July 5, 1949. H. E. ROYS 2,475,200

SIGNAL RECORDING APPARATUS

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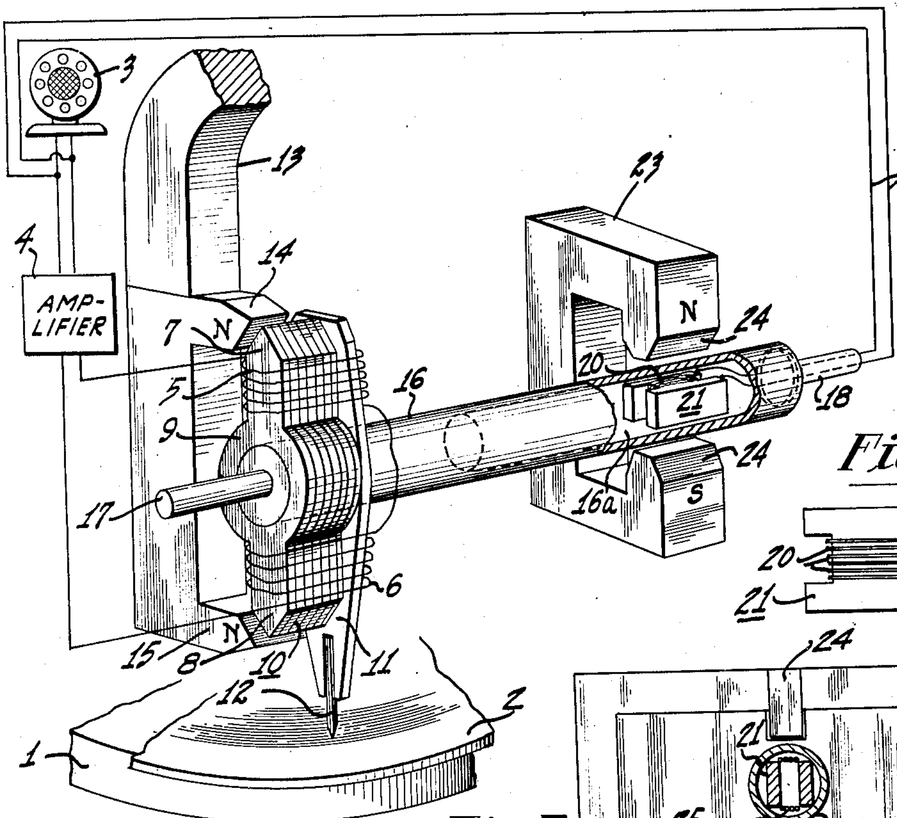
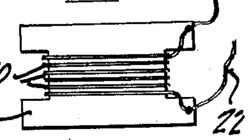


Fig. 1.

Fig. 2.



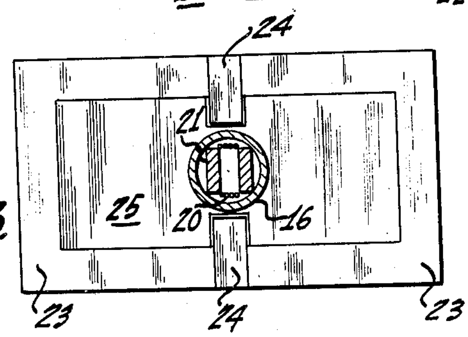


Fig. 3.

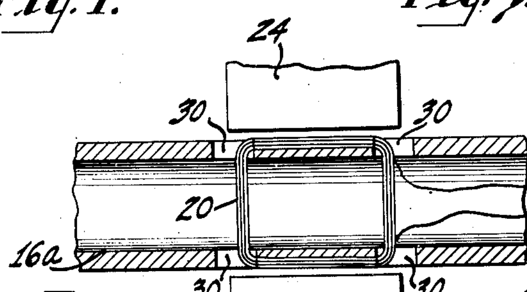


Fig. 4.

