpoint of the

listener, the music may be preferred with a considerably greater amount of reverberation.

In order to provide the amount of reverberation which is desirable from the hearer's standpoint, independent of the characteristics of the studio, whether the latter be natural or artificially modified to suit the requirements of the performers, it has been customary in the past to provide a reverberation chamber at some point in the chain of transmission. Sounds picked up in the studio are reproduced in this chamber by means of a loud speaker and permitted to echo on the walls, and the resulting composite signal is then picked up by a microphone placed in this chamber, and transmitted.

The objections to such a reverberation chamber are manifold. For example, its reverberation characteristics can be altered only to a limited extent and in a somewhat unpredictable manner, and that at the cost of refacing walls, floor and ceiling or placing hangings and carpets thereover. Moreover, to achieve good results it has been found that a reverberation chamber should be not less than 25 feet in length, the other dimensions being comparable. It therefore occupies a considerable amount of space which might profitably be put to other uses.

Furthermore, reverberation chambers are not readily portable, whereas the apparatus of my invention may be readily made so. Therefore, my apparatus readily lends itself to uses in television and in the taking of movie shots where the acoustical properties of the scenery, which may be remote from the studio, are not in accordance with the story.

It is known that sound waves echoing back and forth from the walls, ceiling and floor of a room and being partly attenuated at each successive reflection decay exponentially in time: that is to say, the ratio of the volume of the sound at any given instant to its volume at an instant which is earlier by a given amount, is constant. Therefore, if artificial reverberation is to be produced, the problem presents itself of devising apparatus which shall exhibit the same, or substantially the same, exponential decay characteristic for some physical quantity as does a reverberation chamber for the sound produced therein.

My invention, in one of its aspects, provides a novel solution to this problem. The primary signal picked up in the studio, which is to be modified by the addition of reverberation thereto, is caused to modulate a suitable recording device, which in turn forms a record of the signal on a surface adapted to fugitively retain records

formed thereon. Thereafter, a secondary signal is derived from the record by a suitable signal-translating device responsive thereto.

The recording device may advantageously employ a high-intensity mercury vapor lamp, and the record surface may advantageously be of phosphorescent material coated on the cylindrical periphery of a uniformly rotating disk. Thus a luminous signal record may be formed on the phosphorescent surface by traversing elemental areas of the surface with a beam of light from the lamp. After the disk has rotated a certain distance, the portion of the surface bearing the luminous image record passes a signal-translating device or pickup which may be of the photoelectric type. The signal-translating device thus traverses the elemental areas on which the image record has been formed, and the resulting secondary signal current flowing in the output of the pickup is similar to the primary signal, but delayed with respect thereto by a definite amount. This corresponds to a single reflection of sound from a wall at a given distance from the sound source.

Ordinarily the disk will be rotated at uniform speed. Therefore, by reason of the fact that the phosphorescent disk moves past both the image recorder and pickup at the same speed, the secondary signal will be of the same length as the primary signal, it being understood that the primary signal will in general be a function of time. The strength of the secondary signal may be given any desired value relative to the primary signal by suitable amplification, etc., and the frequency characteristics may be distorted from those of the primary signal by incidental distortions in recording and picking up, or by deliberate distortion by filters, etc. Due to the uniform recording and picking up of the signals, however, the secondary signals can be combined with the primary signals continuously to produce reverberation effects, since the secondary signals represent the same type of sound as the primary signals.

In order to produce a truly reverberatory quality, it is necessary to simulate, not a single echo from one wall, but a succession of echoes from opposite walls. It is this succession of delayed and attenuated sound signals which has the pleasant blending effect usually desired. To simulate, that phenomenon, a plurality of secondary signals may be produced, each delayed and attenuated with respect to its predecessor, and corresponding, therefore, to successive reflections of sound from the walls of a room.

In my previous application, above identified, this is accomplished by utilizing a plurality of pickups spaced about the periphery of the disc, or by feeding back a portion of the secondary signal derived by a single pickup to the recording device, or both.

In the present invention I have found it possible to obtain the plurality of secondary signals in a simpler, more convenient manner by making use of both the image-retaining and image-decaying characteristics of the phosphorescent material, or other suitable record material, to obtain a plurality of successively decaying secondary signals from a single pickup, without requiring the employment of feedback.

When a luminous-image record is formed on phosphorescent material, and the stimulus removed, the record immediately commences to decay in time, and if the phosphorescent material is properly selected and applied, the decay takes

place exponentially but persists a substantial length of time. In accordance with one feature of the present invention, the elemental areas of the phosphorescent surface on which the luminous-image record is recorded are traversed a plurality of times by the signal-translating device during the period in which the record is retained on the surface. In this manner a plurality of successive, successively decaying secondary signals may be derived from a primary signal record by a single signal translating device. In the case of a rotating disc and stationary photoelectric pickup, this may be conveniently accomplished by selecting the diameter and speed of rotation of the disc so that a given element of the disc periphery passes the pickup a plurality of times during the period in which the signal record is retained on the disc. With a uniformly rotating disc and exponential decay of the signal records, the intensities of successive secondary signals derived from the same primary signal record by a single pickup will decay exponentially. This is analogous, therefore, to the successive reflections of sound from parallel walls. This procedure emphasizes the value of employing a material in which the image decays exponentially, since by virtue of this decay the successive secondary signals picked up by a single pickup are attenuated at the proper rate to simulate successive reverberations.

The generation of a plurality of secondary signals by multiple revolutions of the disc may be combined with a plurality of pickups, or with feed-back, or with both, if desired. For example, if for certain purposes a relatively small, rapidly rotating disc be undesirable, it may be that the phosphorescent image record will not persist throughout a sufficiently large number of full revolutions thereof to give a desired effect. In such case, I may employ a plurality of pickups as well. The exponential decay is of value in the case of several pickups also, since the pickups and associated amplifiers may be made identical, relying upon the decay of the image to produce the proper attenuation between the respective secondary signals.

Repeated rotations of the disc, or a plurality of equally spaced pickups, or both together, give an effect analogous to reflection from parallel walls. In the usual case of a closed room with a sound source at an arbitrary position therein, the reverberation is of a more complex character. This effect may be simulated with still greater perfection by the use of feed-back from a pickup to the light source, particularly when the pickup is not placed immediately opposite the light source, but at some intermediate point, or by feed-back from a plurality of pickups. The secondary signals resulting from the combination of feed-back with repetition are of the blended or blurred character which is particularly characteristic of reverberation in a large concert hall or auditorium.

I have found, however, in practice, that good simulation of auditorium reverberation may be obtained by the use of a plurality of pickups, each providing a succession of secondary signals derived from several revolutions of the disc, without the employment of the feed-back.

If desired, the frequency characteristics of the secondary signals may be altered by appropriate means, such as high pass, low pass and band pass filters, to give desired effects. Also, the delay time and reverberation decay time may be

altered by changing the speed of the rotating disk.

The invention is not limited to use in broadcast studios, although it is especially advantageous for such use. It may also be found useful in connection with the recording of phonograph records or sound motion pictures, or in the reproduction thereof.

For a more complete understanding of the invention, reference should be made to the following detailed description of several specific embodiments, taken in connection with the drawings in which—

Fig. 1 is a diagram, mainly schematic, of one embodiment of the invention;

Fig. 1a shows the wave form of the modulating current or light intensity of the light source according to one embodiment of the invention;

Fig. 1b shows the wave form of the modulating current or light intensity of the light source according to a preferred embodiment of the invention;

Fig. 2 is a view, mainly in perspective, showing the geometrical and mechanical relation of certain parts of the apparatus shown in Fig. 1;

Fig. 3 shows a further embodiment of the invention utilizing a multiple optical pickup system with a single photoelectric cell and a cathode-ray tube for the light source;

Fig. 3a shows the trace of the modulated high-frequency beam of the cathode-ray tube of Fig. 3;

Fig. 4 shows a further embodiment in which a number of separate photoelectric cells may be employed either singly or together, and in which a special control circuit for the lamp and special means for combining primary signal and reverberation are shown;

Fig. 4a is a diagram illustrating the manner of combining primary signal and reverberation in Fig. 4;

Fig. 5 shows an embodiment in which the phosphorescent disk is within the envelope of a cathode-ray tube, and in which a single pickup device and a feed-back connection are employed; and

Fig. 6 shows a more elaborate embodiment of my invention in detail, including the circuit for controlling the modulated light source, the photoelectric cell amplifier, and attenuators for controlling the relative amounts of primary and secondary signals transmitted.

Referring now to Fig. 1, a microphone 1 receives a sound signal and converts it into a primary sound electric signal which is amplified by the amplifier 2. From this amplifier the amplified original signal is conducted into two paths, the first path being for direct transmission and leading to the amplifier 3 and the modulator 4 which feeds the radiating antenna 5. The second path is again subdivided, the first branch comprising an attenuator 11 and primary winding 12 of a modulating transformer 13, and the second branch comprising an attenuator 15 and primary winding 16 of a transformer 17. The light source which I prefer to employ is a special mercury arc lamp 20, more fully described hereinafter. The modulating transformer 13 in the first path supplies signal energy to modulate the light source 20, and the transformer 17 in the second path controls the average value of the light source current in a manner to be described.

The mercury arc lamp 20 is shown as in series with a triode 21, a source of D. C. potential 25, a ballast resistance 26, the modulating transformer 13, and a starting transformer 27, the

latter being connected through a switch 27a to a starting source 27b. Momentary closure of the switch 27a places on the lamp 20 a voltage sufficiently high to cause the arc to strike.

