Method and apparatus for electrically recording and reproducing sound or other vibrations.

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This invention relates to a new and improved method and system of electrically recording and reproducing electric currents, more especially those of sound frequency.

In my invention, as hereinafter described, I record the electric current directly by means of its action on a suitable medium, preferably a prepared tape, without the use of any intermediate apparatus, such as a device for causing the electric current to vary the intensity or direction of a beam of light, as is commonly used in recording systems at present in use.

An object of my invention is to simplify the recording and reproducing of electric impulses by eliminating the use of light sensitive materials and any necessity for the development or fixation of the same.

Another object of my invention is the elimination of the use of costly and delicate optical apparatus in the recording system.

Another object of my invention is to simplify and increase the efficiency of the reproduction of the recorded sounds or currents.

Another object of my invention is to provide a system whereby the same machine may be used for recording and immediately reproducing the recorded signals for monitoring and other purposes.

A further object of my invention is to provide an apparatus and method for recording light waves, sound waves, or other mechanical vibrations and automatically reproducing the recorded signals after a predetermined lapse of time.

A further object of my invention is to provide an apparatus in which the recording may be done at one time and the reproducing immediately thereafter or at any desired subsequent time.

Still another object of my invention is to provide a method and apparatus for recording mechanical vibrations by producing indices on a tape and subsequently transforming these indices into an accurate reproduction of the mechanical vibrations.

Another object of my invention is to provide a means for recording sound waves or other mechanical vibrations by producing indices on a tape which can be kept for long periods of time without substantial deterioration.

A further object of my invention is to provide a means for recording light impulses, sound waves, or other mechanical vibrations by producing visual indices on a tape which can be immediately used for analyzing the various frequency characteristics of the vibrations.

Other objects of my invention will be apparent from the following disclosures:

Figure 1 is an assembled view of a combined recording and reproducing mechanism;

Fig. 2 is a schematic diagram of an amplifier;

Fig. 3 is a view, partly in section, taken on line 3–3 of Fig. 1;

Fig. 4 is an elevation of a modified form of recording mechanism;

Fig. 5 is a view, partly in section, taken on line 5–5 of Fig. 4;

Fig. 6 is a view of another form of recording mechanism;

Fig. 7 is a side view of the recording arm of Fig. 6;

Fig. 8 is an end view of the recording arm of Fig. 6;

Fig. 9 is a diagram of a battery-operated recording apparatus;

Fig. 10 is an enlarged view of the recording arm shown in Fig. 1;

Fig. 11 is a section on line 11–11, Fig. 10; and

Fig. 12 shows a fragment of a tape partly used.

A suitable frame is shown in Fig. 1 on which is supported a supply reel 2 and a receiving reel 25. A tape 4, for receiving marks or indices, carrying a suitable chemical compound (as more fully explained hereafter) is fed from the supply reel 2 between a fixed contact 8 and a movable contact 6 of a recording mechanism A, and then, if it is desired to immediately reproduce the recorded signals, is lead over an exposure guide 7 of the reproducing mechanism C. The tape then passes between the rollers 8 and 9 to the receiving reel 3.

A motor 10 is provided to furnish power and operate preferably through any suitable variable speed gear reduction 11 to drive the shaft 12 on which is mounted a pulley 13. Suitable belts 14 and 15 are driven from a portion of the pulley 13 and pass over pulleys 16 and 17 connected to the shafts 18 and 19 which carry the reels 2 and 3 respectively, the shafts 16 and 17 being suitably supported in the frame. The crossed driving belt 20 receives power from pulley 13 for driving the constant speed roller 9 through a suitable pulley connection. The motor 10 is preferably an electric motor of the constant speed type but may be any suitable driving mechanism.

In order that the tape 4 may be passed at constant speed through the apparatus for recording or reproducing, the tape is driven by the constant speed roller 8 and the companion roller 9 resiliently mounted to press against the tape. The belt 14 operating between the pulley 13 and
the receiving reel 3 is so mounted on the pulleys 13 and 16 that it can slip and only revolves the reel 3 at a sufficient rate of speed to keep a suitable tension on the tape as it comes from the constant speed rollers 8 and 9. The tension on the tape from the constant speed rollers revolves reel 2 and unwinds the tape from the reel, but in order to keep a suitable tension on the tape any suitable retardage mechanism may be provided, and in the mechanism shown the belt 15 is mounted between pulleys 13 and 17 so that it tends to drive the reel in the opposite direction, but is sufficiently loosely mounted on the pulleys and act as a brake to keep the desired tension on the tape. When the tension of the constant speed rollers is released from the tape, however, the belt 15, which is provided with more tension than the belt 14, will act as a driving belt for rewinding the tape on the supply reel 2, and in this case the belt 14 acts to retard the reel 3 to preserve the desired tension on the tape.

