

July 1, 1941.

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2,247,924

AUTOMATIC EQUALIZING SYSTEM FOR RECORDING ON DISK RECORDS

Filed Aug. 16, 1938

6 Sheets-Sheet 1

FIG. 1.

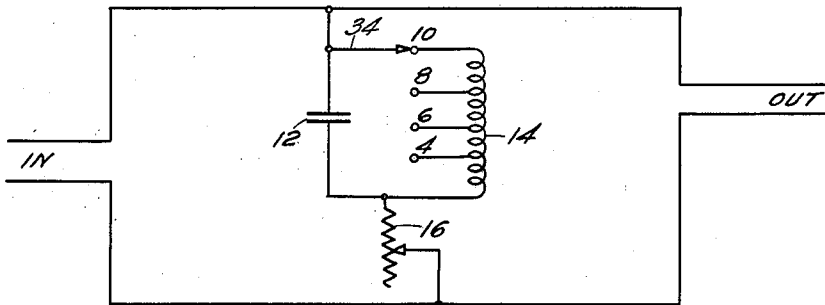
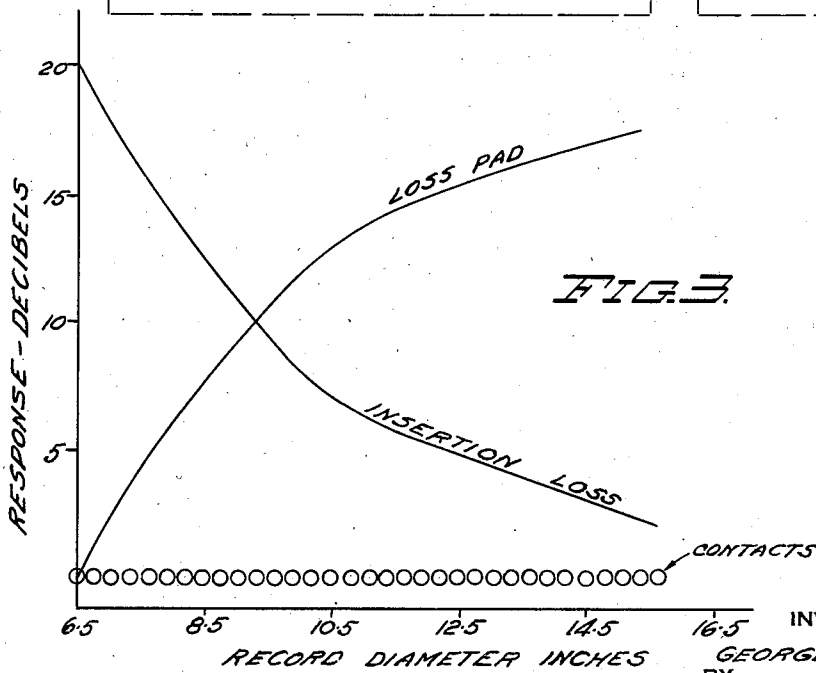
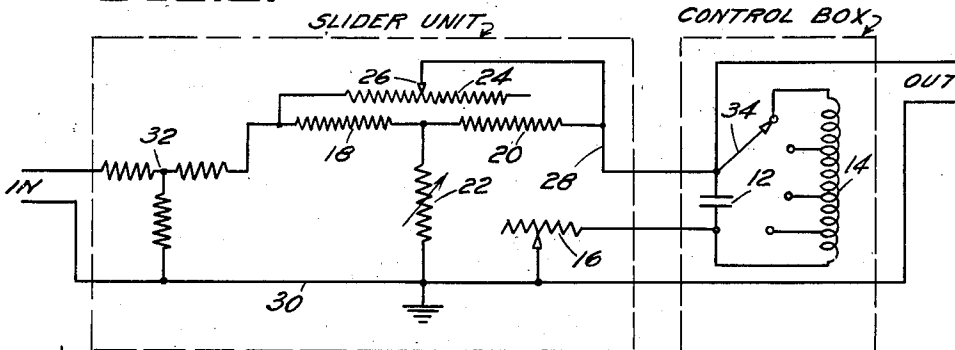


FIG. 2.



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6 Sheets-Sheet 2

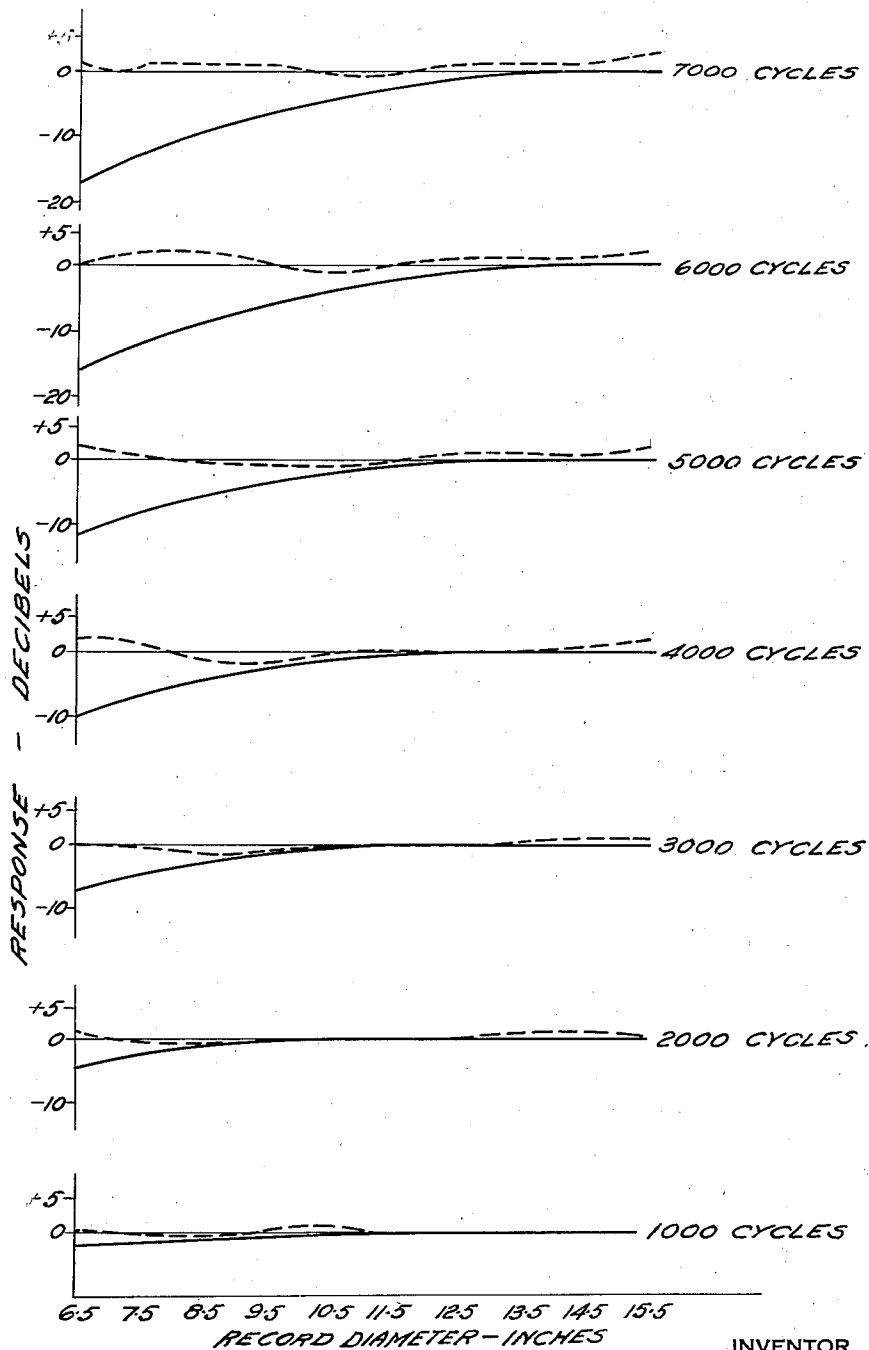


FIG. 4.