For a given value of the D. C. potential source 25 and of the voltage on the grid 24 of the triode 21, a definite biasing current will flow through the lamp 20 and produce a definite brilliancy of the arc. When a signal voltage is placed in series with the circuit by excitation of the transformer 13, the lamp biasing current, and therefore its light, will be modulated at the signal frequency. The ballast resistor 26 serves as a protective device to protect both lamp 20 and tube 21 from the effects of excessive peaks of the signal voltage wave.

If desired, instead of using the energizing circuit shown, the mercury vapor lamp may be energized by a high frequency current which is modulated by the signal, or by other suitable circuits.

The arc is focussed by lenses 20b through a slit 20a (Fig. 2) onto the phosphorescent peripheral surface 30 of a disk 31 which is rotated by any suitable means, such as gear train 32 actuated by a source of mechanical energy, and produces thereon a luminous image record of the signal. As the disk 31 rotates, successive elemental areas of the periphery pass by a pickup device which comprises a slit 33, a lens system 34 and a photoelectric cell 35. That portion of the luminous image record which is instantaneously behind the slit 33 is projected onto the photoelectric cell 35 and gives rise to a current in the output circuit 36 of the cell 35 proportional to the magnitude of that portion of the luminous image record at that instant. This current is then amplified as desired by the amplifier 37, and conducted through the leads 38 to the points 39 where it is mixed with the original signal current for use in transmission or otherwise.

The width of slits 20a and 33 are selected in view of the speed and diameter of the disk so that adequate fidelity is obtained for the maximum frequency of sound to be recorded and picked up. For some uses it may be found that the secondary sound electric signals become attenuated at the higher frequencies to an undesirable extent. In such case the input to the recording lamp 20 may be given a rising characteristic so that the larger input to the lamp at the higher frequencies will compensate for the attenuation in the production of the secondary signals.

Due to the natural decay of the luminous image, and the time elapsed during the passage of a given point of the periphery of the disk from the light source to the pickup device, the photoelectric cell current is reduced in magnitude and delayed in time as compared with the current which would be picked up by a cell placed immediately adjacent the light source.

The combined decay and delay resulting from the system of Fig. 1 as thus far described are equivalent to a single reflection of sound from a wall of given absorptive power and at a given distance from a sound source. To simulate reverberation effects, however, it is desirable to repeat the above succession of events a number of times. This is accomplished by so correlating the speed of rotation and diameter of the disc with the decay characteristic of the phosphorescent material that each elemental area of the periphery passes by pickup 35 a plurality of times during the period in which the image record is retained. Thus, for a given record formed on the phos-

phorescent surface by the light source and fugitively retained thereon, the photoelectric cell will pick up successively a number of secondary signals as the image passes successively by the cell on successive revolutions of the disk. If the phosphorescent material has an exponential luminosity decay characteristic, each of these secondary signals is delayed by a constant time interval with respect to its predecessor, and the ratio of its magnitude with respect to that of its predecessor is constant. The resulting current in the output circuit 36 from the photoelectric cell 35 therefore has the characteristics of a reverberatory echo of the original signal.

It will be understood that during normal operation each elemental area of the phosphorescent periphery of the disc will in general bear simultaneously several different portions of the primary signal, each in a different state of decay. Thus, as a given area of the disc passes the recording device it bears not only the primary signal just recorded on it but also the portions recorded during the several revolutions immediately preceding.

The phosphorescent material on the surface of the disk 31 may be provided in any convenient manner. As an example of a convenient way in which this may be done, the cylindrical surface or periphery of the disk 31 is sprayed with a thin coating of a mixture of a suitable vehicle, such as amylacetate, and phosphorescent material, and dried for use. The vehicle may be water glass, if desired. Also, if desired, the periphery of the disk may first be thinly coated with the vehicle and then a thin layer of phosphorescent material sprinkled or otherwise uniformly spread over and made adherent to the vehicle, which is thereafter dried to adapt it for use. The phosphorescent agent or material is preferably of a character which retains its phosphorescence, when once excited, for a relatively long period of time. Such agent or material may be one or a mixture of the following: Calcium fluoride, zinc sulphide, cadmium sulphide, etc. Each of these materials has a luminosity decay characteristic which is substantially exponential.

As an example of the performance which may be obtained, it has been found that with a disk about 2 feet in diameter, coated with a mixture of a zinc sulphide composition and an amylacetate vehicle, an audible response can still be obtained after about 5 revolutions at 400 R. P. M., the response diminishing to 50% intensity after roughly 0.2 second.

Light sources of various types may be employed in connection with the invention. For example, the so-called light valve may be employed, in which a minute shutter is opened and closed at the signal frequency to admit light from a steady source such as a carbon arc. It is also feasible to utilize a Kerr cell. Or, a cathode-ray tube may be employed as described in connection with Fig. 3. Again, a glow discharge tube may be employed, the intensity of the light being directly controlled by the signal energy. Means other than visible light sources may also be employed, as described in connection with Fig. 5. In any case, the recording device will be selected in view of the particular type of record surface employed.

Although any one of the above-named light sources may be employed, each one has characteristics which render it less satisfactory under some conditions than others. Thus the inertia of the moving parts of the light valve imposes

certain frequency limitations thereon, and the cathode-ray tube, the Kerr cell and the glow discharge tube do not provide as much intrinsic brilliancy as may be desired in certain applications. I therefore prefer to employ a modulated mercury arc. The arc, and one form of associated control circuit which I have found satisfactory, will now be described.

For the light source itself I employ a small heavy-walled tube, preferably of quartz, containing a measured quantity of mercury, and having an electrode at either end. The heavy walls permit the tube to withstand considerable internal pressure, such that the arc, once struck and heated, follows a straight narrow line. I have successfully employed a type H-3 Westinghouse lamp. This lamp is of the high-pressure type and is provided with an outer transparent envelope which is spaced from and surrounds the inner tube containing the mercury. The operating data for this lamp is given as follows:

Rating: 85 watts.

Normal operating pressure: 20-30 atmospheres.

Brilliance: 8 candles per sq. mm.

Efficiency: 35 lumens per watt.

Starting voltage: 400-450 volts, across arc.

Spectral distribution: Fairly even between 3340 and 4920-A. units.

I, however, modify this lamp by removing the outer transparent envelope therefrom. By doing so, I have found that the lamp can be readily modulated by the circuits described herein, and that the modulation range can be considerably increased. Among other advantages, the removal of the outer envelope permits cooling of the inner tube, and hence controlling the pressure within the lamp, by automatically controlled artificial means. The purpose for this cooling control will be described in connection with Fig. 4.

If the average arc current were maintained at a high level, without cooling, excessive heating would ensue, resulting in reduced life and in raising the pressure to such a high value that a large signal might extinguish the arc. The higher the pressure, the higher the starting voltages needed. These difficulties may be avoided by maintaining the average arc current at the lowest safe value and varying this value as the magnitude of the signal is varied.

The variation of the average value of the arc biasing current in accordance with the amplitude of the primary signal is accomplished in Fig. 1 in the following manner. The grid 24 of the tube 21 is connected to the cathode 22 through a parallel circuit of resistance 40 and capacitance 41, which circuit has a preassigned time constant. In parallel with this resistance-capacitance circuit is connected a rectifier 43, which may be a diode, in series with the secondary winding 18 of the transformer 17. The original signal is supplied, through attenuator 15, to the primary winding 16 of the transformer 17. When no signal is impressed on the transformer 17 the grid 24 of the tube 21 is maintained at a potential determined by the "C" battery 42, and the conductance of the cathode-plate circuit is therefore low, resulting in a low average current through the arc lamp 20. When, however, a large signal is impressed on the transformer 17, due to the rectifying action of the circuits 40, 41, 43, the grid potential is raised and the tube conductance increased, resulting in a larger average current through the arc. The time constant of the resistance-capacitance circuit should of

course be such that the grid control is too sluggish to respond to audiofrequency signals in the transformer 17, the biasing current varying substantially in accordance with the envelope of the signal waves. Choice of proper values of the circuit constants and adjustment of the attenuators will result in satisfactory compensation of the average arc current.

The result is shown in Fig. 1b, where the average current is so varied that negative peaks of the signal waves fail to pass below the extinction voltage. Fig. 1b is to be compared with Fig. 1a, the latter representing the wave form of the arc current, and therefore of its brilliancy, when such a control circuit is not employed. Evidently the heating of the lamp envelope is much greater in the case of Fig. 1a than in the case of Fig. 1b; and reduction of heating in the latter case results in maintenance of a low extinction voltage for the arc.

Reduction of the average value of the arc current has further distinct advantage in that it preserves the life of the phosphorescent material on the disk. Controlled cooling of the lamp may be employed, if desired. Also, higher modulation peaks can be employed since, for a short time, raising of the average current is permissible.

Of course, if desired, the circuits for varying the average value of the current through the tube 20 can be omitted. In such case provision should preferably be made for preventing the permanent extinction of the mercury arc by a large modulation signal. If a light source other than a mercury arc is employed such provision may be unnecessary, depending on the character of the light source employed.

Fig. 2 shows the mechanical arrangement of the disk, arc lamp, and pickup device. A rigid bench is provided, having an extension 45 on which the arc lamp is mounted and another extension 46 on which an arm 47 is supported, arranged to turn about the axis of rotation of the disk 31. The pickup device 33, 34, 35 is mounted on the arm 47. A screw 48 is provided for adjusting and maintaining the arm 47 at exactly the desired angle with respect to the extension 45. This arrangement permits the exact time interval between the formation of a luminous image on the phosphorescent surface and the reproduction of the secondary signal to be manually controlled. It is particularly useful when the primary signal is of an impulsive character; for example, a pistol shot or other staccato sound.