The constant speed pulley 8 is carried at one end of the arm 21, which is rotatably supported on a shaft 22 at the other end. Shaft 22 is mounted on frame 1, and a screw tensioning device 23 is also mounted on the frame for adjusting the arm 21 to secure the desired pressure between the rollers 8 and 9 for driving the tape.

In the recording mechanism the fixed contact 5 is mounted on an insulating panel 25, and is preferably of brass but may be of any good electrically conducting material, and is preferably provided with a curved, polished surface 26 to facilitate the passage of the tape thereover and to provide a convex surface.

A movable contact holding arm 27 is mounted for pivotal movement on the pivot member 28 carried by the insulating panel 25. Mounted on the arm 27 is a balance weight 29 which may be adjusted along the threaded portion 30 of the contact arm. Carried by the arm 27 is a collar 31 preferably of insulating material. To one side of the collar, spring 32 is connected, the other end of the spring being carried by an adjusting screw 33 which passes through an aperture on the threaded stud 34 and is adjustable by means of a threaded nut 34 which bears against the stud 34. The stud 34 is mounted to the panel 25. A yoke 35 is also carried by the collar 31, the yoke being provided so that the tape 4 may pass between the sides thereof without contacting therewith. A stud 36 is similarly carried by the panel 25 through an aperture in which the screw 37 is passed, the screw being connected to the yoke 35 by means of a tension spring 38. A nut 39 engages the threaded end of the screw 37 and bears against the stud 38 so that the screw may be adjusted.

A contact holder 40 is pivotally secured to the free end of the arm 27 by means of a screw 41 passing through the members 42 of the contact holder and arm 27. At the outer end of the contact holder 40 a slot 52 is provided to receive a contact blade 6. Secured to the holder 40 is a compression spring 43 in which a set screw 44 is threaded so that the set screw may be adjusted to clamp the blade 6 tightly in the holder.

An amplifier 45, which may be of the type shown in Fig. 2, is provided with suitable terminals 46 and 47. From the terminal 47 a lead 50 electrically connects terminal 46 to the fixed contact 5. The lead 51 connects the terminal 47 through the arm 27 to the movable contact 6.

The contact 6 is preferably a thin, stiff blade of any good electrical conducting material, such as a platinum alloy, steel, phosphor bronze or the like. It should be made of a material that it will resist the wear due to the frictional engagement of the tape and which will stand up under the action of electrical current, and not be readily attacked by the chemical compounds carried by the tape.

For recording frequencies within the audible range the blade 6 should be as thin as practicable and still be sufficiently rigid to resist deformations due to the forces acting thereon by the passing of the tape, and the pressure between it and the fixed contact 5. Steel blades as thin as one and half millims have been successfully used. As the blade wears it may be adjusted in the slot 52 and reset by the set screw 44 to be rigidly held in the contact holder. The width of the blade may vary within wide limits dependent upon the current density used, the resistance of the tape and the width of record desired for reproduction purposes. A blade of one-eighth inch width has given good results with the above described apparatus.

The moment of inertia of the arm 27 about the pivot 4 is very small in order to obtain the desired engagement of the tape so that effective vibration of the contact 6 is prevented. The tension on the springs is also adjustable to cooperate with the moment of inertia as determined by the weight and at the same time regulate the pressure of the contact 6 upon the tape 4 and give the arm 27 a natural period most suitable for recording the impressed signals.

If it is not desired to reproduce the recordings immediately after the recording is made by means of the recording mechanism, the tape 4 may be passed directly to the constant speed rollers 8 and 9.

In the construction shown in Fig. 1, however, the tape is shown as passing through a reproducing mechanism C about to be described.

The reproducing mechanism shown in Fig. 1 consists of a concentrated filament lamp 55 and lens system 56 of the type used in sound film reproduction. The filament 55 is the usual form of selenium lamp. The lamp and lens system is used in my apparatus for concentrating the light on the tape 4 as it passes over the exposure guide 7 through a slotted aperture 57 in the wall of the compartment.

The light is reflected from the tape 4 into a suitable light sensitive device such as a photo-electric cell 58, the resistance of which is thereby caused to vary in response to the variations in intensity of the reflected light, due to indices or markings recorded upon the tape 4. The variations in resistance are translated into voltage variations and amplified in the usual manner by a suitable amplifier indicated at 59. The lamp 55 is supplied with current in any suitable manner such as by the battery 60 or by a transformer and filter or rectifier. The lamp 55 and lens system 56 and the photo-electric cell are preferably enclosed in suitable compartments so that unwanted light does not reach the tape 4 or the photo-electric cell.