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6 Sheets-Sheet 4

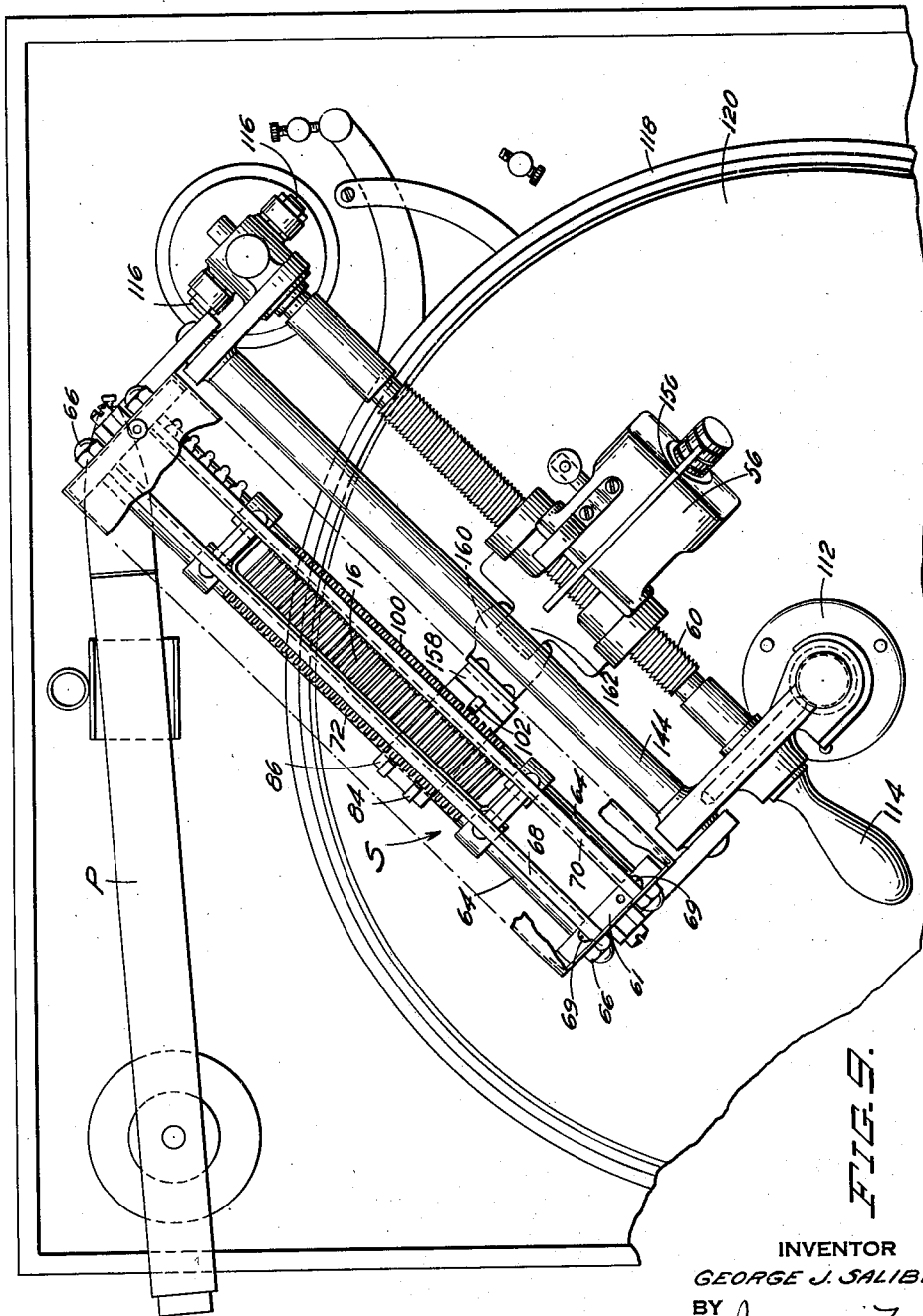


FIG. 9.

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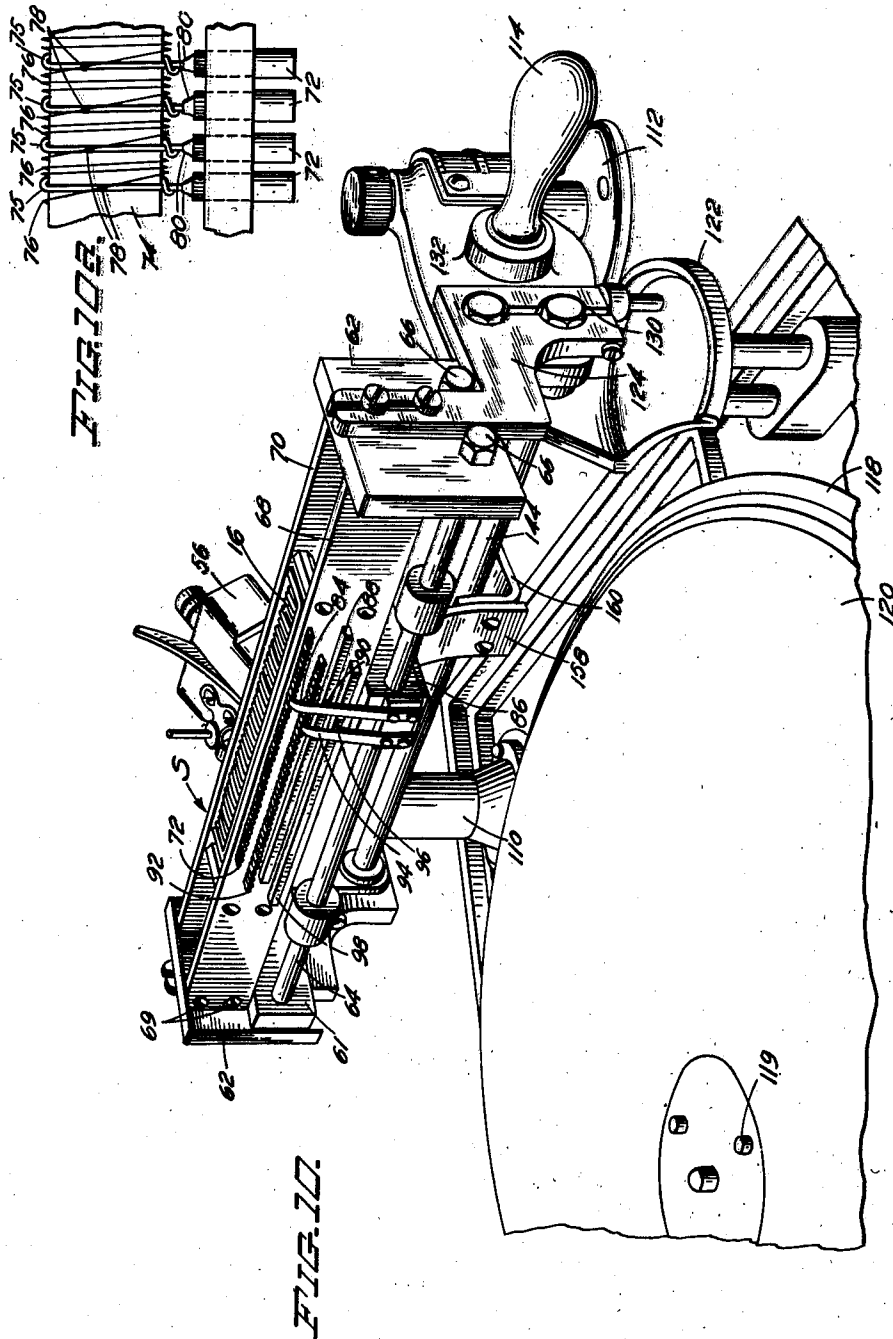
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AUTOMATIC EQUALIZING SYSTEM FOR RECORDING ON DISK RECORDS