By altering the speed of rotation of the disc, or the diameter thereof, or both, the interval between successive secondary signals corresponding to a given primary signal may be changed, and the decay of successive signals altered.

In the case of a secondary signal or echo of an impulsive primary signal, it may be desirable to insure against repetitions. This may be accomplished by erasing the fluorescent image record before it completes a full revolution and returns, in the course of rotation of the disk, to the arc lamp. Erasers may be of any desired construction, but I prefer to employ a source of infrared light. Fig. 1 and Fig. 2 show an eraser of this type, comprising an infrared lamp 58 contained in a housing 58a, a source of current 59 for exciting the lamp, and a switch 59a for rendering it operative when desired.

The image eraser 58a may also be employed for another purpose, by adjusting it so that the

image is only partially erased as it passes the eraser. For a given decay characteristic of the phosphorescent material, the decay between successive secondary signals corresponds to the decay of successive reflections of sound from walls of a given absorptive power. In echo chambers it is sometimes desirable to change the absorptive power of the walls, by refacing, draperies, etc., to alter the intensities of the successive reflections, without changing the time interval between successive reflections. Since it is undesirable to change the phosphorescent material on the disc to give different decay characteristics to simulate different conditions, or to employ a plurality of interchangeable discs, the effective decay of the images on the disc may be altered by diminishing their intensity by partial erasure. Thus the intensity of the primary signal record is diminished over and above the natural decay of the phosphorescent image between successive secondary signals.

This partial erasure to change the intensity of the image between the derivations of successive secondary signals may also be employed in the embodiments described hereinafter. In the case of multiple pickups, it is advantageous to construct the erasing means so as to act upon the images between each pickup, for example, by employing individual erasers between pickups.

In Fig. 3 a cathode-ray tube 50 serves as the light source. Its vertical deflection elements 51 are supplied with high frequency voltage, modulated at the signal frequency, by the oscillator-modulator 53. To facilitate the showing of this figure, the rotating disk 31 and pickup devices 33, 34, 35 are shown in one plane and the cathode-ray tube is shown in a plane perpendicular thereto. It is to be noted that if the disk rotates in a horizontal plane, the deflection of the cathode beam should be in a vertical direction and vice versa.

Fig. 3a show the trace on the phosphorescent periphery 30 of the disk due to excitation by projection of the oscillating light spot on the cathode-ray tube screen 52 onto the disc by lens 50a through slit 20a. It is a "variable width" record, whereas the image record produced by the apparatus of Fig. 1 was essentially a "variable density" record. If desired, the amplitude of the high frequency oscillation of the cathode-ray beam may be kept constant and the intensity of the beam modulated by applying the signal to its control grid, thereby producing a "variable density" record. Or, preferably, both amplitude and grid modulation may be employed, thereby securing a greater volume range.

In Fig. 3 the echo effect due to a single pickup is broadly the same as that described in connection with Fig. 1. In Fig. 3, however, three pickups are shown, each comprising a slit and a focusing lens. They may be placed in any desired positions with respect to each other and the light source. As a given portion of the image record passes behind the first slit 33a, light is collected therefrom by the lenses 34a and reflected by the mirror 55 and the prism 57 onto the photoelectric cell 35. The same is true of the third slit 33b. Light from the second slit 33 passes directly through two parallel faces of the prism 57 to the photoelectric cell.

The output current of the photoelectric cell of Fig. 3 therefore contains three times as many secondary signals as does the output current of the photoelectric cell of Fig. 1, and the echo quality of the resulting composite sound signal

is therefore, generally speaking, three times as great. The relative amplitudes of the secondary signals from the separate pickups may be controlled, if desired, by the interposition of an adjustable stop or aperture in each of the three optical paths between the slits 33, 33a and 33b and the photoelectric cell 35.

This form of multiple pickup, in which the secondary signals are derived optically and combined in a single photoelectric cell has the advantage of keeping the "noise" in the composite signal at a low level, because the noise introduced by the pickup system is only $\frac{1}{3}$ as great as it would be were a separate photoelectric cell and amplifier associated with each pickup device. However, if desired, separate photoelectric cells and separate amplifiers may be employed, and the outputs of the amplifiers combined and fed to the output of the original signal amplifier 3.

In Fig. 1 circuits were described in which the average current through the mercury vapor tube 20 was varied in accordance with the amplitude of the signal, as illustrated in Fig. 1b. In this manner extinction of the lamp by signals of large magnitude can be avoided, and other advantages can be secured. However, although such control is preferred it requires considerable additional equipment. This will be particularly evident from the hereinafter description of Fig. 7. Therefore, the apparatus illustrated in Fig. 4 has been devised to prevent extinction of the lamp without varying the average current through the lamp. Thus the apparatus of Fig. 4 functions in the manner shown in Fig. 1a. Fig. 4 also illustrates means for combining the original signal with the reverberation signal in any desired relative proportions, while maintaining the sum of the two signals constant.

Referring now to Fig. 4, original sound signals from microphone 1 are fed to the primary 12 of modulating transformer 13, as in Fig. 1. The secondary 14 of the modulating transformer is connected in series with the mercury vapor lamp 20, thereby modulating the light in accordance with the original signal. The light from lamp 20 is collected by the large aperture quartz condenser lens 20b and converged onto the phosphorescent periphery of disk 31 through the narrow slit 20a.

As disk 31 rotates in the direction indicated, secondary signals are successively picked up by the four photoelectric cells 35c, 35a, 35 and 35b, spaced substantially 90° apart. The photoelectric cells receive light from the disk through the respective narrow slits 33. If desired, the combination of slit and lenses shown in Fig. 2 may be employed, but it is found that the use of a slit and closely adjacent photoelectric cell, as shown in Fig. 4, is satisfactory, and utilizes the light more efficiently.

The signals picked up by the several photoelectric cells are amplified by respective amplifiers 37, 37a, 37b and 37c. One output terminal of each amplifier is grounded, and the other is connected to respective contacts of switch 61. The blades of switch 61 are connected to one terminal of attenuator 62, and the other terminal of the attenuator is grounded. The several blades of switch 61 may be individually closed so that any desired combination of secondary signals may be obtained. It will be understood that by properly selecting the phosphorescent material of disk 31, and the diameter and speed of rotation of the disk, a plurality of secondary signals may be derived from a single pri-

mary signal by each of the photoelectric cells, as described in connection with Fig. 1.

The original signal from amplifier 2 is supplied to the variable attenuator 63, and attenuators 62 and 63 are connected to respective primary windings 65a and 65b of transformer 65. The secondary winding 65c of this transformer is connected to desired output apparatus, here shown by way of example as amplifier 66 and loud speaker 67. Thus the loud speaker is fed with both the original primary signal and the reverberation signals derived from the rotating phosphorescent disk 31. Attenuators 62 and 63 are controlled by a single knob 64, and are so coupled to control 64 that as one attenuator increases, the other decreases. In this manner the original and reverberation signals may be mixed in any desired ratio, and the sum of the two may be maintained constant. This result is indicated diagrammatically in Fig. 4a.

The operating conditions and control circuit for the mercury vapor tube 20 will now be described. Although any suitable mercury vapor tube may be employed, the high-pressure type, such as the type H-3 Westinghouse lamp described hereinbefore, with the outer transparent envelope removed, has been found satisfactory, and the operating conditions and circuit constants will be described as they are employed with this particular tube. It will be understood, of course, that the operating conditions and circuit constants may vary for different tubes and that therefore the details given hereinafter may be modified accordingly. Furthermore, if desired, the particular values for this tube may also be changed, the operating data given hereinafter being intended only as a specific example of what has been found to be satisfactory.

Although the tube is rated at 85 watts, it has been found advantageous to operate the lamp at 100 watts, in order to modulate as much energy as possible. The constants of the circuits are selected so that the average value of the current (i_{av} of Fig. 1a) is 1 ampere during normal operation, and the average voltage across the terminals of the tubes, 100 volts. With these values a satisfactory brilliant and restricted arc is obtained. This operating point is, in general, not stable, since as the lamp heats up the current therethrough decreases, and as the lamp cools down the current increases. Therefore, automatic cooling, responsive to the current through the lamp, is employed to maintain the lamp at the proper operating point. This cooling is accomplished by the air blower 45 driven by motor 44. The starting and stopping of motor 44 is controlled by the differential relay 19, which in turn is controlled by the current passing through the lamp 20. The differential relay is set to maintain an average current of 1 ampere through the tube. By this means it is found that it is possible to maintain the average current between the limits of 0.95 and 1.05 amperes.

This variation in current produces a corresponding variation in average voltage across the lamp of from 105 to 95 volts. Therefore the average watt output of the lamp changes only about 1 watt (1% of the total watt output).

In series with the lamp 20 are the secondary winding 14 of the modulating transformer 13, the source of D. C. voltage 25 (which may be a power pack), resistance 28 and resistance 29, the latter having the condenser 29a shunted across it. A portion of resistance 29 is shunted by the differential relay 19 so as to provide the actuating

current for the relay. Resistance 28 is provided to supply voltage to an oscillograph (not shown) to check the operation of the circuit. A suitable value for resistance 28 has been found to be 100 ohms. Also, a suitable voltage for source 25 has been found to be about 400 volts. Resistance 29 has been provided for a ballast resistance and, in conjunction with condenser 29a, assists in preventing the extinction of lamp 20 when the modulation carries the voltage across the lamp below the extinction voltage.