While I have shown a well known type of slot image lens system for projecting a band of light on the tape 4, it is to be understood that any means of projecting a concentrated band of light on the tape 4 may be used, such as a plate having
a narrow aperture through which the light passes, and placed directly in front of the tape, and between it and the light source and a light sensitive device responsive to variations in intensity of light, such as a suitable photo cell. In either case, the light reflected from the tape preferably should be a band at least as narrow as the finest width of the finest division recorded on the tape 4 in order to secure faithful reproduction of the highest frequency recorded.

The frequencies which are reproduced depend upon the speed of the tape, the clearness of the definition and width of the recorded indices, and the width of the slot image used for reproducing. The recording and reproduction of higher overtones of voice or music can, of course, be facilitated by increasing the tape speed.

A modified form of recording mechanism is shown in Figs. 4 and 5. In this construction the tape 4 passes between a pair of rollers 60 and 61 which are electrically connected through the leads 62 and 63 and the flexible connections 64 and 65 to the recording amplifier. Their connections slidingly engage the rollers. The roller 61 is mounted for rotation on the fixed pivot 66 which is mounted on an insulating frame 67. The roller 60 is mounted for rotation on the contact arm 68 which is rotatably mounted on the insulating frame 67. Adjustable mechanism is provided for swinging the arm about the pivot 69 to move it toward or away from the tape 4 to adjust the pressure of the rollers upon the tape. The mechanism for making the adjustment consists of a threaded aperture in the stud 71 carried by the frame. The screw 70 is provided with a collar 72 so that the compression spring 73 is held between the screw and the arm 68 to maintain a yielding pressure, whereby irregularities in the tape can be compensated for. The arm 68 has a cut out portion to engage spring 73. In order to move the roller 60 away from tape 4 a tension spring 75 is carried between arm 68 and stud 76.

In this construction the fine markings due to rapidly varying electrical impulses may be recorded on the tape.

Figs. 6, 7 and 8 show still another modified form of recording mechanism. In this form the tape 4 passes over a fixed contact 80. The contact member 81 is attached to a movable arm 82 which is adapted to be raised and lowered by the action of the moving member 83 of a phonograph pick-up or recorder 84 which is adjustable secured to the lever arm 55 by screw 56 engaging with the back of the recorder housing. A tension spring 87 is attached to lever arm 55 at one end and to a securing means 86 at the other end. An adjusting screw 89 working through stud 90 carries a connector 91 which is fastened to lever arm 85 and engages screw 92. An adjusting nut 92 is provided to hold the screw in adjusted position.

The spring 87 and the screw 89 provide a means for accurately positioning the arm 85 so that the movable contact member 81 is held in the desired position. The movable contact lever arm 85 is rotatably connected to insulating panel 93 by shaft 94. Fixed contact 80, stud 90, and spring holder 98 are also mounted to this insulating panel.

The current from a recording amplifier is lead into the actuating winding of the phonograph recorder or pick-up through the terminal leads 88 and 86.

One terminal of a source of direct current potential, such as a battery or generator, is connected to lead 97 and connected to arm 82 through a very flexible lead 86. The other terminal of such source is connected to fixed contact 80 through lead 99. The fixed contact 80 is insulated from the rest of the circuit and is similar in form and function to the contact 5, Fig. 1. The contact member 91 is secured to the arm 82 and is preferably thin for sharply defining the marks or indices recorded on the tape by the action of the electrical current passing between the contacts 80 and 81. In operation the arm 82 tends to move in response to the signals, bringing the contact 81 either in heavy or light contact with the tape, or causing it to leave the tape altogether, according to the direction and intensity of the signals impressed upon the leads 95 and 96. This is especially suitable for recording the ordinary code signals, or any signal not requiring exceedingly fine graduations of frequency or tone.

While I have shown, for convenience, the mounting of considerable of the various recording mechanisms disclosed in this application on an insulating panel, it is to be understood that they may be suitably mounted on a supporting frame and electrically insulated therefrom in any suitable manner.

Fig. 2 shows diagrammatically an electrical sys- tem adapted for recording or reproducing in connection with my invention. A microphone amplifier as illustrated has a pick-up means for use when recording sound waves. In the direct coupled circuit the VT1 is a three element thermonic valve of the heater type commonly having an amplification factor 7 to 10. VT2 is a four element thermonic valve of the heater type having a screened plate. VT3 is an output thermonic valve of large capacity. The grid 105 of VT2 is directly connected to the plate 106 of VT1 and the grid 107 of VT3 is directly connected to the plate 105 of VT3. The plate 108 of VT3 is connected through the milliammeter 109 to the terminal 66.