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6 Sheets-Sheet 5



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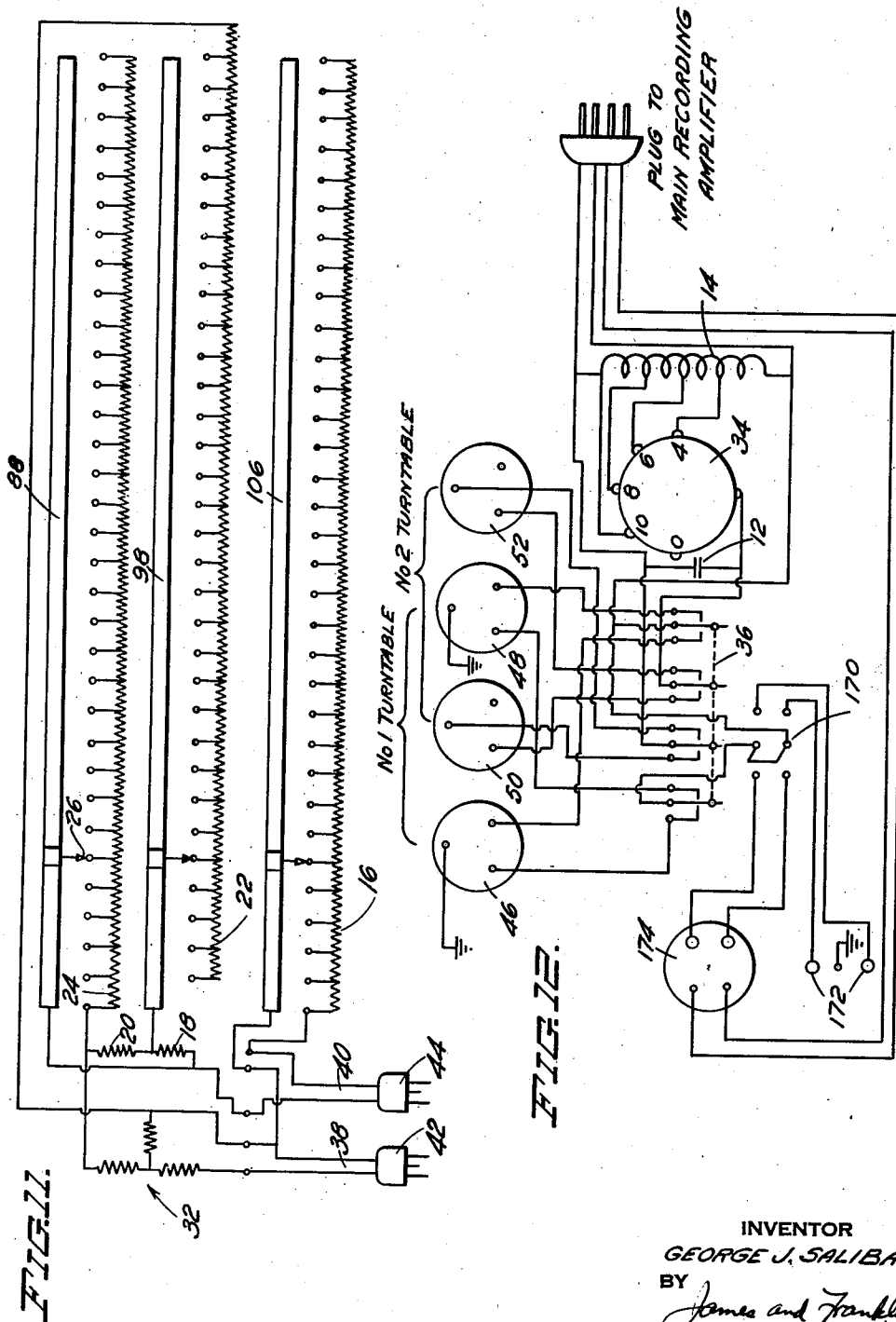
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AUTOMATIC EQUALIZING SYSTEM FOR RECORDING ON DISK RECORDS

Filed Aug. 16, 1938

6 Sheets-Sheet 6



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2,247,924

AUTOMATIC EQUALIZING SYSTEM FOR
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Application August 16, 1938, Serial No. 225,110

16 Claims. (Cl. 179—100.4)

This invention relates to phonographic recording, and more particularly to high quality sound recording on disk records.

The primary object of my invention is to generally improve sound recording on disk records, especially with a view to obtaining high fidelity and uniform volume over the entire face of the record and even when using the so-called "slow speed" or "long playing" records.

In accordance with standard recording practice, the turntable and record rotate at a uniform speed. The linear speed at the outside of the record is much higher than the linear speed near the center of the record. The wave length is therefore greater at the outside of the record than at the inside. This is of no consequence with low frequencies, for there is still ample room at the inside of the record, but with high frequencies, the wave length at the inside is reduced to a very small value. In other words, the undulations in the sound track become crowded together at the center of the record, and this may cause a loss of high frequency volume at the center relative to the outside of the record, with a corresponding loss of fidelity. This difficulty was not no noticeable with the older high speed records turning at 78 R. P. M., because with such records the linear speed even at the inside of the record is relatively high, but the difficulty has been greatly aggravated since the introduction and use of the so-called "slow speed" or "long playing" record which turns at only $33\frac{1}{3}$ R. P. M.

One specific object of my invention is to overcome the foregoing difficulty and to provide equalizing means for automatically increasing the high frequency response at the center of the record compared to the outside of the record. This may be done manually by means of known electrical equalizing circuits, but unfortunately, variation of the equalizing circuit changes the insertion loss of the circuit and thus produces changes in volume. In accordance with a further feature and object of my invention, I provide a special compensating attenuator which is varied simultaneously with the equalizing means, and in such a manner as to compensate for any change in the insertion loss caused by the equalizing means. In this way both the frequency response and the volume may be brought to a uniform constant value throughout the record.

Further objects of my invention are to devise automatic means of the aforesaid character which may be readily attached to standard recording machines of known type; which will be maintained in proper relation to the cutting

head of the recorder at any point on the record and irrespective of whether or not the record is played through continuously; which will include means for adjusting the resonance frequency of the equalizer so that it may be suited to the type of cutting head used on the recorder; which will include means facilitating a changeover from one turntable to another when dealing with a lengthy recording requiring more than one record; which will be effective with recorders working from the outside of the record in or from the inside of the record out; and which may be disengaged when not desired, as for example, when recording on small diameter high speed records.

To the accomplishment of the foregoing and other objects which will hereinafter appear, my invention consists in the sound recording and equalizing means and their relation one to the other, as hereinafter are more particularly described in the specification and sought to be defined in the claims. The specification is accompanied by drawings in which:

Fig. 1 is a schematic wiring diagram of an equalizer circuit;

Fig. 2 is a schematic wiring diagram of an equalizing circuit combined with a compensating attenuator network, and further indicating the apportionment of the apparatus elements between the slider unit carried by the recorder, and the control box which is separate and may be used with several turntables;

Fig. 3 is a graph explanatory of the operation of the invention;

Fig. 4 is a graph illustrating the beneficial results obtained by use of the invention;

Fig. 5 is a perspective view showing the slider unit and control box combined with a recorder or turntable;

Fig. 6 is an end elevation of the slider unit and feed screw of the recorder;

Fig. 7 is an opposite end elevation;

Fig. 8 is a section through the same;

Fig. 9 is a plan view with the cover of the slider unit partially cut away;

Fig. 10 is a perspective view with the feed screw swung out of the way, as when playing back the record, and with the cover of the slider unit removed;

Fig. 10a is a detail explanatory of the construction of the variable resistors;

Fig. 11 is a wiring diagram of the slider unit; and

Fig. 12 is a wiring diagram of the control box.