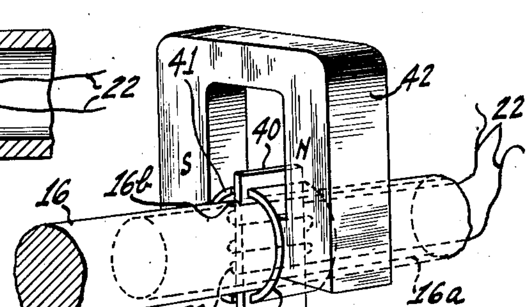


Fig. 5.

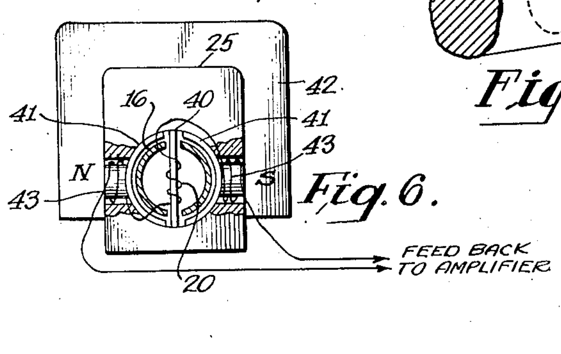


Fig. 6.

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SIGNAL RECORDING APPARATUS

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5 Claims. (Cl. 179—100.4)

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This invention relates to electrical sound recording apparatus, and more especially to a record cutting system which utilizes audio frequency feedback.

In electrical sound recording systems employing an audio frequency amplifier which feeds a cutter driving coil, it has been proposed, heretofore, to make use of degenerative or negative audio frequency feedback to the amplifier. Generally, in these prior systems, an audio frequency voltage is derived from vibration of the cutter armature and this voltage is fed back to the amplifier in a degenerative sense so as to minimize harmonics. Other advantages are also secured by means of the degenerative feedback arrangement. Such systems are generally illustrated in the prior art by U. S. Patent No. 2,161,489 granted to Leonard Vieth on June 6, 1939, and U. S. Patent No. 2,162,986 granted to Charles F. Weibusch on June 20, 1939. In these various systems, it is important that there be a minmum of interaction between the reactance element which drives the cutter and the reactance element which generates the audio frequency feedback voltage. Various devices have been utilized in the past to prevent interaction between these reactive elements. It is also important, in systems of this type, to insure mechanical synchronization between the driving reactance element and the feedback reactance element so that the audio frequency feedback voltage is accurate in representation of the audio frequency current output of the microphone which feeds the driving amplifier.

The primary object of my present invention is to provide an improved electrical sound recording apparatus which will have these and other desirable characteristics.

Another object of my present invention is to provide an improved system of the type referred to above, my improvement consisting essentially of at least a partly hollow supporting shaft for the cutter armature, the supporting shaft housing within its interior, in somewhat spaced relation to the driving coil, a reactance element which provides the audio frequency feedback voltage.

Another important object of my present invention is to provide a record cutting system employing a cutter armature having diametrically opposed extensions which are surrounded by the driving coils, the armature being carried by a supporting shaft one end of which is hollow for housing a feedback coil which is located in the field of a permanent magnet whereby vibration of the armature causes generation of audio frequency voltages in the feedback coil, the driving coil and feedback coil being sufficiently spaced from each other to prevent any substantial interaction between the two.

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A further and also very important object of my present invention is to provide an improved recording system as aforesaid which employs stabilized feedback and in which distortion is thereby reduced to a minimum.

Still another object of my present invention is to provide an improved recording system as above set forth which will have a substantially flat frequency response, largely as a result of the fact that a rigid mechanical system with but a single resonant frequency is employed in contradistinction to the compliantly coupled, multi-section mechanical systems generally employed in the prior art and in which each section is resonant at a different frequency.

An additional object of my present invention is to provide an improved recording system as above set forth the frequency response and sensitivity of which will not change materially with variations in temperature.

It is also an object of my present invention to provide an improved recording system as set forth above of which the frequency response will be independent of the load applied to the cutting or recording stylus.

Still other objects of this invention are to improve generally the efficiency and reliability of record cutter systems of the type specified above, and more especially to provide such systems which are economical in cost, durable in construction, and highly efficient in use.