The circuit shown in this figure is that of a direct connected amplifier differing from others of this type mainly in the values of the resistance and capacities used, which values are given below by way of example. 111 is a grid biasing resistance having a value of 25,000 ohms. Variable resistance 112, in series with resistance 113, has a maximum value of about 500,000 ohms. 113 is a fixed resistance of 500,000 ohms and is connected at one end to resistance 112 and at the other end between resistances 117 and 118. 114 is a grid biasing resistance for the valve VT2 and has a value of 25,000 ohms. 115 is a potentiometer having a resistance of about 400 ohms. 116 is a resistance of 5,000 ohms and resistance 117 has a value of 15,000 ohms. Resistance 118 has a value of 10,000 ohms and resistance 119 has a value of about 250,000 ohms, and may be variable. Condensers 120 and 121 have a value of about a half a micro-farad each. Condensers 122 and 123 are filter condensers, and have values of one micro-farad and two micro-farad capacity, respectively. Condensers 124 and 125 are one micro-farad each. 126 is a blocking condenser of about one-half micro-farad capacity. The values of these re-
sistances and condensers are those which I have found to give good results and these values may be departed from without affecting the spirit of the invention. A power transformer 127 has a primary winding adapted to the voltage and frequency of the circuit from which it is desired to draw power. The transformer 127 is also provided with three low tension windings lighting the filaments of the various valves employed in the amplifier and the high tension winding for use in conjunction with the rectifier valve 128 to provide high tension direct current for the various valves employed in the amplifier. The rectifier valve 128 is a full wave rectifier which is used as a half wave rectifier by having its plates connected as shown in Fig. 2 for the purpose of obtaining an increased output. The choke 129 should have a value of about 30 henries inductances. Terminal 130 is provided so that if desired, a loudspeaker for direct monitoring purposes may be connected between the terminal 130 and the terminal 136.

The points 131, 131, 131 indicated as grounded in Fig. 2 are connected to each other and this may be conveniently accomplished by connecting them to the metal frame or a suitable ground. In Fig. 9 is shown, diagrammatically, another system for supplying the varying electrical impulses to the recording contacts 140, 141 between which the tape 4 passes. These contacts are similar to those herebefore described.

In this form the signal to be recorded is supplied to the tube VT4, through audio amplifying transformer 142. The current passes from the battery 143, through the filament of the tube VT4, and is regulated in amount by the resistance 144. The battery 145 furnishes a suitable negative potential to the control member of the tube VT4 by a secondary winding of the audio frequency transformer 142. The potential of the control member relative to the filament can be adjusted by potentiometer 145. The battery 145 supplies the plate current to the tube VT4 through the contact members 140 and 141, and through the milliammeter 147 to the plate of the tube VT4. The operation of this device is as follows:

Incoming signals are impressed upon the control member of the tube VT4 by means of the audio frequency transformer or other means whereby the current in the plate circuit is caused to vary in accordance with these signals. The variations in the current passing through the tape at the contacts 140 and 141 cause marks or indices of different intensities to be formed upon the tape by the action of the current, proportional in intensity and frequency to the impressed signals.

The simplified form shown in Fig. 9 is especially convenient for recording telegraph messages, wherein the familiar "dot and dash" system is used.

For recording purposes a record receiving element is desired which is composed of a material which will carry chemicals reactive to the passage of electric current, and on which indices can be progressively recorded. A convenient form for such an element is that of a band or tape. It is desirable for the band or tape to have a smooth surface so that the movable electrode may readily maintain substantially uniform relation thereto. As an example of such material, I have found that a rag paper having a smooth calendered surface, or a sulphite paper not heavily filled or glazed, may be used.

The tape is treated or impregnated, preferably with a chemical solution which will react, upon the passage of an electric current between suitable contact electrodes, to produce a series of markings or spots corresponding to the frequency and intensity of the electric current impressed on the tape. A fragment of tape 4 with such marks or indices thereon is shown in Fig. 12.

Preferably, it is desired to use such a chemical solution which will produce marks of colored lines or dots, so that these lines or dots may be readily reproduced by means of a photo cell, or in any other manner.

I have found that a suitable bath for treating 15 these bands or tapes may be made with 150 parts of water, 20 parts of potassium ferro cyanide and 1 part of potassium cyanide.

The tape may be pressed to remove the excessive moisture, or dried, or otherwise conditioned. It is more convenient for use and for handling to have the tape only a low moisture content. I have found that the moisture content of the tape may vary over wide limits, from the almost normal content of paper of about 10% to a nearly saturated condition. However, as stated above, for practical purposes the low moisture content is desirable.

The use of potassium ferro cyanide and potassium cyanide in the impregnating bath gives a 30 tape upon which a clear, colored series of indices, such as dots or lines, may be formed by subjecting the tape to a varying electric current. The potassium cyanides seems to be of benefit in the solution, in that the dots or lines appear to be more sharp and defined when this is used, and this may be because the potassium cyanide acts as a solvent for minute portions of the decomposed product at the edges of the dots or lines formed by the action of the electric current on the tape.