It is known that there is a progressive attenuation of high frequencies as the record groove

radius decreases, this being particularly noticeable on slow speed or $33\frac{1}{3}$ R. P. M. recordings. To compensate for this attenuation there must be a corresponding increase in the high frequency response of the amplifier used to feed the cutting head. One method of changing the amplifier response involves the use of a resonance circuit tuned to a high frequency, say, 6000 or 8000 cycles, while another method involves the use of a filter to attenuate the low frequencies. The present invention may be applied to either method, although it is specifically disclosed in connection with the first-named method. In either case the degree of equalization may be varied by a suitable control device, as, for example, a variable resistor, and this resistor may be varied automatically in response to movement of the cutting head. In either case, therefore, the net result may be made the same.

The reason it is well nigh impossible in disk recording to get uniform frequency response without equalization, is because of the varying linear speed of the needle point. This is due to the constantly changing radius as is apparent from the following equation:

$$(1) \quad V = 2\pi RN$$

in which

V=linear velocity of needle point

R=radius of disk

N=speed of turntable.

Since the turntable is revolving at a given constant speed, the only variable is "R" radius. Increasing "R" increases the needle velocity. Recordings at 78 R. P. M. raise no serious problem, due to the relatively high needle velocity. It is at $33\frac{1}{3}$ R. P. M. that the problem becomes serious enough to make the use of equalization extremely important, although equalization may, if desired, also be used at 78 R. P. M.

The wave length of a sound wave on the record is a function of the needle velocity, as is seen from the following equation:

(2)

$$\lambda = \frac{V}{F}$$

in which

λ =Wave length

V=Velocity

F=Frequency.

Since $V=2\pi RN$ (Equation 1) we can substitute $2\pi RN$ for V in Equation 2 and we now have,

$$\lambda = \frac{2\pi RN}{F}$$

If the radius "R" or the speed "N" is reduced the wave length is reduced. High frequency response is governed mostly by the radius of curvature of the modulated groove and the radius of curvature of the needle point, and it is the wave length that determines the radius of curvature of the modulated groove. Therefore, if the wave length becomes shorter, the radius of curvature of the groove becomes smaller, and it becomes increasingly difficult to reproduce the high frequencies.

The type of equalizer which is most commonly used because of its sharper characteristics and its greater efficiency consists of a capacitor and reactor tuned to resonance at the frequency at which equalization is desired. If such a network is placed in shunt with a line, voltage will be

built up appreciably at resonance. The circuit for such an equalizer is shown in Fig. 1. The capacitor 12 is in shunt with the inductor 14, and together are resonant to a frequency of, say, 10,000 cycles. The inductor 14 may be variably tapped to produce resonance at lower frequencies, say, 8000, 6000 and 4000 cycles. The resistor 16 is connected in series with the equalizing circuit, and varies the degree of equalization or the effectiveness of the equalizing circuit on the line. In other words, the rheostat controls the slope of the curve. With all the resistance in, very little or no equalization takes place, and when the resistance is all out, maximum equalization takes place.

This form of equalizer is known and has been used in two different ways. In one, the slope of the curve is adjusted to compensate for the mean attenuation and the rheostat is left set throughout the entire recording. The disadvantage with this method is that equalization takes place over the entire disk with no attention being paid to the changing radius and consequent increase of needle velocity. As pointed out previously this increase of velocity will increase the high frequency response and this fact plus the equalization will produce a record that will be over-equalized; that is, the "highs" will be too prominent. In the other way of using this equalizer, the latter is set for its maximum point (assuming recording from the inside out), and as the cutting head moves to the outside of the disk the amount of equalization is manually reduced by increasing the resistance of the rheostat.

Inasmuch as the human element and mental judgment is the prime factor in obtaining good results with this method, it is quite obvious that there is no assurance whatsoever of uniform properly equalized recordings. Moreover, while adequately skillful manipulation may be approached by an expert working in a large studio for the making of a master record in wax for subsequent manufacture of commercial records, no such skill can be expected from the vast number of owners of instantaneous recording units which produce transcriptions on aluminum or acetate disks for immediate playback.

Another important difficulty with this method is the fact that resonant equalizers introduce an insertion loss that depends on the amount of equalization taking place. When equalization is reduced the insertion loss becomes less and the volume becomes greater. It becomes necessary then for the operator to compensate for this increase in volume as he cuts the equalizer out. To do this he must operate both his volume control and equalizer rheostat simultaneously and this requires the use of both hands. If a long program is being recorded requiring the use of two turntables, the operator is left with no opportunity to get his second turntable ready while the first one is cutting.

In accordance with the present invention, the equalizer and a special compensating attenuator network (different from and additional to the regular volume control unit) are moved together as a unit, and are moved automatically by the cutting head. Referring to Fig. 2, it will be seen that the equalizer 12, 14, 16 is supplemented by any suitable attenuation network, in this case a bridge T, although it will be understood that a T pad, an H pad, or a ladder pad, or the like may be used. The bridge T is somewhat simpler than an ordinary T in necessitating only two instead of three variable resistors. The network com-

prises fixed resistors 18 and 20, and a variable resistor 22 arranged in T form. A variable resistor 24 is connected in shunt to the fixed resistors 18 and 20, and the movable contact arm 26 is connected to the line 28. The other line 30 is, of course, connected at the bottom of the T, that is, to the lower end of variable resistor 22.

A fixed T pad 32 is also shown in Fig. 2. This is a refinement which is not essential, but which is desirable to prevent reflection back into the line when the variable network is moved down to zero setting. In the specific structure here described, the fixed T pad 32 is selected to produce a loss of 5 decibels. It will be noted that the parts of the diagram are divided into two rectangles, one rectangle being marked "Slider unit," and the other being marked "Control box." It will also be noted that all of the variable resistors, that is, the resistors 16, 22 and 24, are included in the slider unit. This is structurally convenient in order that all of the variable resistors may be varied together as a unit.

The apparatus is shown applied to a recording machine in Figs. 5 through 10 of the drawings. Referring to Fig. 5, the two main parts of the apparatus above referred to are the slider unit generally designated S and shown attached directly behind the feed screw 60 of the machine, and the control box C which is a separate unit, and is shown in the foreground of Fig. 5. The control box contains the reactor 14 and the capacitor 12 (not shown), and the control 34 for selecting different resonant frequencies as desired. It also contains a throw-over switch 36 for use with two slider units S, as when working with double turntables for long recording. A single control box C is then employed with both turntables. The cables 38 and 40 are connected by means of plugs 42 and 44 with sockets 46 and 48 on the control box. Cables 38 and 40 extend to the slider unit S. Another pair of sockets 50 and 52 is provided for use when working with two turntables, these sockets providing connection to the slider unit of the other turntable. The cable 54 extends from the control box to the main recording amplifier which is generally indicated at A. A single main amplifier is used whether recording on one or two turntables. The main amplifier unit A is provided with a regular volume control VC and a meter M to indicate the output. These are commonly used in order to keep the output at a desired level in recording. The volume control is preferably kept constant during any one recording, its main function being to establish the desired amplification gain for the particular recording. It is important to keep in mind that this volume control is retained and is used in the regular way even when using the special compensating attenuator disclosed in the present description, and housed in the slider unit S. The object of the compensating attenuator is to maintain uniform gain across the face of the record, assuming that the volume control VC is left unchanged during the recording.

In passing, it may be mentioned that the main amplifier A is commonly provided with a loudspeaking reproducer indicated at R, for test playback of the records. Appropriate change-over switches are provided, and the amplifier may be used to amplify the record out-put before feeding the same to the reproducer R. The recording machine is therefore conveniently provided with a special pick-up arm P, and when using the pick-up the recording mechanism is moved out of the

way. For this purpose, the lead screw mechanism is pivotally mounted at 110, and the driving flange 112 together with the feed screw mechanism may be elevated by means of a handle 114 about horizontal pivots 116. In this way the driving flange 112 may be freed of driving screws 119 (Fig. 10) projecting upwardly from the turntable 118 through the record disk 120, and the entire feed mechanism may then be swung bodily about the pivot 110 until it is rested on a suitable support or rest plate 122. It will be understood that the slider unit S is so mounted on the feed mechanism that it too is bodily swung with the feed mechanism out of the way of the turntable and record, thus clearing the latter for use of the pick-up P.

