

Oct. 31, 1944.

S. D. EILENBERGER

2,361,752

MAGNETIC RECORDING AND REPRODUCING SYSTEM

Filed Feb. 22, 1943

3 Sheets-Sheet 1

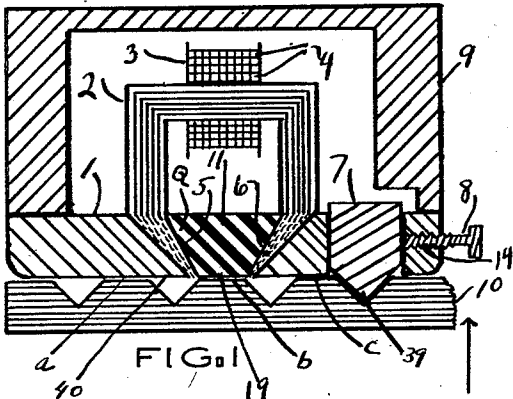


FIG. 1

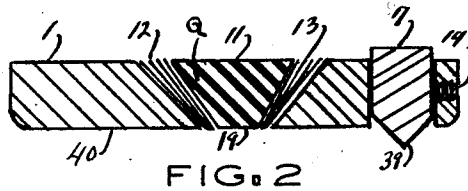


FIG. 2

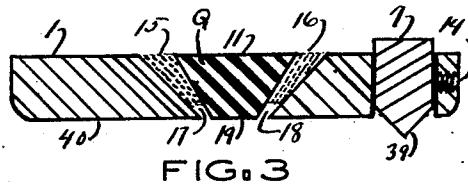


FIG. 3

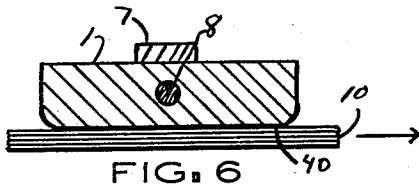


FIG. 6

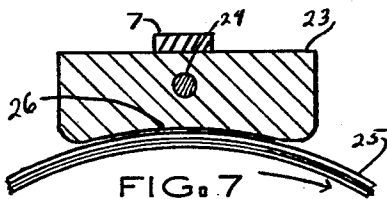


FIG. 7

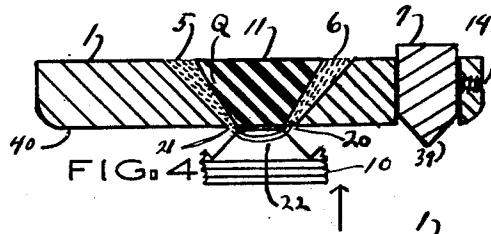


FIG. 4

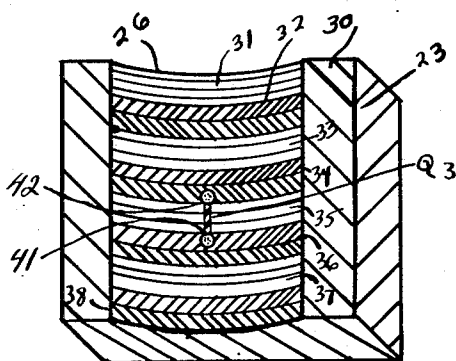


FIG. 8

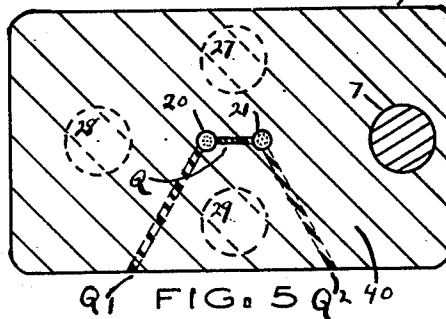


FIG. 5

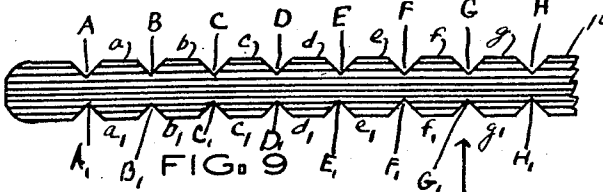


FIG. 9

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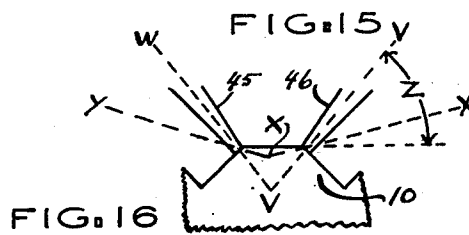
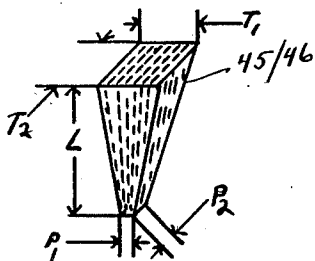