Other impregnating chemicals may also be used, such, for example, as a solution of starch and potassium iodide, but this has not given as satisfactory results, because the dots or lines produced on the tape have not been as permanent as those produced by the potassium ferro cyanide bath, and the solution is more expensive.

The treated tape is preferably loaded on a reel or roll and, as shown in Fig. 1, fed from the reel 2 over the fixed contact 5 and under the movable contact 6. The speed of feeding the tape is preferably adjusted to give the best results, depending upon the frequency and intensity of the electric current passing between the contacts.

For example, I have found that in recording voice signals I can use speeds as low as 4½" (inches) per second, but it is usually preferable, for the best results, to use somewhat higher speeds to bring out the peculiar characteristics of a particular voice. For recording music, the speeds should preferably be somewhat higher than for voice. I have produced satisfactory music recordings with speeds not higher than 12 inches to 14 inches per second.

It is to be noted, however, that the optimum speed of recording is dependent, not only upon the speed of the current, and the reaction speed of the chemicals used to treat the tape, but also upon the quality of the results which it is desired to obtain.

Also, it may be noted that heat is liberated at the contact point when recording, and it may be that this liberation of heat facilitates the recording. The heating may be regulated by varying...
ing the signal intensity, the amplifier controls or the output impedance of the amplifier or by other well known means.

In operation, the position of the weight 29 (Fig. 1) on the recording arm 27 and the tension of the springs 32 and 38 are adjusted to give the arm 27 a natural period, which will help the movable contact 6 to follow smoothly any minute irregularities in the surface of the tape and prevent the arm from following an external impulse and responding to forced vibrations. An electric current flows from the rectifier 28 through the choke 29 (Fig. 2) to terminal 47 (Figs. 1 and 2) through the arm 27 and movable contact 6 through the tape 4 to the fixed terminal 5, through lead 50 and terminal 46 (Fig. 1) to the plate of VT3 (Fig. 2), from the plate of VT3 to the filament of VT3, from the filament of VT3 through the transformer winding 135, where it divides, part going back to rectifier 128 through resistance 132 and transformer winding 138, and part going to the plates of VT2 and VT1, through resistances 118, 119, 113 and 112, thence back to the rectifier 128.

When no signal is acting on the apparatus, the grid of VT1 is sufficiently negative with respect to the cathode so that the current flowing in the plate circuit is small. The drop through resistances 112 and 113 is, therefore, small, and grid 105 of VT2 is sufficiently positive so that a larger than normal current flows through the plate 105. The drop through resistance 118 is, therefore, larger than normal, and the grid 101 of VT3 is more negative than normal with respect to the filament 134 and current flowing to the plate 108, the milliammeter 109, terminal 46, and the moving contact and tape, is small. If the grid of VT1 is made more positive by an incoming signal, or otherwise, the current in the plate circuit of VT1 will increase, the current in the plate circuit of VT2 will decrease, and the current through the plate circuit of VT3 and the treated tape will increase, causing a line on the tape, the width of which is proportional to the time of duration of the signal or positive condition of the grid of VT1, and the intensity of which is proportional to the intensity of the current through the tape. Thus, a rapidly varying electro-motive force, such as the therapist, is transmitted as sound waves applied to the microphone 135 (Fig. 2) results in producing a series of fine indices or marks, such as lines, on the tape, the nature or character and frequency of which correspond to the volume and frequency of the succession of sound waves which are being recorded.

The signals impressed upon the grid 107 of the vacuum tube VT3 are of sufficient intensity to swing the grid potential to a positive value, causing marked variations in the plate current of the tube. The milliammeter 109 indicates these variations and furnishes a criterion of the character of the record being made upon the tape. It sometimes happens that the tape has what might be termed a "threshold" value of current, so that a current of sufficient intensity must be applied to the grid of the tube before a record is made. The normal direct current component of the plate current of the valve VT3 is usually sufficient for this purpose, but in case a larger direct current component is required, the plate current of the valve VT3 may be increased by connecting a resistance, as 132, between the center tap of the filament transformer for VT3 and the ground side 131 of the high tension winding.

Although I have shown in Fig. 2 a direct connected amplifier operated from an alternating current source, it is to be understood that this invention is not limited to the type of amplifier shown, for example, a transformer coupled amplifier or a resistance capacity coupled amplifier operated either from dry batteries, accumulators, or by proper rectifying means from an alternating current source may be employed.

In order to disclose the working of my invention I have shown an ordinary carbon microphone transmitter 135 connected, by means of its transformer and battery 136, to terminals 137 and 138 of the amplifier shown in Fig. 2. It is to be understood, however, that a radio receiving set or other devices for transforming light waves, sound waves or other mechanical vibrations into electrical energy may be utilized in place of the transmitter microphone.