In operation, the lamp is initially ignited by closing switch 49. Since no current is flowing in the circuit, the full voltage of battery 25 is impressed across the tube 20, and this voltage should be selected to be above the ignition voltage of the tube. As the lamp heats up, the current therethrough gradually decreases until it reaches a value of about 1 ampere. At this point the differential relay begins to function and thereafter maintains the average current through the lamp at one ampere by starting the blower when the current goes below 1 ampere and stopping the blower when the current goes above 1 ampere. The modulating signal supplied to the circuit through transformer 13 modulates the current in the manner shown in Fig. 1a.

If the modulating signal becomes of sufficiently large magnitude to carry the voltage across the lamp below the extinction voltage during the negative half-cycle, the lamp would tend to be extinguished. If completely extinguished, reignition would be difficult since the increased pressure under normal operating conditions raises the starting voltage considerably above the initial starting voltage. However, at the higher frequencies the lamp does not appear to be completely extinguished, probably due to the fact that the deionization time of the lamp is sufficiently long to enable the rising voltage, after the negative peak has passed, to continue excitation of the lamp.

At lower frequencies there appears to be a strong tendency for the lamp to be completely extinguished. The circuit of Fig. 4 has therefore been designed to prevent the extinction from becoming permanent. Of course, there is a certain amount of distortion introduced by the failure of the lamp to follow the negative peaks of large amplitude signals, but such distortion may not be particularly objectionable since the reverberation need not have the same clarity and faithfulness as the original signal, provided of course that the distortion does not become excessive.

The reasons why the circuit of Fig. 4 serves to prevent permanent extinction of the lamp after the passing of large amplitude signals are not completely known. Therefore the following explanation, although it is believed helpful, is not insisted upon, it being known as a fact that the circuit will function satisfactorily for the uses to which it has been put.

Assuming for the moment that condenser 29a is removed from the circuit, if current through the lamp ceases the full voltage of battery 25 plus the modulating voltage is impressed across the lamp, since the voltage drop in the resistances is then zero. In such case, as soon as the sum of the two voltages rises above the ignition voltage of the lamp at the condition of the lamp then prevailing, the lamp will reignite. After ignition, current through the resistances causes a voltage drop therein and the D. C. voltage across the lamp decreases to its average operat-

ing voltage, here selected as 100 volts. If the frequencies are not too low, this circuit appears to function satisfactorily.

At low frequencies, however, as stated before, it is found that the lamp tends to be permanently extinguished. The condenser 29a has been found to avoid this difficulty. With this condenser in circuit, a large portion of the modulating current is by-passed around resistance 29. Suitable values of resistance 29 and capacitance 29a have been found to be 200 ohms and 60 mfd., respectively. With these values it will be observed that the impedance of the condenser at 60 cycles is small as compared to that of the resistance. Even at 30 cycles the condenser impedance is substantially smaller. Therefore, the total impedance of the circuit to the alternating modulating signal is lower than without the condenser, and yet the impedance to direct current remains the same. For this reason the magnitude of the modulating signal necessary to fully modulate and to extinguish the lamp is less, relative to the voltage of battery 25, than without the condenser. Thus, at a given instant after extinction, the voltage across the lamp is higher than without the condenser, and therefore the lamp is prevented from being permanently extinguished.

No doubt other factors enter into the maintenance of operation of the lamp, but it is believed that the foregoing will suffice to indicate how the circuit functions, it being remembered that the accuracy of the theory is not insisted upon.

Fig. 5 shows a modification in which the phosphorescent disk 31 is enclosed within the glass envelope 50 of a cathode-ray tube. The disk 31 is preferably propelled by external means such as induction means, shown in the drawings as comprising two magnets 70 and 72 excited respectively by windings 71 and 73, which may be supplied with currents which are out of phase with respect to each other.

The modulated light source of Fig. 5 is a modified form of that shown in Fig. 3. When the energy of an electron beam is employed to excite the fluorescent screen of a cathode-ray tube to form a spot of light thereon, and this light is in turn utilized to excite phosphorescence of the record-receiving surface of the disk, much light is lost in the course of the energy transformations. In the modification of Fig. 5, the phosphorescent surface is directly impinged by the electron beam, thereby avoiding such losses. The tube shown has vertical deflecting elements 51 and a conventional electrode structure including focusing means. Any of the several methods of modulating the beam described in connection with Fig. 3 may be employed.

Only a single pickup is illustrated in Fig. 5, although more may be employed if desired, and provision is made for feeding back a portion of the secondary signal produced by this pickup to the modulating deflecting plates 51 of the cathode-ray tube. This therefore results in a duplicate echo effect, the first part being due to repeated rotations of the disk 31 and the second due to feed-back. The pickup is advantageously disposed outside of the cathode-ray tube, and the photoelectric cell 35 is contained in a housing 74 provided with a collimator tube 75 for collecting light from a passing image record and projecting it into the photoelectric cell.

The output of the photoelectric cell 35 is amplified by amplifier 37 and impressed across the

resistances 68 and 69, one terminal of each resistance being grounded. A desired portion of the composite signal across resistor 68, namely, that portion between the adjustable tap and ground, is supplied to points 39 for mixing with the original signal from amplifier 3. A desired portion of the voltage across resistor 69 is supplied through the attenuator 11 to the high frequency oscillator and modulator 53. Thus, the image record produced on the phosphorescent surface of the disk by the cathode-ray beam comprises both the primary signal and the composite secondary signal picked up by the photoelectric cell. This feed-back signal is again picked up by the photoelectric cell, supplied to the output circuit, and also fed back to the disk, and so on.

The magnitudes of primary and feed-back signals are selected so as not to saturate the phosphorescent disk, and in general the magnitude of the secondary signal fed back will be less than that of the corresponding primary signal, so as to avoid instability due to feed-back oscillations.

Referring now to Fig. 6, this figure shows an embodiment designed for convenient and flexible control of the amount and character of the reverberation introduced into the primary signal, and a circuit for varying the average D. C. current through the lamp somewhat similar to that of Fig. 1 but possessing certain advantages thereover. In Fig. 6, the current from the microphone 1 is conducted through the amplifier 2 and thence into two paths, the one path leading through amplifier 100 which may be short-circuited by the switch 101, through attenuator 102, transformer 103, switch 104, amplifier 105, and finally to a reproducer, here shown as a loudspeaker 106.

The second path from the microphone amplifier 2 leads through transformer 110 to amplifier 111 and transformer 112, where it is in turn subdivided into two subpaths, the first providing modulation of the arc current in accordance with the signal and the second providing control energy for varying the average value of the arc current. The first path leads through a high-capacity condenser 119, the mercury arc lamp 20, the ballast resistor 26, and back to the transformer 112. The transformer 112 should be so chosen that its impedance does not form an excessive part of the total impedance of this series circuit 112, 119, 20, 26.

The D. C. arc current is supplied from a source of potential 25 through a plurality of triodes 21 in parallel, the cathodes 22 of the triodes being connected to one side of the condenser 119 and the negative terminal of the source of potential 25 being connected to the other side. These triodes should be capable of carrying the D. C. component of the full load arc current. I have found that excellent results are obtained by the use of sixteen 2A3 tubes in parallel, their anodes being connected to the high potential terminal of the source 25. The source of potential 25 must be capable of delivering the full load arc current and supplying the voltage drops in the triodes 21, the arc 20, and the ballast resistor 26. A power rectifier with a rating of 500 milliamperes at 1000 volts has been found satisfactory. Condenser 119, connected across the control tubes, serves to relieve the latter of the signal current load.

A reversing switch 26a is interposed in the leads to the arc lamp 20 to prolong the life of the lamp. Since the material of its cathode becomes gradually evaporated, it is of advantage to inter-

change anode and cathode each time the apparatus is used.

The arc is started by momentarily closing the switch 26b, thereby short-circuiting a portion of the ballast resistor 26.

In the simpler modifications of my control circuit I have shown connections for rectifying a portion of the signal and applying the result directly to the control grids of modulating tubes. In order to obtain the requisite high time constant, these systems involve fairly high grid impedances. The circuit shown in the upper part of Fig. 6 overcomes this difficulty. Thus a portion of the signal-output current of the transformer 112 is led through attenuator 113 and transformer 114 to a full-wave rectifier 115. Between the center tap 116 of the plate winding of the transformer 114 and the cathode 117 of the rectifier tube 115 is connected the time constant circuit 40, 41, which may comprise a 4 megohm resistance and a .05 mfd. condenser in parallel. Two screen grid tubes 120 are provided to amplify and utilize the rectified voltage, cathodes 121 being connected through a biasing resistor 122 and a bias battery 123 to one side of the resistance-capacitance circuit 40, 41 and control grids 125 being connected to the other side. A separate source of anode potential 127 is provided, having its negative terminal connected through the resistor 122 to the cathodes 121. The screen grids 126 are connected to the positive terminal of this source 127 through resistance 128 and the plates 124 are connected to the same terminal, through the resistor 129.

The grids 24 of the D. C. control tubes 21 are connected, through the bias battery 42 and the resistance 129 to the cathodes 22. The resistance 129, which serves as the load impedance of the rectifier system and as the input impedance of the control tubes, may have a relatively low value, which results in greatly improved stability of operation of the control circuit while still maintaining as high a time constant in the rectifier circuit 40, 41, 115 as desired.