The slider unit S is mounted at the rear of the feed mechanism so that the contact arms of the slider mechanism may be coupled directly to the cutting head carrier 56 for movement thereby. The slider unit contains three variable resistors one of which controls the slope of the equalizer curve, while the others compensate for changes in volume, as was previously described. As the cutting head 58 is fed across the face of the disk by the carrier 56, which in turn is moved by the feed screw 60, the variable resistors are changed simultaneously, and they are appropriately tapped so that the proper amount of equalization with the proper volume is obtained for each location of the cutting head, that is, for each diameter at which the recording is taking place.

Proper equalization and volume are always obtained regardless of whether the feed is from inside to the outside or vice versa, and the operator can start at any point with assurance that the equalizer is properly adjusted.

Fig. 3 shows the curves of the insertion loss of the equalizer (equal to the amount of equalization) and the loss pad. The abscissa represent the different diameters of the disk and the points along the abscissa represent the different contact points of the slider unit. At the inside of the disk the insertion loss is at a maximum while the loss of the pad is at a minimum. As the recording head travels towards the outside of the disk the equalization is decreased and therefore the insertion loss is decreased and the volume rises. But as pointed out above, since the arm of the loss pad is coupled directly to the slider arm of the rheostat, the loss is increased the same amount that the insertion loss is decreased, and the final result is a straight line. The pad is of the T-type or similar type, to insure constant impedance at all settings.

Considering the mechanical arrangement in greater detail, and referring to Figs. 6 through 10 of the drawings, the slider unit S comprises inverted T-shaped end pieces 61 with flanged, highly conductive, sheet metal auxiliary end cover pieces 62 at the outsides thereof. These end pieces are spaced apart by means of tie rods 64, the end pieces being secured to the ends of the tie rods by means of the outside nuts 66. The tie rods 64, as will later appear, function as slide rods for the contact arms. The end pieces 61 have strips of insulation 68 and 70 secured thereto by means of screws 69. Strip 68 is provided with a line of closely spaced contacts 72, as is best shown in Fig. 10. These are connected at suitable points to a resistor, which is preferably formed in the manner indicated in Fig. 10a, the resistor comprising a strip 74 of a suitable insulation, said strip having separate, independent spaced loops 75 of relatively heavy connector wire secured

thereabout at a spacing corresponding to the spacing of the contacts 72.

A thin and preferably insulated resistance wire 76 is wound in the spaces between the loops 75, the amount of winding in each space depending on the resistance value needed at that particular step. The resistance wire is continuous, and in passing from one section to the next, it overlies the loops 75, thus facilitating connection, as by a touch of solder at the points 78. A change of a half turn is obtainable by crossing at the opposite side. The contacts 72 are soldered to the free ends of the loops 75, as is indicated at 80. The entire resistance unit extends in a horizontal plane adjacent the line of contacts 72, as is indicated in Fig. 8 by the numeral 22, and is protected because of its location between the rigid insulation strips 68 and 70.

The line of contacts 72 is slidably engaged by a preferably double or laminated spring contact arm 84. This is mounted on a block or slide 86 which is slidable along the rods 64 previously referred to. The block 86 is preferably made of insulation, and in order to avoid the necessity for providing a flexible connection to the moving block, I provide a continuous contact bar 88 and an auxiliary contact arm 90 which underlies contact arm 84 and is electrically connected therewith. The auxiliary arm 90 is also preferably laminated, and it slides on the contact bar 88, and this in turn is connected in circuit to form a connection to the movable arm 84. The end of contact arm 84 is made wide enough to straddle the spacing between the successive contacts so that there is no open-circuit as the contact arm is moved.

Another line of contacts is indicated at 92, this being engaged by contact arm 94 supplemented by auxiliary contact arm 96, said contact arms being mounted on block 86. The auxiliary contact arm engages continuous bar 98. Contact series 92 is connected to a resistor constructed like that previously described, and indicated at 24 in Fig. 8. It will be noted that the position of series 92 and bar 98 is sidewardly displaced or staggered somewhat relative to series 72 and bar 68, thus compensating for the relatively sideward displacement of contact arms 84 and 94. The contacts shown on the rear insulation strip 68 are connected to the two variable resistors of the bridge T network.

The contacts for the variable resistor of the equalizing circuit are disposed on the front strip 70. This will be clear on reference to Fig. 8, showing the line of contacts 100 engaged by contact arm 102 supplemented by auxiliary contact arm 104 sliding on continuous contact bar 106. Contacts 100 are connected to resistor 16. This may be like that previously described, except that here the variations in steps are very great, being as little as 5 ohms at one end, and as much as 100 ohms at the other end, hence a change may be made to a finer or higher resistance wire toward the latter end.

The main and auxiliary contact arms 102 and 104 are mounted on the slidable block 86 so that all of the contact arms move together with the block, thus simultaneously varying all three variable resistors, the precise amount of resistance variation depending on the apportionment of the resistance winding, as was explained in connection with Fig. 10a. This amount is non-uniform, and it is primarily for that reason that I go to the extra trouble and expense of providing

the lines or series of contacts, instead of using a contact moving in simple direct engagement with a bare resistance winding.

The slider unit S is mounted on the recording machine with the aid of two end brackets 124 and 126 best shown in Figs. 6 and 7. The upper arm of these brackets is slotted to receive attaching screws 128 which pass through the end plate 62 and are threaded into the end pieces 61. The lower arms of the brackets are slotted at 130 and are cut away to fit closely about the nuts 132, which form a part of the recording machine. The split parts of the bracket are clamped together against the nuts 132 by means of clamping screws 134. In this way the brackets and consequently the entire slider unit are readily secured to the recording machine.

The slider unit is covered by means of a protective cover and shield 136, this shield being received about the inwardly bent flanges of the end pieces 62. The cover is preferably made of a highly conductive metal such as copper, and is secured to the end pieces by means of suitable small screws not shown in the drawings. On this matter of shielding, it may be mentioned that the cables which interconnect the control box C and the slider unit, are preferably shielded cables of the type commonly used in the art.

Although the recording machine is of conventional character, it may not be amiss to mention a few points of its construction which bear upon the operation of the slider unit. Specifically, the flange 112 driven by pins or screws 119 (Fig. 10) on turntable 118 functions to drive a worm 140 (Fig. 6) which meshes with a worm gear 142 secured to the end of lead screw 60. This provides the necessary synchronous rotation of the lead screw. The bearing housings at each end of the lead screw are held in rigid spaced relation by means of tie bars 144 (Figs. 8 and 9), and it is at the ends of these tie bars 144 that the nuts 132 previously referred to, are secured.

The lead screw oscillatably carries a cutting head carrier 56. This is freely movable along the lead screw except for a lever 146 pivoted on the carrier 56 at the point 148 (Fig. 8) and having its outer end formed into a depressible handle 150. The opposite end of lever 146 engages the thread on lead screw 60, as will be understood from inspection of Fig. 8. It will be clear that normally the carrier 56 is locked to the lead screw, but by depressing the handle 150 the carrier is freed for movement along the lead screw. The cutting head 58 is pivotally mounted on the carrier 56, as by means of a pivotal connection 152. The cutting pressure is controlled with the aid of a spring 154 which relieves a part of the weight of the cutting head. The effect of spring 154 is variable by means of an adjusting screw 156. The cutting head and carrier may be tilted upwardly and rearwardly out of the way, about the lead screw 60 until the hook 156 rests upon the upper part of the two main tie rods 144.

In accordance with the present example of the invention, the slidable block 86 carrying the contact arms of the resistors is connected to the carrier 56 in the following manner. An arm 158 is secured to the bottom of the block and has connected to it a forwardly projecting bifurcated piece 160 (Figs. 8, 9 and 10). The carrier 56 is provided with a rearwardly projecting finger 162 which exactly fits between the branches of member 160. The parts are thus engaged during the recording operation, and the block 86 is

caused to move along with the carrier 56 and the cutting head 58. When the carrier and cutting head are swung upwardly and rearwardly out of the way the parts 162 and 160 are disengaged.