It will be seen that I have shown a mechanism making it possible to record on a tape and then immediately reproduce the record for monitoring or other purposes. It will also be seen that the reproducing apparatus can be operated without a recording mechanism to reproduce recordings that have already been made, since the recordings on the tape are of such a nature that the tape can be kept for long periods of time before being reproduced without deterioration of the record.

Furthermore, my invention furnishes a method of introducing a delay between the production of speech or music and the reproduction of the same. For instance, if it be desired to reproduce the speech or music shortly after its production, and the length of time between the recording mechanism and the reproducing mechanism is 14 inches and the tape is running at the rate of 14 inches per second, a delay of one second between the recording and the reproduction of the sound will occur. This delay will occur while the tape is traveling from the recording point to the reproducing point. This time obviously may be varied by changing the distance between the recording and reproducing points to obtain the desired amount of delay.

There are many interesting and useful applications of this: for instance, such as when a person desired to play a phrase of music, or speak a few sentences, and have that phrase or speech reproduced as soon as he is through playing or speaking, in order that he may obtain an idea of how it sounds and what the resultant effect is; or when a delay is desired as in two-way wireless communication, to allow time for cutting off the transmitter and cutting in the receiver without apparent interruption in the communication.

A further advantage of this device lies in its ability to render signals or messages unintelligible in transmission. This may be accomplished either by running the tape with indices recorded thereon, backward through the reproducing device for transmission, receiving and recording on another tape, and running that tape backward through a reproducing device for intelligible reception of the signals as messages, or by running the tape through the reproducing device and transmitter at a rate of speed sufficiently high to prevent intelligible reception and then receiving and recording at a rate of speed corresponding to the transmitting speed and reproducing the message by running the tape at a lower rate of speed.

It will be noted that an important advantage of my invention is that the tape may be used with a low moisture content, so that it appears...
to be substantially dry, and can, therefore, be readily handled in reeling and storing, and held in this condition without the necessity of maintaining the tape immediately before recording.

It will also be seen that after the recording is made the moisture content is substantially immaterial, and that the tape may be wound on reels, rolls, or the like, and stored for long periods of time until it is desired to use it for reproduction.

Also, it will be seen that a relatively narrow tape, such as one-half inch, may be used, and that a large amount of recording will be relatively light and may be easily stored and transported. It may be noted, however, that a tape sufficiently wide to have impressed thereon a plurality of series of indices by passing the tape successive times through the recording mechanism may be used.

It will also be seen that, instead of treating or coating a tape with chemical compounds to enable it to receive the marks or indices, such compounds may be incorporated in the paper or other material from which the tape is made during the manufacture of the tape.

Furthermore, it is to be understood that the particular forms of apparatus shown and described, and the particular procedure set forth, are presented for purposes of explanation and illustration and that various modifications of said apparatus and procedure can be made without departing from the invention as defined in the appended claims.

What I claim is:

1. Apparatus for recording electrical impulses, which comprises, in combination, a movable tape carrying a substance adapted to react to the passage of an electric current therethrough, a thermionic valve or valves, means for applying varying voltages to the thermionic valve or valves, means coating with the movable tape for impressing the resultant varying electrical output of the thermionic valve or valves thereon, said means comprising electrodes, one of which is a thin blade disposed transversely of the tape, and means for moving said tape, whereby successive lines are produced on the tape transversely thereof, each line being produced by a single electrical impulse.

2. Apparatus for recording and reproducing sound waves in the audible range which comprises, in combination, a movable tape carrying a substance adapted to react to the action of an electric current, a thermionic valve, means for receiving sound waves and transforming them into electrical impulses and for subjecting the control member of said thermionic valve to said impulses, means for moving the tape, means for impressing the electrical output of said valve on successive portions of the tape to form a series of indices, means for impressing a light beam upon indices of the moving tape and reflecting the light into a light-sensitive device of the type capable of transforming light variations into electrical impulses, and means for transforming these electrical impulses into high frequency sound waves whereby vocal and musical sounds may be accurately recorded and reproduced.

3. Apparatus for recording and reproducing sound waves in the high frequency audible range, which comprises in combination, a movable tape carrying a substance adapted to react to the effect of electric current thereon, a thermionic valve, means for receiving said sound waves and transforming them into electrical impulses, means for applying said electrical impulses to the thermionic valve, electrodes disposed transversely of the tape on opposite sides of the tape connected to receive the resultant varying electrical output of the thermionic valve, means for transforming light beams upon said indices of the moving tape and reflecting the light into a light-sensitive device of the type capable of transforming light variations into electrical impulses, and means for transforming these electrical impulses into high frequency sound waves whereby vocal and musical sounds may be accurately recorded and reproduced.