The rotating disk 31 is shown, driven by a constant speed motor. In order to obtain uniformity of speed it is advisable to use a synchronous motor, with gear reduction if necessary. Three photoelectric cell pickups 35, 35a, 35b with associated slits (not shown) are equally spaced about the disk 31. Their cathodes are connected through blocking condenser 130 to a control grid 131 of an amplifier tube 132, and their anodes to adjustable taps on resistors 133, 133a, 133b which are connected across a source of potential 134 whose negative terminal is grounded. The grid 131 of the tube 132 constitutes the input electrode of a resistance-coupled amplifier of conventional form.

The amplified voltage of the signal from the photoelectric cells 35, 35a, 35b appears across a transformer 136 and then passes through two filters, one a high pass filter 137 and the other a low pass filter 138. This arrangement permits of differential control of the frequency characteristics of the secondary signal.

The signal is then fed through an attenuator 141, a transformer 142, and the switch 104 to the amplifier 105 and is finally reproduced in the loudspeaker 106. If desired, attenuators 102 and 141 may be coupled to a single control, as described for attenuators 62 and 63 in connection with Figs. 4 and 4a, to maintain constant output. The switch 104 is preferably of the three-pole, three-way type. When connected as shown, pri-

mary signals alone are passed at the lowest position, secondary signals alone at the middle position, and both primary and secondary signals at the upper position.

When the switch is in the position shown (the upper position) it will be observed that the secondary windings of the transformers 103 and 142 are in series, and therefore a secondary signal voltage is impressed on the attenuator 102 in reverse direction. When the amplifier 100 is in the circuit, this secondary voltage is blocked thereby, but when the amplifier 100 is short-circuited by the switch 101, the secondary voltage may pass to the transformer 110 and thus be supplied along with the primary signal voltage to the amplifier 111. This results in feedback as described in connection with Fig. 5.

The apparatus of Fig. 6, therefore, affords a triplicate echo effect. The first part is due to successive revolutions past each photoelectric cell; the second is due to the use of a plurality of cells; and the third is due to feed-back. If desired, only a single pickup may be employed, without feed-back. Again, it may be desired to employ either feed-back or a number of pickups. Lastly, both a number of pickups and feed-back may be employed together. All of these changes may be accomplished merely by switching.

The term "phosphorescent" has been used in the present specification to describe those materials in which the luminescence persists after the excitation is removed, this phenomenon being known as "phosphorescence." Phosphorescence is distinguished from "fluorescence," in the strict meaning of the terms, in that the latter applies to the luminescence given off during excitation. The term "fluorescent," however, is often applied to materials which exhibit both fluorescence and phosphorescence, since many materials exhibit both effects.

In the embodiments herein described a rotating disk has been employed. If desired, other forms of moving record-receiving members may be employed, such as endless belts, etc. Also, the surface bearing the phosphorescent material may be maintained stationary and the means for recording and picking up the signals moved relative thereto, preferably in a manner such as to repeatedly traverse an endless area or band of the surface. In general it may be stated that any suitable means for producing a traversal of elemental areas of the phosphorescent surface by the recording and signal translating (pickup) devices may be employed, if desired.

Furthermore, although a phosphorescent surface is found to be especially suitable for the purposes of the invention, if desired, other types of fugitively record-retaining material may be employed. An example of such a type is a surface capable of storing electrostatic charges and having adequate leakage to produce the desired decay effects.

Although the invention is especially suited for the production of echo or reverberation effects in the sound signalling art, it may also be found useful in other arts where a delayed replica of a primary signal, particularly in connection with a commingling thereof with the primary signal, is desired. Even in the sound signalling art, the production of the primary signal may of course be accomplished in ways other than those particularly described, such as from records, etc. Also, the derived secondary signals may be employed in any way desired, such as, for example, in

the making of records, for modulating a carrier frequency, in making sound film, etc., or simply to obtain a delayed signal per se.

The essentials of the preferred form of the invention as well as certain modifications thereof will be clear from the above description, and it will be apparent that further modifications may be made without departing from the spirit thereof.

I claim:

1. The method of deriving a plurality of secondary signals from a primary signal which comprises, producing a record of the primary signal which persists for a substantial period and gradually decays during said period, and deriving a plurality of secondary signals from said record by successively traversing said record a plurality of times during the period in which the record of the primary signal persists.

2. The method of deriving a plurality of secondary signals from a primary signal which comprises, recording on a substantially endless band of a phosphorescent surface a gradually decaying phosphorescent record of the primary signal which persists for a substantial period, and deriving a plurality of secondary signals from said phosphorescent record by successively traversing said endless band a plurality of times during the period in which the record of the primary signal persists.

3. The method of deriving a plurality of secondary sound electric signals from a primary sound electric signal which comprises, recording on a substantially endless band of a phosphorescent surface a gradually decaying phosphorescent record of the primary sound electric signal which persists for a substantial period, and photoelectrically deriving a plurality of secondary sound electric signals corresponding to said primary sound electric signal from the phosphorescent record thereof by successively traversing said endless band a plurality of times during the period in which the record of the primary signal persists.

4. The method of introducing reverberation into a primary sound electric signal which comprises, continuously recording on elemental areas within an endless band of a phosphorescent surface a phosphorescent record of the primary sound electric signal by repeatedly traversing said endless band, said phosphorescent record persisting for a substantial period and gradually decaying during said period, deriving a plurality of successively decaying secondary sound electric signals corresponding to said primary sound electric signal from the phosphorescent record thereof by repeatedly traversing said endless band with a photoelectric signal-translating device at a speed such that a plurality of traversals take place during the period in which the record of the primary signal persists, and combining the primary sound electric signal and the secondary sound electric signals so derived therefrom.

5. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, means for forming a signal record on said record surface, translating means adapted to derive a signal from a signal record on said record surface, and means for moving said translating means and said record surface relative to each other so that a signal record on said record surface passes said translating means a plurality of times during the period in which the signal record is retained on said record surface, whereby a plurality of

signals may be derived from said signal record by the translating means during said period.

6. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, means for forming on elemental areas of said record surface a primary signal record corresponding to a primary signal, a signal translating device adapted to derive a secondary signal from a primary signal record on said elemental areas by a traversal thereof, and means for producing a plurality of traversals of said elemental areas by said signal-translating device during the period in which the primary signal record is retained on said record surface, whereby a plurality of secondary signals may be derived from a primary signal record by said signal-translating device during said period.

7. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, said records gradually decaying during the period in which they are retained, means for forming on elemental areas of said record surface a primary signal record corresponding to a primary signal, a signal-translating device adapted to derive a secondary signal from a primary signal record on said elemental areas by a traversal thereof, and means for producing a plurality of traversals of said elemental areas by said signal-translating device during the period in which the primary signal record is retained on said record surface, whereby a plurality of successively decaying secondary signals may be derived from a primary signal record by the signal-translating device during said period.

8. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, said records gradually decaying during the periods in which they are retained, recording means responsive to a primary electric signal and adapted to form on successive elemental areas of an endless area of said record surface a modulated primary signal record corresponding to said primary electric signal, a signal-translating device responsive to signal records on said elemental areas and adapted to derive a secondary electric signal similar to a primary signal recorded thereon by a traversal of said elemental areas successively, and means for producing a traversal of said endless area of the record surface by said signal-translating device a plurality of times during the period in which a primary signal record is retained thereon so as to produce a plurality of successively decaying secondary electric signals similar to a primary signal recorded on elemental areas of said endless area.

9. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, said records gradually decaying during the period in which they are retained, recording means responsive to a primary electric signal and adapted to form on successive elemental areas of an endless area of said record surface a modulated primary signal record corresponding to said primary electric signal, a signal-translating device responsive to signal records on said elemental areas and adapted to derive a secondary electric signal similar to a primary signal recorded thereon by a traversal of said elemental areas successively, means for producing a traversal of said endless area of the record surface by said signal-translating device a plurality of times during the period in

which a primary signal record is retained thereon so as to produce a plurality of successively decaying secondary electric signals similar to a primary electric signal recorded on elemental areas of said endless area, and means for combining said primary electric signal with the secondary electric signals so derived therefrom.

10. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, said records gradually decaying during the period in which they are retained, a recording device responsive to a primary signal and adapted to form a corresponding primary signal record on elemental areas of said record surface by a traversal thereof, a signal-translating device responsive to signal records on said elemental areas and adapted to derive secondary signals similar to primary signals recorded thereon by a traversal of said elemental areas, and means for producing a repeated traversal of a substantially endless band of said record surface by said recording device to thereby record primary signals on elemental areas within said endless band and a repeated traversal of said endless band by said signal-translating device at substantially the same speed as the traversal thereof by the recording device, said speed of traversal being sufficient to produce a plurality of traversals of the endless band by the signal-translating device during the period in which a primary signal record is retained on the record surface so as to derive a plurality of successively decaying secondary signals similar to a primary signal recorded on elemental areas of said endless band.

11. In a signal-translation apparatus, in combination, a luminescent record surface adapted to fugitively retain luminous records formed thereon, said luminous records gradually decaying during the period in which they are retained, a recording device responsive to a primary electric signal and adapted to record a corresponding luminous primary signal record on elemental areas of said luminescent surface by a traversal thereof, means for producing relative movement between said recording device and said luminescent surface such that a substantially endless band of said luminescent surface is repeatedly traversed by said recording device, a photoelectric signal-translating device responsive to a luminous record on said luminescent surface and adapted to derive a secondary electric signal similar to a primary signal recorded on elemental areas of said surface by a traversal thereof, and means for producing relative movement between said signal-translating device and said luminescent record surface such that the signal-translating device repeatedly traverses said endless band at a speed such that a plurality of traversals take place during the period in which a primary signal record is retained thereby so as to derive a plurality of successively decaying secondary electric signals similar to a primary signal recorded on elemental areas of said endless band.