This disengagement is not essential or even important, and other constructions may be used in which the parts are not disengaged. One advantage of arranging for disengagement is that the slider may, if desired, be moved out of the way if not wanted, as, for example, if using the recording machine for recording on small diameter records at 78 R. P. M. It may be mentioned that these recording machines are commonly provided with a driving motor arranged to drive the turntable at either of two standard speeds. It may also be mentioned that in using the large diameter slow speed records, the minimum diameter employed is about 6 inches; hence in the present device, the specific slider unit S here shown is designed for an effective range between about 6 and 16 inches diameter. In recording on small high speed records, a minimum diameter of only 3 inches may be used; hence in dealing with such records, it is better to dispense with the use of the short slider unit. It will be understood, however, that theoretically, a longer slider unit may be designed and constructed which will function all the way from 3 to 16 inches in diameter, and which will therefore be useable with both small-diameter high speed and large-diameter slow speed records. In such case a permanent connection between the slider block and cutting head may be preferable.

Referring now to Fig. 11, I there show a wiring diagram of the slider unit. The arrangement does not differ in principle from the diagram shown in Fig. 2, but the parts have been rearranged in closer similarity to their actual disposition in the slider unit. The equalizing resistor 16 and the variable resistors 22 and 24 of the bridge T pad correspond to the similarly numbered resistors in Fig. 2. The contact bars 88, 98 and 106 correspond to those referred to in connection with Figs. 8 and 10 of the drawings. The fixed resistors 18 and 20 and the fixed T pad 32 will also be understood from the previous description. They are wound on a strip 19 (Fig. 8).

In the actual design of the unit the following procedure was followed. A single frequency tone was recorded over the entire face of the record, and the output of reproduction was measured. This was done at different frequencies, specifically 1000, 2000, 3000, etc. cycles. The results obtained are indicated by the solid line curves in Fig. 4. It will be noted that there is a rapid increase in the loss of output toward the center of the record when dealing with the higher frequencies. The corresponding loss at low frequencies is comparatively slight. From these curves the characteristics of the equalizing circuit were computed, and the amount of resistance to be inserted with the equalizing circuit to help level out the response curves. In this way the resistance steps for the rheostat or equalizing resistor 16 were preliminarily established. The unit was then constructed, and was tried out experimentally. Readjustment of a number of the resistance steps was found necessary and they were made. The following tabulation shows the values of resistor 16 in a specific case in which 34 contacts are used for recording from a diameter of 6½ inches to a diameter of 15¾ inches. With 112 lines per inch feed screw, the resulting recording is 15 minutes in duration. The con-

tacts are spaced on centers approximately 0.141 apart.

Contact tap	Rheostat resistance in ohms	Pad loss in decibels
1.....	32	0
2.....	5	1.25
3.....	8	2.5
4.....	8	3.5
5.....	7	4.5
6.....	10	5.5
7.....	15	6.5
8.....	18	7.5
9.....	15	8.5
10.....	17	9.25
11.....	20	10.0
12.....	25	10.75
13.....	30	11.5
14.....	30	12.5
15.....	25	13.5
16.....	45	13.75
17.....	20	14.0
18.....	30	14.25
19.....	20	14.5
20.....	45	14.75
21.....	25	15.00
22.....	45	15.25
23.....	45	15.50
24.....	30	15.75
25.....	30	16.00
26.....	100	16.25
27.....	100	16.50
28.....	100	16.75
29.....	100	17.00
30.....	100	17.25
31.....	100	17.50
32.....	100	17.75
33.....	100	18.00
34.....	100	20.00

In the above table the contacts are numbered from the small diameter toward the large diameter, that is, in the direction of recording from inside out, as is now commonly done with instantaneous recordings. The 32 ohm value is a residual resistance in the equalizer. Following that, it will be noted that the steps vary greatly in amount from a small value of 5 ohms to a large value of 100 ohms. It will also be noted that the resistance steps do not vary in a uniform manner, but increase and decrease several times. This refers, of course, to the individual steps or differences, for the total resistance is increasing at all times, it being the sum of all of the preceding steps.

As was anticipated, the response curves then obtained were not leveled out, because of the effect of the insertion loss caused by the equalizing circuit. The response curves still departed from the desired level response, but they now all varied in the same direction and to substantially the same extent, instead of differing widely from one another with changes in frequency, as is indicated in Fig. 4 by the original solid line curves.

The departure from desired response was then corrected by the compensating attenuator. The necessary compensation may be expressed as a desired loss in decibels to be caused by the attenuator. The values in question are set forth in the third column of the table presented above. The advantage of expressing the loss in this way is that the steps are then applicable to any desired type of attenuator network. The actual resistance values will differ depending upon the type of network used, but in each case the resistance values should be so selected as to produce the decibel loss indicated in the foregoing table. It will be understood that a substantially constant impedance attenuator should be used, for otherwise the changes in impedance will upset the computations and will make necessary progressive readjustment of all of the values both for the equalizing circuit and for the compensating attenuator.

Using the values given in the above table, I have obtained the response curves indicated by the dotted lines in Fig. 4. It will be observed that the various curves have been substantially leveled off; and that in no case is there a departure of more than about two decibels from theoretically perfect response. The response curves may, of course, be made even better than those shown in Fig. 4 by continued empirical experimentation in an effort to refine the actual obtained results.

In Fig. 12 I set forth a wiring diagram of the control box C, and it will be understood that the connection sockets 46 and 43 for one turntable as well as the mating connection sockets 50 and 52 for a second turntable, correspond to those shown in Fig. 5. The nature of the change-over switch 36 will also be clear from Fig. 12, it comprising four single-pole, double throw switches all moved by a single control handle. The double-pole double throw switch 170 corresponds to the toggle switch 170 in Fig. 5, and is for changing over from radio to microphone, that is, from recording a radio broadcast directly without intermediate sound reproduction, to recording through a microphone. The microphone is connected to the terminals 172. A radio receiver is connected by means of a plug inserted in a receptacle 174. The capacitor 12 and inductor 14 are the main parts of the equalizing circuit and the resonant frequency of this circuit may be varied by means of a selector 34 corresponding to the similarly numbered part in Figs. 1, 2 and 5.

It may be mentioned that the frequency selector is provided mainly to accommodate different cutting heads on the recording machine. I recommend the use of a high quality cutting head which will respond to 7000 cycles, and in such case the selector 34 is tuned to 8000 cycles. However, if the recording machine has a cutting head which will respond to only, say, 4000 cycles, it would be futile to tune the equalizer to 8000 cycles, and no appreciable beneficial result would be obtained. Instead, in such case, it should be tuned to, say, 4000 cycles.

It is believed that the construction and operation as well as the many advantages of my improved equalizing system for disk recording, will be apparent from the foregoing description thereof. The device compensates continuously, for the variation in frequency corresponds with changing groove radius. It is entirely automatic in operation. Nothing is left to the skill of the operator except the simple monitoring of the volume level received from the studio. The use of my invention makes the frequency response of an instantaneous transcription substantially the same from beginning to end. The tremendous loss present without equalization, as shown by the solid line curves in Fig. 4, is eliminated, and the response is instead made substantially uniform, the curves being practically flat for every frequency whether 1000 or 7000 cycles. The equalizer may be used at low levels. I have found that even a novice with only a few minutes' instruction in the rudiments of recording, can make records that have the brilliancy and crispness so essential to the best grade of high fidelity recordings. A high quality cutting head capable of at least 7000 cycle response should be used, and for the playback, the pick-up should have a low needle impedance. The records should preferably be cellulose coated disks with low surface noise. By taking care of these points, it will be found that high fidelity recordings may be readily made by wholly inexperienced operators, and instan-

taneous transcriptions may be produced which are fully equal in quality to those recorded in wax by skilled engineers employed in large studios for the manufacture of quantity production commercial records. The unit as here described may be readily mounted on a standard machine in a few minutes.

It will also be apparent that while I have shown and described my invention in a preferred form, many changes and modifications may be made in the structure disclosed, without departing from the spirit of the invention defined in the following claims.