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

Figure 1 is a partly sectional and partly diagrammatic view showing a circuit organization according to one form of my invention,

Figure 2 is a detailed view of the pick-up coil and mounting therefor of Fig. 1,

Figure 3 is an end elevation of a feedback unit according to my present invention employing a short-circuiting shield,

Figure 4 is an enlarged, fragmentary, sectional view showing a different form of mounting for the feedback coil,

Figure 5 is a fragmentary, perspective view of another modification of my invention in which a different form of feedback unit is employed, and

Figure 6 is an end elevation of a feedback unit similar to that shown in Figure 5 and supplied with a short-circuiting shield and with bucking coils around the pole pieces.

Referring more particularly to the drawing, wherein conventional operations of the system are schematically represented since they are well known to those skilled in the art of cutting records, there is shown, in Fig. 1, a turntable 1 of conventional construction which carries a record blank 2 on the upper surface of which the impressions corresponding to desired sounds are to be recorded by engraving or cutting. Since those skilled in the art of cutting records are fully familiar with the details of mounting the record on the turntable and proper centering of the record, it is not believed necessary to describe such details any further.

A microphone 3, which may be of any well known and desired form, picks up the sound to be recorded and feeds to an audio frequency amplifier 4 the audio frequency currents which it generates. The amplifier 4 may be of any well known construction. It is desirable to use an amplifier which has a wide band characteristic. More specifically, it is desirable to use an audio frequency amplifier of several cascaded stages and which has substantially zero phase shift up to 30,000 cycles per second or over. Here, again, such an amplifier is well known to those skilled in the art and therefore need not be described in further detail.

The amplified output of the amplifier 4 is fed to a pair of fixed armature driving coils 5 and 6. These coils are disposed, respectively, about a pair of somewhat spear-shaped arms or sections 7 and 8 which extend in diametrically opposed relation from the hub or sleeve section 9 of a laminated armature 10. The laminations of the armature may be held together by cement, rivets, or any other suitable means. It will be noticed that the coils 5 and 6, as shown in Fig. 1, are connected in series between the output terminals of the amplifier 4. However, the coils 5 and 6 may be connected in parallel relation depending upon the electrical impedance desired. A stylus bar 11, which may have the same shape, generally, as the armature 10, is secured to the armature and carries a cutting or engraving stylus 12 for coaction with the record blank 2 in well known manner.

A permanent magnet 13, which may be of the usual U-shape, provides a fixed, magnetic field for the armature 10. The magnet 13 is provided with two sets of opposed pairs of pole pieces adjacent the tapered ends of the armature sections 7 and 8, only the North poles 14 and 15 being shown in the drawing, since this arrangement is quite well known. Thus, the tapered end of the armature section 7 is disposed between one cooperating pair of north and south pole pieces, and the tapered end of the armature section 8 is likewise disposed between the other pair of cooperating north and south pole pieces.

The armature is secured, through its hub 9, to a horizontal shaft 16 of light-weight, non-magnetic material (such as aluminum, magnesium, suitable alloys of either of these metals, or the like), the shaft 16 being substantially rigid torsionally and being hollow at the end remote from the armature 10 for a purpose to be presently

set forth. For rotatably mounting the shaft 16, it may be provided with shaft extensions 17 and 18 (the latter also hollow) of reduced diameter, the extensions 17 and 18 being supported in suitable bearings (not shown) in well known manner. As the audio frequency signal currents flow through the armature driving coils 5 and 6, the varying magnetic fields set up thereby will react with the permanent magnetic field through the laminated armature supplied by the magnet 13, and as a result, the armature 10 will vibrate at the signal frequencies to effect vibration of the stylus bar 11 and the cutter 12. Thus, the cutter 12 will cut a track or groove in the blank 2 which will correspond to the audio frequency signals picked up by the microphone 3.