12. In a signal-translation apparatus, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a recording device responsive to a modulated primary electric signal and adapted to record a corresponding modulated phosphorescent primary signal record on elemental

areas of said phosphorescent surface passing thereby, means for producing a continuous uniform relative movement between said recording device and said phosphorescent surface such that
 5 elemental areas of an endless band of said phosphorescent surface repeatedly pass said recording device, whereby a modulated primary signal may be continuously recorded on the elemental areas of said endless band, a signal-translating device
 10 responsive to a phosphorescent record on said phosphorescent surface and adapted to derive a secondary electric signal similar to said primary electric signal from the phosphorescent primary signal record on elemental areas of said surface
 15 passing thereby, means for producing a continuous uniform relative movement between said signal-translating device and said phosphorescent record surface such that elemental areas of said endless band repeatedly pass said signal-
 20 translating device at substantially the same speed as said elemental areas pass said recording device, said speed being such that elemental areas of said endless band pass said signal-translating device a plurality of times during the period in
 25 which phosphorescent records are retained thereby so that a plurality of successive, successively decaying secondary electric signals similar to said primary signal recorded on elemental areas in said endless band are derived therefrom, and
 30 means for combining said primary electric signal with the secondary electric signals so derived therefrom.

13. In apparatus for deriving a plurality of secondary sound signals from a primary sound signal, in combination, a record surface adapted to
 35 fugitively retain records formed thereon, means for forming on elemental areas of said record surface a primary sound signal record corresponding to a primary sound signal, a signal-
 40 translating device adapted to derive a secondary signal from a primary sound signal record on said elemental areas by a traversal thereof, and means for producing a plurality of traversals of
 45 said elemental areas by said signal-translating device during the period in which the primary sound signal record is retained on said record surface, whereby a plurality of secondary signals
 50 corresponding to a primary sound signal may be derived from a primary sound signal record during said period.

14. In apparatus for deriving a plurality of secondary sound electric signals from a primary sound electric signal, in combination, a record
 55 surface adapted to fugitively retain records formed thereon, said records gradually decaying during the period in which they are retained, a recording device responsive to a primary sound electric signal and adapted to form a corre-
 60 sponding primary sound signal record on elemental areas of said record surface by a traversal thereof, a signal-translating device responsive to signal records on said elemental areas and adapted to derive secondary sound electric signals
 65 similar to recorded primary sound signals by a traversal of the elemental areas, and means for producing a repeated traversal of a substantially endless band of said record surface by
 70 said recording device to thereby record primary sound signals on elemental areas within said endless band and a repeated traversal of said
 75 of traversals of the endless band by the signal-

translating device during the period in which a primary sound signal record is retained on the record surface so as to derive a plurality of successively decaying secondary sound electric signals similar to a primary sound signal recorded
 5 on elemental areas of said endless band.

15. In apparatus for deriving a plurality of secondary sound signals from a primary sound signal, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent
 10 records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, means for forming on elemental areas of said phosphorescent record surface a primary sound signal record corre-
 15 sponding to a primary sound signal, a signal-translating device adapted to derive a secondary signal corresponding to a primary sound signal from a primary sound signal record on said
 20 elemental areas by a traversal thereof, and means for producing a plurality of traversals of said elemental areas by said signal-translating device during the period in which a primary sound signal
 25 record is retained thereon to thereby derive a plurality of successive, successively decaying secondary signals corresponding to a primary sound signal during said period.

16. In apparatus for deriving a plurality of secondary sound electric signals from a primary sound electric signal, in combination, a phosphorescent record surface adapted to fugitively
 30 retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a recording device responsive to a primary sound
 35 electric signal and adapted to form a corresponding primary sound signal record on elemental areas of said record surface by a traversal thereof, a signal-translating device responsive to signal records on said elemental areas and adapted
 40 to derive secondary sound electric signals similar to primary sound signals recorded on said elemental areas by a traversal thereof, means for producing a repeated traversal of a substantially
 45 endless band of said record surface by said recording device to thereby record primary sound signals on elemental areas within said endless band and a repeated traversal of said endless
 50 band by said signal-translating device at substantially the same speed as the traversal thereof by the recording device, said speed of traversal being such as to produce a plurality of traversals
 55 of the endless band by the signal-translating device during the period in which phosphorescent records are retained thereby so that a plurality of successive, successively decaying secondary
 60 sound electric signals similar to a primary sound signal recorded on elemental areas in said endless band are derived therefrom, and means for combining said primary sound electric signal
 65 with the secondary sound electric signals so derived therefrom.

17. In apparatus for introducing reverberation into a primary sound electric signal, in combination, a phosphorescent record surface adapted to
 65 fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a recording device responsive to a modulated
 70 primary sound electric signal and adapted to record a corresponding modulated phosphorescent sound signal record on elemental areas of said phosphorescent surface passing thereby, means for producing a continuous uniform relative
 75 movement between said recording device and

said phosphorescent surface such that elemental areas of an endless band of said phosphorescent surface repeatedly pass said recording device, whereby a modulated primary sound signal may be continuously recorded on the elemental areas of said endless band, a photoelectric signal-translating device responsive to a phosphorescent record on said surface and adapted to derive a secondary sound electric signal similar to said primary sound electric signal from the phosphorescent primary sound signal record on elemental areas of said surface passing thereby, means for producing a continuous uniform relative movement between said signal-translating device and said phosphorescent record surface such that elemental areas of said endless band repeatedly pass said signal translating device at substantially the same speed as said elemental areas pass said recording device, said speed being such that elemental areas of said endless band pass said signal-translating device a plurality of times during the period in which phosphorescent records are retained thereby so that a plurality of successive, successively decaying secondary sound electric signals similar to a primary sound electric signal recorded on elemental areas in said endless band are derived therefrom, and means for combining said primary sound electric signal with the secondary sound electric signals so derived therefrom.

18. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, said records gradually decaying during the period in which they are retained, recording means responsive to a primary signal and adapted to form on successive elemental areas of an endless area of said record surface a modulated primary signal record corresponding to said primary signal, signal-translating means responsive to signal records on said elemental areas and constructed and adapted to simultaneously derive a plurality of secondary signals from a corresponding plurality of spaced areas within said endless band by simultaneous traversals thereof, and means for producing traversals of said endless area of the record surface by said signal-translating means a plurality of times during the period in which a primary signal record is retained on said record surface so as to produce a plurality of successive secondary signals similar to a primary signal recorded on elemental areas of said endless area during each traversal of the endless area by the signal-translating means during said period.

19. In apparatus for deriving a plurality of secondary sound signals from a primary sound signal, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a recording device responsive to a primary sound signal and adapted to form a corresponding phosphorescent primary sound signal record on elemental areas within an endless band of said record surface by a traversal thereof, signal-translating means responsive to signal records on said elemental areas and including a plurality of elements spaced apart along said endless band so that a corresponding plurality of spaced areas within said endless band may be simultaneously traversed by said signal-translating means to thereby simultaneously derive a plurality of secondary sound signals from said spaced areas, and means for producing traversals of said endless area of the record sur-

face by said signal-translating means a plurality of times during the period in which a primary signal record is retained on said record surface so as to produce a plurality of successive secondary signals similar to a primary signal recorded on elemental areas of said endless area during each traversal of the endless area by the signal-translating means during said period.

20. In apparatus for introducing reverberation signals into a primary sound electric signal, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a recording device responsive to a modulated primary sound electric signal and adapted to record a corresponding modulated phosphorescent sound signal record on elemental areas of said phosphorescent surface passing thereby, means for producing a continuous uniform relative movement between said recording device and said phosphorescent surface such that elemental areas of an endless band of said phosphorescent surface repeatedly pass said recording device, whereby a modulated primary sound signal may be continuously recorded on the elemental areas of said endless band, a plurality of photoelectric signal-translating devices responsive to a phosphorescent record on said surface and adapted to derive secondary sound electric signals similar to said primary sound electric signal from the signal record on elemental areas of said surface passing thereby, said signal-translating devices being spaced apart along said endless band, means for producing a continuous uniform relative movement between said signal translating devices and said phosphorescent record surface such that elemental areas of said endless band repeatedly pass said signal translating devices at substantially the same speed as said elemental areas pass said recording device, said speed being such that elemental areas within said endless band pass the signal-translating devices a plurality of times during the period in which phosphorescent records are retained thereby so that a plurality of successive secondary sound electric signals similar to a primary sound electric signal recorded on elemental areas of said endless band are derived therefrom by each of said signal-translating devices during said period, and means for combining said primary sound electric signal with the secondary sound electric signals so derived therefrom.

21. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, said records gradually decaying during the period in which they are retained, recording means responsive to an electric signal and adapted to form on successive elemental areas of an endless area of said record surface a primary signal record corresponding to a primary electric signal, a signal-translating device responsive to signal records on said elemental areas and adapted to derive a secondary electric signal similar to a primary signal recorded thereon by a traversal of said elemental areas successively, means for producing a traversal of said endless area of the record surface by said signal-translating device a plurality of times during the period in which a primary signal record is retained on said record surface so as to produce a plurality of successively decaying secondary electric signals similar to a primary signal recorded on elemental areas of said endless area, and means for feeding back at least a portion of

said secondary electric signals to said recording means for recording on said record surface.