I claim:

1. An automatically equalized system for recording sound on ungrooved disk records, said system comprising a turntable, means to drive the same at slow speed to make possible long recordings, a cutting head, and feed mechanism including gearing driven by the turntable for positively feeding the cutting head over the turntable in order to groove the ungrooved disk records, an equalizer for increasing the high frequencies relative to the low frequencies, means to vary the effect of the equalizer, a compensating attenuator independent of vacuum tube bias and connected in a low impedance line outside of any vacuum tube circuits which may form a part of the complete apparatus, and a control device automatically and positively moved by the positively driven feed mechanism for simultaneously varying the effect of the equalizer and the compensating attenuator, the equalizer being so varied as to compensate for loss of high frequencies by amplifying the high frequencies being fed to the cutting head near the center of the record more compared to the low frequencies than at the outer part of the record, without decreasing the high frequencies at the outer part of the record, and the compensating attenuator being so varied as to compensate for changes in insertion loss and volume caused by the aforesaid changes in the equalizer, whereby automatic frequency equalization is obtained without concomitant changes in volume.

2. An automatically equalized system for recording sound on ungrooved disk records, said system comprising a turntable, a cutting head, a feed mechanism including gearing driven by the turntable for positively feeding the cutting head over the turntable in order to groove the ungrooved disk records, a manually operable volume control, an equalizer comprising an inductance and condenser arranged in parallel and tuned to a high frequency for increasing the high frequencies relative to the low frequencies, means to vary the effect of the equalizer, a compensating attenuator, and a control device automatically moved by the positively driven feed mechanism in accordance with the position of the cutting head on the record for simultaneously varying the effect of the equalizer and the compensating attenuator, the equalizer being so varied as to compensate for loss of high frequencies by amplifying the high frequencies being fed to the cutting head near the center of the record more compared to the low frequencies than at the outer part of the record, and the compensating attenuator being so varied as to compensate for changes in insertion loss and volume caused by the aforesaid changes in the equalizer, whereby automatic frequency equalization is obtained without changes in volume, other than intentional changes in volume made by means of the manually operable volume control.

3. Sound recording apparatus comprising a turntable for use with disk records, means to drive the same at slow speed for long recordings, a precision feed device, means to drive the same in synchronism with the rotation of the turntable, a cutting head positively moved over the record by the feed device, a frequency equalizing circuit, a variable resistor for controlling the effect of the equalizing circuit, a compensating attenuator including a variable resistor and other resistances forming a substantially constant impedance attenuator, a plurality of contact arms for varying said resistors, means connecting said contact arms for simultaneous movement as the cutting head moves in response to the feed device, the resistors being so proportioned that the frequency response is substantially equalized and the volume is maintained substantially uniform over the face of the record.

4. Sound recording apparatus comprising a turntable for use with disk records, means to drive the same at slow speed for long recordings, a feed screw, means to rotate the same in synchronism with the rotation of the turntable, a cutting head positively moved over the record by the feed screw, a frequency equalizing circuit, a resistance for controlling the effect of the equalizing circuit, a series of closely spaced contacts arranged to tap the resistance at desired points, a compensating attenuator including a variable resistor and other resistances forming a substantially constant impedance attenuator, a line of contacts arranged to tap the attenuator resistor at desired points, said lines of contacts being disposed collateral to the feed screw, a plurality of contact arms for engaging said lines of contacts, means for moving said contact arms simultaneously with the cutting head in response to the feed screw, the contacts being so tapped into the resistors that the frequency response is substantially equalized and the volume is maintained substantially uniform over the face of the record.

5. Sound recording apparatus comprising a turntable for use with disk records, a feed screw, means to rotate the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed screw, an equalizer circuit comprising an inductance and a condenser connected in parallel and tuned to a high audio frequency, a resistance connected in series with said equalizer circuit for controlling the effect of the same, a series of closely spaced contacts arranged to tap the resistance at desired points, a compensating attenuator circuit including a variable resistor and other resistances forming a substantially constant impedance attenuator, a series of closely spaced contacts arranged to tap the attenuator resistor at desired points, said resistors and said lines of contacts being disposed near and collateral to the feed screw, a plurality of contact arms for engaging said lines of contacts, means connecting said contact arms to the cutting head for simultaneous bodily movement of the cutting head and the contact arms by means of the feed screw, the contacts being so tapped into the resistors that the frequency response is equalized and the volume is maintained uniform over the face of the record.

6. Sound recording apparatus comprising a turntable for use with disk records, a motor for turning said turntable, a feed device and means to move the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed device, an equalizer com-

prising a capacitor and an inductor arranged in parallel and tuned to a high audio frequency, a frequency selecting switch for varying the inductor to make the equalizer resonant to a desired high frequency, a variable resistor in series with said equalizer to vary the effect thereof, a compensating attenuator circuit comprising resistors arranged to form a substantially constant impedance network, at least one of said resistors being variable, a movable contact arm for varying each of the variable resistors, and means for simultaneously moving said contact arms as the cutting head is moved in response to movement of the feed device.

7. Sound recording apparatus comprising a turntable for use with disk records, a motor for turning said turntable at slow speed, a feed screw and means to rotate the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed screw, an equalizer comprising a control box containing a capacitor and an inductor arranged in parallel and tuned to a high audio frequency, a frequency selecting switch on said control box for varying the inductor to make the equalizer resonant to a desired high frequency, a variable resistor connected in series with said equalizer but located outside said control box to vary the effect thereof, a compensating attenuator circuit comprising resistors arranged to form a substantially constant impedance network, at least one of said resistors being variable, both of the aforesaid variable resistors being disposed adjacent and longitudinally collateral to the feed screw and each having a line of closely spaced contacts connected thereto for tapping the same at desired points, a slidable contact arm for engaging each of the lines of contacts, and means for bodily moving said contact arms simultaneously along with the cutting head in response to rotation of the feed screw.

8. Sound recording apparatus comprising a turntable for use with disk records, a motor for turning said turntable, a feed screw disposed over the turntable, means to rotate the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed screw, a resistor unit, and means to attach the same adjacent the feed screw, said resistor unit including a guide, a carriage slidable on said guide, means projecting from said carriage for engaging the cutting head in order to move the carriage with the cutting head, a plurality of strips of insulation disposed collaterally of said guide, a resistance wire wound on said strips in variable amounts or groups of turns, a rigid strip of insulation disposed adjacent the aforesaid strips, two rows of small closely spaced contacts and two continuous strips of metal extending along said rigid strip of insulation, the aforesaid groups of turns of one resistor being connected to the contacts of one line, and the groups of turns of the other resistor being connected to the contacts of the other line, two sets of multiple spring contact fingers insulatedly mounted on the aforesaid carriage, one of said sets having its ends moving in engagement with one row of contacts and one continuous metal strip, and the other of said sets moving in engagement with the other continuous line of contacts and the other continuous metal strip, and a housing for shielding the contacts of said resistor unit against dust.

9. Sound recording apparatus comprising a turntable for use with disk records, a motor for

turning said turntable, a feed screw disposed over the turntable, means to rotate the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed screw, an equalizer comprising a capacitor and an inductor connected in parallel and tuned to a high audio frequency, a resistor unit, and means to attach the same adjacent the feed screw, said resistor unit including a guide, a carriage slidable on said guide, means projecting from said carriage for engaging the cutting head in order to move the carriage with the cutting head, a plurality of strips of insulation disposed collaterally of said guide, a resistance wire wound on said strips in variable amounts or groups of turns, a rigid strip of insulation disposed adjacent the aforesaid strips, two rows of small closely spaced contacts and two continuous strips of metal extending along said rigid strip of insulation, the aforesaid groups of turns of one resistor being connected to the contacts of one line, and the groups of turns of the other resistor being connected to the contacts of the other line, two sets of multiple spring contact fingers insulatedly mounted on the aforesaid carriage, one of said sets having its ends moving in engagement with one row of contacts and one continuous metal strip, and the other of said sets moving in engagement with the other continuous line of contacts and the other continuous metal strip, a housing for shielding the contacts of said resistor unit against dust, means connecting one of the resulting variable resistors in series with the aforesaid parallel resonant equalizer circuit, means appropriately connecting the other variable resistor to other resistors to form a substantially constant impedance attenuator network the resistance increments of the equalizer resistor being selected to so amplify high frequencies at the center of the record as to equalize the frequency response over the entire record, and the resistance increments of the attenuator resistor being so selected as to compensate for changes in insertion loss caused by the aforesaid changes in the equalizer, so as to obtain uniform volume.