In accordance with my invention, audio frequency feed back voltage is fed to the input of the amplifier 4 so as to eliminate harmonics and secure other well known advantages. For this purpose, there is mounted within the hollow or tubular portion 16*a* of the armature shaft 16 a pick-up or feedback coil 20 wound on a suitable form 21, the coil being arranged with its axis normal to that of the driving coils 5 and 6 to minimize coupling therebetween. The output of the feedback coil 20 is fed back to the input of the amplifier 4 by a pair of leads 22 which are brought out through the hollow shaft extension 18. In general, the voltage fed back to the amplifier 4 is degenerative or negative voltage. However, in some cases, regenerative or positive feedback voltage may be employed to advantage, as explained by H. S. Black in his article "Stabilized feedback amplifiers," Bell System Technical Journal, vol. 13, Jan. 1934, page 9, paragraphs 1 and 2.

Cooperating with the coil 20 is a permanent magnet 23 so disposed that the coil 20 lies in the air gap between its pole tips 24. The magnet 23 supplies a fixed magnetic flux through the coil 20 and constitutes therewith an electrodynamic system of well known form. As the rigid shaft 16 rotates in response to the signal energy fed through the driving coils 5 and 6, it will simultaneously similarly rotate the feedback coil about its (the shaft's) axis to synchronously vibrate the coil 20. The turns of the coil 20 will then more or less cut the magnetic lines of force in the field supplied by the magnet 23 and, as a result, voltages will be induced in the coil 20 which are of audio frequency and which are accurate counterparts of the audio frequency currents flowing in the driving coils 5 and 6. By feeding these audio frequency voltages back to the amplifier 4, the advantages of my present invention are realized.

The feedback coil 20 and the driving coils 5 and 6 should be spaced from each other a distance such that there can be very little interaction between these reactive elements. Furthermore, since the pickup coil 20 is housed within the interior of the tubular section of shaft 16, this also provides a degree of shielding for the coil 20. In addition, the entire tubular section 16*a* (or at least that portion of it which is occupied by the coil 20) and the pole piece tips 24 may be completely enclosed in a copper shield 25 for greater shielding, as shown in Fig. 3. The feedback voltage generated across the coil 20 must of necessity be an accurate representation of the velocity of the shaft 16 and the armature coupled thereto. Since the shaft 16 is positively locked to the armature 10 and also to the coil form 21, and since the shaft 16 is rigid torsionally, there will be a rigid mechanical coupling between the coil 20 and the armature 10. This is one of the advantages of my present invention, namely, the fact that a substantially perfect mechanical coupling is secured between the armature 10 and the feedback coil 20.

In the form of my invention shown in Fig. 4, the tubular shaft section 16a is provided with aligned openings 30 and the feedback coil 20 is wound directly on the shaft 16 through these openings. As in the case of Fig. 1, the axis of the feedback coil 20 is normal to that of the driving coils 5 and 6 to minimize magnetic coupling therebetween. Also, since the shaft 16 is of non-magnetic material, this will further tend to minimize the coupling between the feedback and the driving coils.

In the form of my invention shown in Fig. 5, the armature shaft portion 16a is formed with a diametrical slot 16b in which is placed a magnetic armature 40. The feedback coil 20 is wound on the armature 40 which is rigidly secured to the shaft 16, and the armature 40 cooperates with a pair of substantially semi-circular pole pieces 41 which embrace the shaft portion 16a and which are supplied with flux by a permanent magnet 42. Since the armature 10, the shaft 16 and the armature 40 are rigidly coupled together for vibration as a unit, it will be apparent that vibration of this unit will cause voltages at signal frequencies to be generated in the feedback coil 20. If desired, a copper shield may be placed around the feedback coil, its armature 40 and the field structure 41, 42 to minimize coupling between the coil 20 and the coils 5 and 6. If such copper shielding or the shielding of Fig. 2 (which is more effective at the high frequencies than at the low frequencies) is insufficient, it may be found advantageous to add bucking coils 43 (Figure 6) around the pole pieces of the feedback unit, and perhaps also around the shaft 16. Such bucking coils should, of course, have the proper number of turns connected in series with and in correct phase relation with respect to the feedback coil 20 so as to oppose and cancel out any voltage generated in the latter coil due to coupling between the coils 5 and 6 and the coil 20. This method of cancellation is quite well known and is disclosed in the above identified Vieth patent.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many other modifications may be made without departing from the scope of my invention, as set forth in the appended claims.