22. In apparatus for introducing reverberation signals into a primary sound electric signal, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a recording device responsive to a primary sound electric signal and adapted to form a corresponding primary sound signal record on elemental areas of said record surface by a traversal thereof, a signal-translating device responsive to signal records on said elemental areas and adapted to derive secondary sound electric signals similar to primary sound signals recorded thereon by a traversal of the elemental areas, means for producing a repeated traversal of a substantially endless band of said record surface by said recording device to thereby record primary sound signals on elemental areas within said endless band and a repeated traversal of said endless band by said signal-translating device at substantially the same speed as the traversal thereof by the recording device, said speed of traversal being such as to produce a plurality of traversals of the endless band by the signal-translating device during the period in which phosphorescent records are retained thereby so that a plurality of successive, successively decaying secondary sound electric signals similar to a primary sound signal recorded on elemental areas in said endless band are derived therefrom, means for feeding back at least a portion of said secondary sound electric signals to said recording device so that further secondary sound electric signals may be derived from the record of the signals fed back, and means for combining said primary sound electric signal with the secondary sound electric signals so derived therefrom.

23. In apparatus for introducing reverberation signals into a primary sound electric signal, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a recording device responsive to a modulated primary sound electric signal and adapted to record a corresponding modulated phosphorescent sound signal record on elemental areas of said phosphorescent surface passing thereby, means for producing a continuous uniform relative movement between said recording device and said phosphorescent surface such that elemental areas of an endless band of said phosphorescent surface repeatedly pass said recording device, whereby a modulated primary sound signal may be continuously recorded on the elemental areas of said endless band, a plurality of photoelectric signal-translating devices responsive to a phosphorescent record on said surface and adapted to derive secondary sound electric signals similar to said primary sound electric signal from the signal record on elemental areas of the surface passing thereby, said signal-translating devices being spaced apart along said endless band, means for producing a continuous uniform relative movement between said signal-translating devices and said phosphorescent record surface such that elemental areas of said endless band repeatedly pass said signal-translating devices at substantially the same speed as said elemental areas pass said recording device, said speed being such that elemental areas with-

in said endless band pass the signal-translating devices a plurality of times during the period in which phosphorescent records are retained thereby so that a plurality of successive secondary sound electric signals similar to a primary sound electric signal recorded on elemental areas of said endless band are derived therefrom by each of said signal-translating devices during said period, means for feeding back at least a portion of said secondary sound electric signals to said recording device so that further secondary sound electric signals may be derived from the record of the signals fed back, and means for combining said primary sound electric signal with the secondary sound electric signals so derived therefrom.

24. In apparatus for introducing reverberation signals into a primary sound electric signal, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, means responsive to a primary sound electric signal for forming on elemental areas of said phosphorescent record surface a corresponding primary sound signal record, a signal-translating device adapted to derive a secondary sound electric signal corresponding to a primary sound electric signal from a primary sound signal record on said elemental areas by a traversal thereof, means for producing a plurality of traversals of said elemental areas by said signal-translating device during the period in which a primary sound signal record is retained thereon to thereby derive a plurality of successive, successively decaying secondary sound electric signals corresponding to a primary sound electric signal by said signal-translating device during said period, an output circuit, means for supplying said primary sound electric signal to said output circuit, a selective filter, and means for supplying said secondary sound electric signals to said output circuit through said selective filter.

25. In apparatus for introducing reverberation signals into a primary sound electric signal, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a recording device responsive to a modulated primary sound electric signal and adapted to record a corresponding modulated phosphorescent sound signal record on elemental areas of said phosphorescent surface passing thereby, means for producing a continuous uniform relative movement between said recording device and said phosphorescent surface such that elemental areas of an endless band of said phosphorescent surface repeatedly pass said recording device, whereby a modulated primary sound signal may be continuously recorded on the elemental areas of said endless band, a signal-translating device responsive to a phosphorescent record on said phosphorescent surface and adapted to derive a secondary sound electric signal similar to said primary sound electric signal from the phosphorescent primary sound signal record on elemental areas of said surface passing thereby, means for producing a continuous uniform relative movement between said signal-translating device and said phosphorescent record surface such that elemental areas of said endless band repeatedly pass said signal translating device at substantially the same speed as said elemental areas pass said recording device, said

speed being such that elemental areas of said endless band pass said signal translating device a plurality of times during the period in which phosphorescent records are retained thereby so that a plurality of successive, successively decaying secondary sound electric signals similar to a primary sound signal recorded on elemental areas in said endless band are derived therefrom, an output circuit, means for supplying said primary sound electric signal through a variable attenuator to said output circuit, means for supplying said secondary sound electric signals through a variable attenuator to said output circuit, and coupling means between said attenuators for changing the attenuations produced by said attenuators in opposite directions when the attenuators are varied so as to maintain the sum of the primary and secondary signals substantially constant as their ratio is changed.

26. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, means for forming on elemental areas of said record surface a primary signal record corresponding to a primary signal, a signal-translating device adapted to derive a secondary signal from a primary signal record on said elemental areas by a traversal thereof, means for producing a plurality of successive traversals of said elemental areas by said signal-translation device during the period in which the primary signal record is retained on said record surface, whereby a plurality of secondary signals may be derived from a primary signal record by said signal-translating device during said period, and means for partially erasing the primary signal record between successive traversals of said elemental areas by said signal translating device.

27. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, said records gradually decaying during the period in which they are retained, means for forming on elemental areas of said record surface a primary signal record corresponding to a primary signal, a signal translating device adapted to derive from the passing thereby of a primary signal record on said elemental areas a secondary signal corresponding to said primary signal, means for producing relative movement between said signal-translating device and said record surface such that elemental areas bearing a primary signal record pass said signal-translating device a plurality of times during the period in which the primary signal record is retained on said record surface, whereby a plurality of successively decaying secondary signals similar to said primary signal may be derived from a primary signal record by said signal-translating device during said period, and means for partially erasing the primary signal record between successive passings of the record by said signal-translating device to thereby augment the natural decay of the primary signal record between the derivations of successive secondary signals.

28. In a signal-translation apparatus, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a recording device responsive to a modulated primary electric signal and adapted to record a corresponding modulated phosphorescent primary signal record on elemental

areas of said phosphorescent surface passing thereby, means for producing a continuous uniform relative movement between said recording device and said phosphorescent surface such that elemental areas of an endless band of said phosphorescent surface repeatedly pass said recording device, whereby a modulated primary signal may be continuously recorded on the elemental areas of said endless band, a signal-translating device responsive to a phosphorescent record on said phosphorescent surface and adapted to derive a secondary electric signal similar to said primary electric signal from the phosphorescent primary signal record on elemental areas of said surface passing thereby, means for producing a continuous uniform relative movement between said signal-translating device and said phosphorescent record surface such that elemental areas of said endless band repeatedly pass said signal-translating device at substantially the same speed as said elemental areas pass said recording device, said speed being such that elemental areas of said endless band pass said signal-translating device a plurality of times during the period in which phosphorescent records are retained thereby so that a plurality of successive, successively decaying secondary electric signals similar to said primary signal recorded on elemental areas in said endless band are derived therefrom, a source of infrared radiation positioned and adapted to partially erase a primary signal record between successive passings of elemental areas of said endless band by said signal translating device to thereby augment the natural decay of the primary signal record between the derivations of successive secondary signals, and means for combining said primary electric signal with the secondary electric signals so derived therefrom.

29. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, means for forming on said record surface a primary signal record corresponding to a primary signal, means for successively deriving a plurality of secondary signals from said primary signal record, and means for partially erasing the primary signal record between the derivations of successive secondary signals.

30. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, said records gradually decaying during the period in which they are retained, means for forming on elemental areas of said record surface a primary signal record corresponding to a primary signal, means for successively deriving a plurality of secondary signals from a primary signal record on said elemental areas by successive traversals of said elemental areas during the period in which the primary signal record is retained thereon, and means for partially erasing the primary signal record between the successive traversals of said elemental areas to thereby augment the natural decay of the primary signal record between the derivations of successive secondary signals.

31. In a signal-translation apparatus, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a recording device responsive to a modulated primary electric signal and adapted to record a corresponding modulated phosphorescent primary signal record on elemental areas of said phosphorescent surface passing

thereby, means for producing a continuous uniform relative movement between said recording device and said phosphorescent surface such that elemental areas of an endless band of said phosphorescent surface repeatedly pass said recording device, whereby a modulated primary signal may be continuously recorded on the elemental areas of said endless band, means responsive to a phosphorescent record on said surface and adapted to successively traverse said elemental areas during the period in which the primary signal record is retained thereon to thereby derive a plurality of successive secondary electric signals similar to said primary electric signal, means for irradiating said elemental areas between the successive traversals thereof with infrared light to partially erase the primary signal record thereon and thereby augment the natural decay of the primary signal record between the derivations of successive secondary signals, and means for combining said primary electric signal with the secondary electric signals so derived therefrom.

32. In a signal-translation apparatus, in combination, a record surface adapted to fugitively retain records formed thereon, said records gradually decaying during the period in which they are retained, a cathode-ray recording device adapted to produce a record on elemental areas of said record surface, means for oscillating the cathode-ray beam in said recording device at a relatively high frequency to form a line record on said record surface, means for modulating the amplitude of the oscillations of the cathode-ray beam and the intensity of the beam in accordance with a primary signal to thereby produce corresponding modulated line records on said record surface, means for traversing successive line elements of said record surface with said cathode-ray recording device to form a record of said primary signal thereon, a signal-translating device adapted to derive a secondary signal corresponding to said primary signal from a primary signal record on said line elements by a traversal thereof, and means for producing a plurality of traversals of said line elements by said signal-translating device during the period in which the primary signal record is retained on said record surface, whereby a plurality of successively decaying secondary signals similar to said primary signal may be derived from a primary signal record by said signal-translating device during said period.