4. Apparatus for recording and reproducing sound waves in the high frequency audible range, which comprises in combination, a movable tape carrying a substance adapted to react to the effect of electric current thereon, a thermionic valve, means for receiving said electrical impulses, means for applying said electrical impulses to the thermionic valve, electrodes disposed transversely of the tape on opposite sides of the tape connected to receive the resultant varying electrical output of the thermionic valve, means for moving said tape between said electrodes whereby indices are produced on successive portions of the tape transversely thereof and of materially greater length than width and corresponding in spacing and intensity to the frequency and intensity of the original sound waves, means for impressing light beams upon said indices of the moving tape and reflecting the light into a light-sensitive device of the type capable of transforming light variations into electrical impulses, and means for transforming these electrical impulses into high frequency sound waves whereby vocal and musical sounds may be accurately recorded and reproduced.

5. Apparatus for recording and reproducing sound waves in the audible range which comprises, in combination, a movable tape carrying a substance adapted to react to the action of an electric current, a thermionic valve, means for receiving sound waves and transforming them into electrical impulses and for subjeecting the control member of said thermionic valve to said impulses, means for moving the tape and means for impressing the electrical output of said valve on successive portions of the tape in the form of transverse lines of materially greater length than width, and means controlled by said tape for producing electrical impulses corresponding to those impressed on the tape and for transforming these electrical impulses into sound waves corresponding to those produced by the electrical impulses previously impressed on the tape.

6. A method of recording electrical impulses upon a tape carrying a substance adapted to react to the effect of electric current thereon, which consists in applying varying voltages to a thermionic valve or valves, impressing the resultant varying electrical output of said valve or valves on successive portions of said tape to form fine transverse lines proportional in spacing and intensity to the variation of the current in frequency and intensity while moving the tape at a substantially uniform speed and thereby causing successive portions of the moving tape to receive
the effect of the electrical impulses impressed thereon and to be differentiated from other portions of the tape.

7. A method of recording electrical impulses on a tape carrying a substance adapted to react to the effect of electric current thereon, which consists in applying varying voltages to a thermionic valve with said tape as a substantially uniform speed in proper relation to electrical contacts to receive electrical impulses therefrom, impressing the resultant varying electrical output of said valve or valves on said tape to form successive fine transverse lines of materially greater length than width and proportional in spacing and intensity to the varying electrical output of said valve or valves while the tape is moving relative to the contacts, and thereby causing portions of the moving tape to receive the effect of the electrical impulses impressed thereon and to be differentiated from other portions of the tape.

8. A method of reproducing mechanical vibrations, which consists in transforming said vibrations into electrical impulses, applying the electrical impulses to a thermionic valve, impressing the resultant varying electrical output of said valve on portions of a tape, carrying a substance adapted to react to the effect of electric current thereon, to cause successive indices to be produced on said tape, causing a light beam to impinge upon said indices on the moving tape and to be reflected into a light sensitive device of a type capable of transforming light variations into electrical impulses, and transforming these electrical impulses into mechanical vibrations of substantially the same frequency and intensity as those originally transformed into electrical impulses.

9. A method of reproducing mechanical vibrations, which consists in transforming said vibrations into electrical impulses, applying the electrical impulses to a thermionic valve, moving at a uniform rate a tape carrying a substance adapted to react to the effect of electric current, impressing the resultant varying electrical output of said valve on portions of said tape, to cause successive transverse lines to be produced on said tape, causing a light beam to impinge upon said transverse lines on the moving tape and to be reflected into a photo cell, and transforming the resulting electrical vibrations of said cell into mechanical vibrations.

10. A method of reproducing mechanical vibrations, which consists in transforming said vibrations into electrical impulses, applying the electrical impulses to a thermionic valve, moving at a uniform rate a tape carrying a substance adapted to react to the effect of electric current, impressing the resultant varying electrical output of said valve on portions of said tape, and reproducing from said indices the recorded signal after a predetermined lapse of time.

11. A method of reproducing sound vibrations, which consists in transforming said vibrations into electrical impulses, impressing the electrical impulses on a moving tape carrying a substance adapted to react to the effect of electric current thereon, to produce successive indices on said tape and automatically reproducing from said indices the recorded sound vibrations after a predetermined lapse of time.

12. The herein described method of transmitting mechanical vibrations, such as code signals or sound waves, and maintaining them secret during transmission, which consists in transforming said vibrations into electrical impulses and recording said impulses by impressing them upon a moving tape carrying a substance which reacts to the effect of electric current, producing electrical impulses by causing a light beam to impinge on said tape and be reflected into a photo cell while moving said tape at a speed which is relatively high as compared to the recording speed, and transmitting the electrical impulses so produced to a second recording apparatus similar to the first and having a tape moving at a relatively high rate of speed corresponding to that of the first tape and reproducing the mechanical vibrations from the second tape at a speed corresponding to the original recording speed.