I claim as my invention:

1. In signal recording apparatus, the combination of an oscillatory system comprising a rotary shaft which is substantially rigid torsionally, a magnetic armature rigidly secured to said shaft, and a feed-back coil also rigidly secured to said shaft, said shaft, armature and coil being rotatable as a substantially rigid unit on the axis of said shaft, a driving coil associated with said armature, means including an amplifier for feeding signal current to said driving coil whereby to effect rotary oscillation of said unit at signal frequencies, means for inducing voltages in said feed-back coil at signal frequencies upon oscillation thereof at said frequencies, and means for feeding back to the input of said amplifier the output voltages of said feed-back coil, said feed-back coil being so disposed relative to said driving coil that the axes of said coils are substantially normal to each other, whereby said coils are in substantially non-inductive relation to each other.

2. In signal recording apparatus, the combination of an oscillatory system comprising a rotary shaft which is substantially rigid torsionally, a magnetic armature rigidly secured to said shaft, and a feed-back coil also rigidly secured to said shaft, said shaft, armature and coil being rotatable as a substantially rigid unit on the axis of said shaft, a driving coil associated with said armature, means including an amplifier for feeding signal current to said driving coil whereby to effect rotary oscillation of said unit at signal frequencies, means for inducing voltages in said feed-back coil at signal frequencies upon oscillation thereof at said frequencies, and means for feeding back to the input of said amplifier the output voltages of said feed-back coil, said shaft having a hollow portion, and said feed-back coil being mounted within said hollow portion.

3. In signal recording apparatus, the combination of an oscillatory system comprising a rotary shaft which is substantially rigid torsionally, a magnetic armature rigidly secured to said shaft, and a feed-back coil also rigidly secured to said shaft, said shaft, armature and coil being rotatable as a substantially rigid unit on the axis of said shaft, a driving coil associated with said armature, means including an amplifier for feeding signal current to said driving coil whereby to effect rotary oscillation of said unit at signal frequencies, means for inducing voltages in said feed-back coil at signal frequencies upon oscillation thereof at said frequencies, and means for feeding back to the input of said amplifier the output voltages of said feed-back coil, said shaft having a hollow portion with said feed-back coil mounted therein, and said armature being secured to said shaft in spaced relation to said feed-back coil longitudinally along said shaft.

4. In signal recording apparatus, the combination of an oscillatory system comprising a rotary shaft which is substantially rigid torsionally, a magnetic armature rigidly secured to said shaft, and a feed-back coil also rigidly secured to said shaft, said shaft, armature and coil being rotatable as a substantially rigid unit on the axis of said shaft, a driving coil associated with said armature, means including an amplifier for feeding signal current to said driving coil whereby to effect rotary oscillation of said unit at signal frequencies, means for inducing voltages in said feed-back coil at signal frequencies upon oscillation thereof at said frequencies, and means for feeding back to the input of said amplifier the output voltages of said feed-back coil, said shaft having a hollow portion adjacent one end thereof with said feed-back coil mounted therein, and said armature being secured to said shaft adjacent its other end.

5. In signal recording apparatus, the combination of an oscillatory system comprising a rotary shaft which is substantially rigid torsionally, a magnetic armature rigidly secured to said shaft, and a feed-back coil also rigidly secured to said shaft, said shaft, armature and coil being rotatable as a substantially rigid unit on the axis of said shaft, a driving coil associated with said armature, means including an amplifier for feeding signal current to said driving coil whereby to effect rotary oscillation of said unit at signal frequencies, means for inducing voltages in said

feed-back coil at signal frequencies upon oscillation thereof at said frequencies, and means for feeding back to the input of said amplifier the output voltages of said feed-back coil, a bucking coil in said unit and rotatable therewith, said bucking coil being serially connected with said feed-back coil and therewith being so inductively coupled and related to said driving coil as to generate counter voltages and balance out from the circuit of said feed-back coil voltages induced therein as a result of any stray inductive coupling between said driving coil and said feed-back coil.

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