33. In apparatus for deriving a plurality of secondary sound signals from a primary sound signal, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a cathode-ray recording device adapted to produce a phosphorescent record on elemental areas of said record surface, means for oscillating the cathode-ray beam in said recording device at a relatively high frequency to form a line record on said record surface, means for modulating the amplitude of the oscillations of the cathode-ray beam and the intensity of the beam in accordance with a primary sound signal to thereby produce corresponding modulated line records on said record surface, means for repeatedly traversing successive line elements of a substantially endless band of said phosphorescent record surface with said cathode-ray recording device to form a record of said primary sound signal thereon, a

signal-translating device adapted to derive a secondary signal corresponding to a primary sound signal from a primary sound signal record on said line elements by a traversal thereof, and means for producing a plurality of traversals of said line elements by said signal-translating device during the period in which a primary sound signal record is retained thereon to thereby derive a plurality of successive, successively decaying secondary signals corresponding to a primary sound signal by said signal-translating device during said period.

34. In apparatus for deriving a plurality of secondary sound signals from a primary sound signal, in combination, a phosphorescent record surface adapted to fugitively retain phosphorescent records formed thereon, said phosphorescent records gradually decaying during the period in which they are retained, a cathode-ray recording device adapted to produce a phosphorescent record on elemental areas of said record surface, means for oscillating the cathode-ray beam in said recording device at a relatively high frequency to form a line record on said record surface, means for modulating the amplitude of the oscillations of the cathode-ray beam and the intensity of the beam in accordance with a primary sound signal to thereby produce corresponding modulated line records on said record surface, means for repeatedly traversing successive line elements of a substantially endless band of said phosphorescent record surface with said cathode-ray recording device to form a record of said primary sound signal thereon, a signal-translating device adapted to derive a secondary signal corresponding to a primary sound signal from a primary sound signal record on said line elements by a traversal thereof, and means for producing a traversal of said line elements by said signal-translating device to thereby derive a secondary signal corresponding to said primary sound signal.

35. In a signal-translation apparatus, in combination, a lamp of the mercury-vapor type, means for producing a biasing current in said lamp, means for modulating the said biasing current to thereby modulate the light emitted by said lamp in accordance with a primary signal, means for slowly varying the magnitude of said biasing current substantially in accordance with the amplitude of the primary signal, a record surface responsive to the light of said lamp and adapted to fugitively retain records formed thereon by said light, means for traversing elemental areas of said record surface with light from said lamp to produce a primary signal record thereon corresponding to said primary signal, a signal-translating device adapted to derive a secondary signal from a primary signal record on said elemental areas by a traversal of said elemental areas, and means for producing a plurality of traversals of said elemental areas by said signal-translation device during the period in which the primary signal record is retained on said record surface, whereby a plurality of secondary signals may be derived from a primary signal record by said signal-translating device during said period.

36. In apparatus for deriving a plurality of secondary sound signals from a primary sound signal, in combination, a lamp of the mercury-vapor type, an energizing circuit for said lamp including a source of voltage adapted to provide a biasing current in said lamp, means for modulating the said biasing current in accordance

with a primary sound signal to thereby modulate the light emitted by said lamp in accordance with the primary sound signal, means responsive to the amplitude of the waves of said sound signal for varying the magnitude of said biasing current substantially in accordance with the envelope of said waves, the last-mentioned means being correlated with the amplitude of the sound signal and the energizing circuit so that during normal operation the current through the lamp does not fall substantially below the extinction current, a phosphorescent record surface responsive to the light of said lamp and adapted to fugitively retain phosphorescent records formed thereon by said light, said phosphorescent records gradually decaying during the period in which they are retained, means for traversing elemental areas of said record surface with light from said lamp to produce a primary signal record thereon corresponding to said primary sound signal, a signal-translating device adapted to derive a secondary signal from a primary signal record on said elemental areas by a traversal of said elemental areas, and means for producing a plurality of traversals of said elemental areas by said signal-translation device during the period in which the primary signal record is retained on said record surface, whereby a plurality of secondary signals may be derived from a primary signal record by said signal-translating device during said period.

37. In apparatus for deriving a plurality of secondary sound signals from a primary sound signal, in combination, a lamp of the mercury-vapor type, an energizing circuit for said lamp including a source of voltage adapted to provide a biasing current in said lamp, means for modulating the said biasing current in accordance with a primary sound signal to thereby modulate the light emitted by said lamp in accordance with the primary sound signal, means responsive to the amplitude of the waves of said sound signal for varying the magnitude of said biasing current substantially in accordance with the envelope of said waves, a phosphorescent record surface responsive to the light of said lamp and adapted to fugitively retain phosphorescent records formed thereon by said light, said phosphorescent records gradually decaying during the period in which they are retained, means for traversing an endless band of said surface with light from said lamp to thereby produce a modulated phosphorescent primary sound signal record on said surface, a signal-translating device responsive to a phosphorescent signal record and adapted to derive a secondary sound electric signal corresponding to a primary sound signal recorded on said surface by a traversal thereof, and means for traversing said endless band of the phosphorescent surface with said signal-translating device.

38. In a signal-translation apparatus, in combination, a mercury-vapor lamp, means for modulating the light of said lamp in accordance with a primary signal, a cooling device positioned and adapted to cool said lamp, means for controlling the operation of said cooling device to maintain the average value of the current through the lamp substantially constant, a record surface responsive to the light of said lamp and adapted to fugitively retain records formed thereon by said light, means for traversing elemental areas of said record surface with light from said lamp to produce a primary signal record thereon corresponding to said primary signal, a signal-translating

device adapted to derive a secondary signal from a primary signal record on said elemental areas by a traversal of said elemental areas, and means for producing a plurality of traversals of said elemental areas by said signal-translation device during the period in which the primary signal record is retained on said record surface, whereby a plurality of secondary signals may be derived from a primary signal record by said signal-translating device during said period.

39. In a signal-translation apparatus, in combination, a mercury-vapor lamp, an energizing circuit for said lamp including means for modulating the light of said lamp in accordance with a primary signal, a cooling device positioned and adapted to cool said lamp, means responsive to the current passing through said lamp for controlling the operation of said cooling device to maintain the average value of said current during normal operation of said lamp substantially constant, a record surface responsive to the light of said lamp and adapted to fugitively retain records formed thereon by said light, means for traversing elemental areas of said record surface with light from said lamp to produce a primary signal record thereon corresponding to said primary signal, a signal-translating device adapted to derive a secondary signal from a primary signal record on said elemental areas by a traversal thereof, and means for producing a plurality of traversals of said elemental areas by said signal-translation device during the period in which the primary signal record is retained on said record surface, whereby a plurality of secondary signals may be derived from a primary signal record by said signal-translating device during said period.

40. In a signal-translation apparatus, in combination, a mercury-vapor lamp of the high-pressure type, an energizing circuit for said lamp including a source of direct current voltage, means for modulating the light of said lamp in accordance with a primary sound signal, a cooling device positioned and adapted to cool said lamp, relay means responsive to the current passing through said lamp for controlling the operation of said cooling device to maintain the average value of said current during normal operation of said lamp at a substantially constant value, said relay means operating to increase the cooling of said lamp when the average current therethrough falls below said value and to decrease the cooling when the average current exceeds said value, a luminescent record surface responsive to the light of said lamp and adapted to fugitively retain luminous records formed thereon by said light, said luminous records gradually decaying during the period in which they are retained, means for producing relative movement between said lamp and said luminescent surface such that a substantially endless band of said surface is repeatedly traversed by light from said lamp to produce a modulated luminous primary signal record on said surface corresponding to said primary sound signal, a signal-translating device responsive to a luminous record on said luminescent surface and adapted to derive a secondary electric signal similar to a primary signal recorded on said surface by a traversal thereof, and means for producing relative movement between said signal-translating device and said luminescent record surface such that the signal-translating device repeatedly traverses said endless band at a speed such that a plurality of traversals take place during the period in which a primary sig-

nal record is retained thereby so as to derive a plurality of successively decaying secondary sound electric signals corresponding to a primary sound signal recorded on said endless band.

41. In apparatus employing a mercury-vapor lamp as a source of modulated light, in combination, means for modulating the light of said lamp, a cooling device positioned and adapted to cool said lamp, and means for controlling the operation of said cooling device to maintain the average value of the current through the lamp substantially constant.

42. In apparatus employing a mercury-vapor lamp as a source of modulated light, in combination, an energizing circuit for said lamp including means for modulating the light of said lamp in accordance with a primary signal, a cooling device positioned and adapted to cool said lamp, and means responsive to the current passing through said lamp for controlling the operation of said cooling device to maintain the

average value of said current during normal operation of said lamp substantially constant.

43. In apparatus employing a mercury-vapor lamp of the high-pressure type as a source of modulated light, in combination, an energizing circuit for said lamp including a source of direct current voltage, means for modulating the light of said lamp in accordance with a primary sound signal, a cooling device positioned and adapted to cool said lamp, and relay means responsive to the current passing through said lamp for controlling the operation of said cooling device to maintain the average value of said current during normal operation of said lamp at a substantially constant value, said relay means operating to increase the cooling of said lamp when the average current therethrough falls below said value and to decrease the cooling when the average current exceeds said value.

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