10. Sound recording apparatus comprising a turntable for use with disk records, a motor for turning said turntable, a feed screw disposed over the turntable, means to rotate the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed screw, a resistor unit, and means to attach the same adjacent the feed screw, said resistor unit including a plurality of guide rods, a carriage slidable on said guide rods, a fork projecting from said carriage for engaging the cutting head in order to move the carriage with the cutting head, a plurality of strips of insulation disposed collaterally of said rods, a resistance wire wound on said strips in variable amounts or groups of turns, loops of heavier wire bent around said strips at uniform spacing and soldered to the resistance wire, a rigid strip of insulation disposed adjacent the aforesaid strips and collaterally of the rods, two rows of small closely spaced contacts and two continuous strips of metal extending along said rigid strip of insulation, the aforesaid loops of metal of one resistor being connected to the contacts of one line, and the loops of the other resistor being connected to the contacts of the other line, two sets of multiple spring contact fingers insulatedly mounted on the aforesaid carriage, one of said sets having its ends moving in engagement with

one row of contacts and one continuous metal strip, and the other of said sets moving in engagement with the other continuous line of contacts and the other continuous metal strip, and a housing for shielding the contacts of said resistor unit against dust.

11. Sound recording apparatus comprising a turntable for use with disk records, a motor for turning said turntable, a feed screw disposed over the turntable, means to rotate the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed screw, an equalizer comprising a capacitor and an inductor connected in parallel and tuned to a high audio frequency, a resistor unit, and means to attach the same adjacent the feed screw, said resistor unit including a plurality of guide rods, a carriage slidable on said guide rods, a fork projecting from said carriage for engaging the cutting head in order to move the carriage with the cutting head, a plurality of strips of insulation disposed collaterally of said rods, a resistance wire wound on said strips in variable amounts or groups of turns, loops of heavier wire bent around said strips at uniform spacing and soldered to the resistance wire, a rigid strip of insulation disposed adjacent the aforesaid strips and collaterally of the rods, two rows of small closely spaced contacts and two continuous strips of metal extending along said rigid strip of insulation, the aforesaid loops of metal of one resistor being connected to the contacts of one line, and the loops of the other resistor being connected to the contacts of the other line, two sets of multiple spring contact fingers insulatedly mounted on the aforesaid carriage, one of said sets having its ends moving in engagement with one row of contacts and one continuous metal strip, and the other of said sets moving in engagement with the other continuous line of contacts and the other continuous metal strip, a housing for shielding the contacts of said resistor unit against dust, means connecting one of the resulting variable resistors in series with the aforesaid parallel resonant equalizer circuit, and means appropriately connecting the other variable resistor to other resistors to form a substantially constant impedance attenuator network.

12. Sound recording apparatus comprising a turntable for use with disk records, a motor for turning said turntable, a feed screw disposed over the turntable, means to rotate the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed screw, an equalizer comprising a capacitor and an inductor connected in parallel and tuned to a high audio frequency, a resistor unit, and means to attach the same adjacent the feed screw, said resistor unit including a plurality of guide rods, a carriage slidable on said guide rods, a fork projecting from said carriage for engaging the cutting head in order to move the carriage with the cutting head, a plurality of strips of insulation disposed collaterally of said rods, a resistance wire wound on said strips in variable amounts or groups of turns, loops of heavier wire bent around said strips at uniform spacing and soldered to the resistance wire, a rigid strip of insulation disposed adjacent the aforesaid strips and collaterally of the rods, two rows of small closely spaced contacts and two continuous strips of metal extending along said rigid strip of insulation, the aforesaid loops of metal of one resistor being connected to the con-

tacts of one line, and the loops of the other resistor being connected to the contacts of the other line, two sets of multiple spring contact fingers insulatedly mounted on the aforesaid carriage, one of said sets having its ends moving in engagement with one row of contacts and one continuous metal strip, and the other of said sets moving in engagement with the other continuous line of contacts and the other continuous metal strip, a housing for shielding the contacts of said resistor unit against dust, means connecting one of the resulting variable resistors in series with the aforesaid parallel resonant equalizer circuit, means appropriately connecting the other variable resistor to other resistors to form a substantially constant impedance attenuator network, the resistance increments of the equalizer resistor being selected to so amplify high frequencies at the center of the record as to equalize the frequency response over the entire record, and the resistance increments of the attenuator resistor being so selected as to compensate for changes in insertion loss caused by the aforesaid changes in the equalizer.

13. Sound recording apparatus comprising a turntable for use with disk records, a motor for driving the same, a precision feed device, means to drive the same in synchronism with the turntable, a cutting head positively moved over the record by the feed device, a frequency equalizing circuit, a variable resistor for controlling the effect of the equalizing circuit, a compensating attenuator circuit comprising resistors arranged to form a substantially constant impedance network, at least one of said resistors being variable, a plurality of contact arms for varying said resistors, means for simultaneously moving said contact arms as the cutting head is moved in response to movement of the feed device, and a fixed T resistor network at the input to the attenuator.

14. Sound recording apparatus comprising a turntable for use with disk records, a motor for turning said turntable, a feed screw disposed over the turntable, means to rotate the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed screw, a resistor unit, and means to attach the same adjacent the feed screw, said resistor unit including a guide, a carriage slidable on said guide, means projecting from said carriage for engaging the cutting head in order to move the carriage with the cutting head, a plurality of strips of insulation disposed collaterally of said guide, a resistance wire wound on said strips in variable amounts or groups of turns, a rigid strip of insulation disposed adjacent the aforesaid strips, two rows of small closely spaced contacts

extending along said rigid strip of insulation, the aforesaid groups of turns of one resistor being connected to the contacts of one line, and the groups of turns of the other resistor being connected to the contacts of the other line, and two spring contact fingers insulatedly mounted on the aforesaid carriage, one moving in engagement with one row of contacts, and the other moving in engagement with the other line of contacts.

15. Sound apparatus comprising a turntable for use with disk records, a motor for turning said turntable at slow speed, a feed screw and means to rotate the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed screw, an equalizer comprising a control box containing a capacitor and an inductor arranged in parallel, a frequency selecting switch on said control box for varying the inductor to make the equalizer resonant to a desired frequency, a variable resistor connected in series with said equalizer but located outside said control box to vary the effect thereof, a compensating attenuator circuit comprising resistors arranged to form a constant impedance network, a plurality of said resistors being variable, all of said variable resistors being disposed adjacent and longitudinally collateral to the feed screw and each having a line of closely spaced contacts connected thereto for tapping the same at desired points, a slidable contact arm for engaging each of the lines of contacts, means for bodily moving said contact arms along with the cutting head in response to rotation of the feed screw, a plurality of connection plugs on said control box for connecting the control box to variable resistors on two recording turntables, and a change-over switch on said control box for connecting the equalizer circuit to either of the turntables.

16. Sound recording apparatus comprising a turntable for use with disk records, a motor for turning said turntable, a feed device and means to move the same in synchronism with the rotation of the turntable, a cutting head moved over the record by the feed device, an equalizer comprising a capacitor and an inductor arranged in parallel and tuned to a high audio frequency, a variable resistor in series with said equalizer to vary the effect thereof, a compensating attenuator circuit comprising resistors arranged to form a substantially constant impedance network, at least one of said resistors being variable, a movable contact arm for varying each of the variable resistors, and means for simultaneously moving said contact arms as the cutting head is moved in response to movement of the feed device.

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