13. Apparatus for recording and reproducing electrical impulses which comprises, in combination, a movable tape carrying a substance to react to the action of an electrical current thereon, a pair of rollers disposed on opposite sides of the tape and connected to receive the electrical impulses, means for moving the tape between said rollers whereby transverse lines of greater length than width are produced on said tape, terminating such transverse lines on the moving tape, means for impressing a beam of light upon said lines of said moving tape and causing the light coming from said tape to pass into a light sensitive device of the type capable of transforming light variations into electrical impulses.

14. Apparatus for recording sound waves which comprises, in combination, a movable tape carrying a substance adapted to react to the effect of electric current thereon, a thermionic valve, means for receiving said sound waves and transforming them into electrical impulses, means for applying the electrical impulses to the thermionic valve, electrodes disposed on opposite sides of the tape, and connected to receive the resultant varying electrical output of the thermionic valve, one of the electrodes including a thin blade mounted transversely on the side of the tape, said electrode being mounted for yielding movement relative to the tape so that the electrode may have a natural period most suitable for recording the impressed signals, whereby transverse indices of relatively fine gradations corresponding to the basic frequencies and harmonics of the sounds being recorded are produced on the tape.

15. The method of recording and reproducing a varying electric current, which consists in impregnating an opaque record member with a chemical which changes its color on the passage of electricity therethrough, passing said current through an amplifying system whereby the variations in said current are sensibly amplified, passing said opaque record between electrodes connected to said amplifier whereby said amplified current is passed through said record and discolors it along a predetermined course in a manner corresponding to the variations in said current, impinging a constant beam of light on said opaque record along said predetermined course, causing reflected light from said record along said predetermined course to pass into a photo cell, and amplifying the electrical impulses produced by said cell, thereby a varying electric current whose variations correspond in frequency and intensity with the original electric current is obtained.

16. Apparatus for recording electrical impulses which comprises, in combination, a tape carrying a substance adapted to react to the effect of an electric current, said tape having such a relatively low moisture content that it appears dry, a thermionic valve, means for moving the tape,
means for impressing the output of the valve on successive portions of the tape to form transverse lines of materially greater length than width on said tape, said lines varying in spacing and intensity in proportion to the impulses impressed upon the valve.

17. A tape of the character on which sharply contrasting lines, varying in spacing and intensity, may be produced under the influence of a rapidly varying electric current, which comprises a paper tape impregnated with a solution of a chemical capable of change of color upon the passage of an electric current through the chemical, the moisture content of the tape being such that the tape appears dry but contains more than 10% moisture.

18. Apparatus for recording and reproducing sound waves in the audible range, which comprises, in combination, a movable tape carrying a substance adapted to change in color from the effect of electric current thereon, means for receiving such sound waves and transforming them into electrical impulses, an electrical amplifying system including one or more thermionic valves, means for applying said electrical impulses to the amplifying system, electrodes disposed transversely of the tape on opposite sides thereof connected to receive the resultant varying electrical output of the amplifying system, means for moving said tape between said electrodes whereby discolorations are produced on successive portions of the tape transversely thereof of materially greater length than width and varying in frequency and intensity with the variations in frequency and intensity of the original sound, means for impinging a light beam upon said indices of the moving tape, and means for passing the resultant varying reflected light into a light sensitive device of the type capable of transforming light variations into electrical impulses, and means for transforming these electrical impulses into sound waves, whereby vocal and musical sounds may be accurately recorded and reproduced.

19. Apparatus for recording electrical impulses comprising in combination, a tape carrying a substance adapted to react to the passage of electrical current therethrough, means for moving said tape, a plurality of thermionic valves directly coupled in cascade, a source of high tension direct current, the majority of which current must pass through said tape and last of said thermionic valves in cascade to the other valves directly coupled to said last valve, means for impressing varying electrical impulses on the control member of the first of said thermionic valves in cascade, whereby successive indices in the form of distinct transverse lines are formed on said tape which correspond in spacing and intensity proportionally to the frequency and intensity of the impressed electrical impulses.

20. The method of recording electrical impulses on a tape carrying a substance adapted to react to the effect of electric current thereon, which consists in applying varying electrical impulses to a thermionic valve, applying the output of the valve to an electro-magnetic member capable of vibrating in response to varying electrical impulses and having a thin recording blade electrode, feeding the tape at a substantially uniform speed over a stationary electrode spaced from the first electrode, and applying direct current across said electrodes and through the tape disposed therebetween, whereby the effect of the electrical impulses impressed upon the valve are impressed on the tape in the form of transverse lines of greater length than width.

21. An opaque paper tape impregnated with a chemical and having indices impressed thereon as the result of the direct application to said tape of electrical impulses, said indices comprising visual, successive, transverse lines relatively narrow in width and of materially greater length than width, and also being proportional in spacing and intensity to said electrical impulses.

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