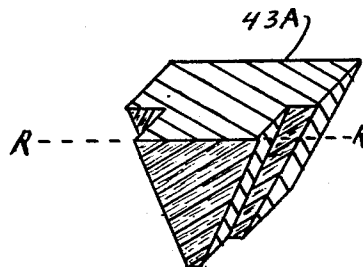
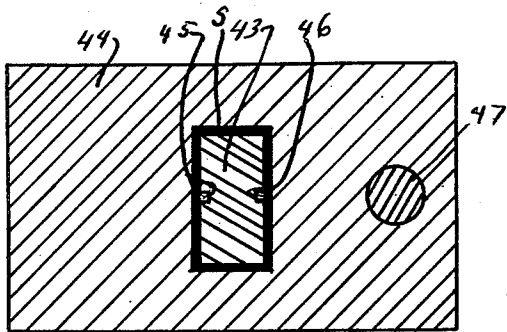
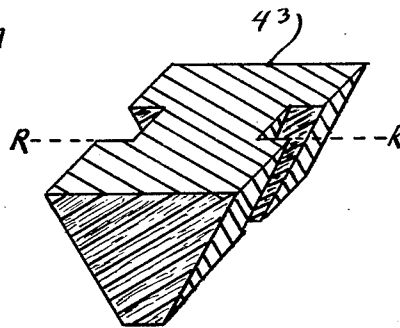
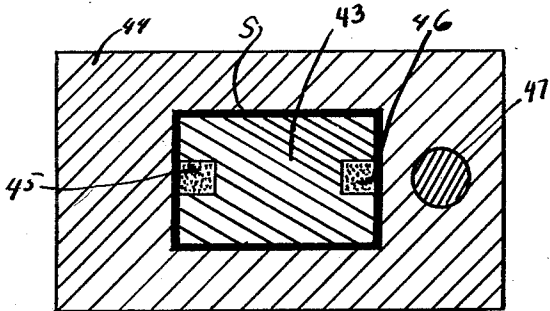
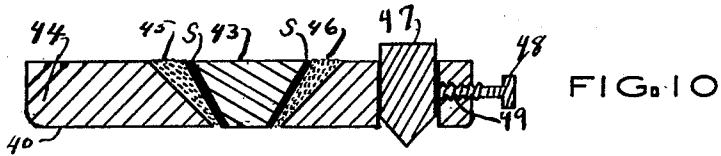
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MAGNETIC RECORDING AND REPRODUCING SYSTEM

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3 Sheets-Sheet 2



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2,361,752

MAGNETIC RECORDING AND REPRODUCING SYSTEM

Filed Feb. 22, 1943

3 Sheets-Sheet 3

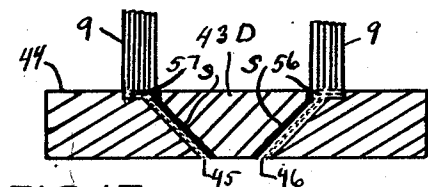


FIG. 17

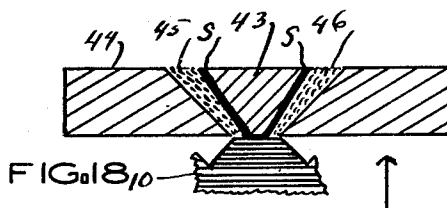


FIG. 18

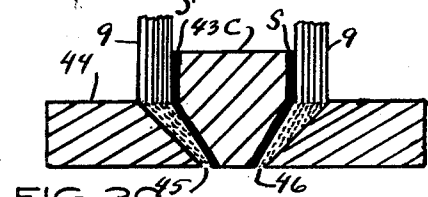


FIG. 20



FIG. 19

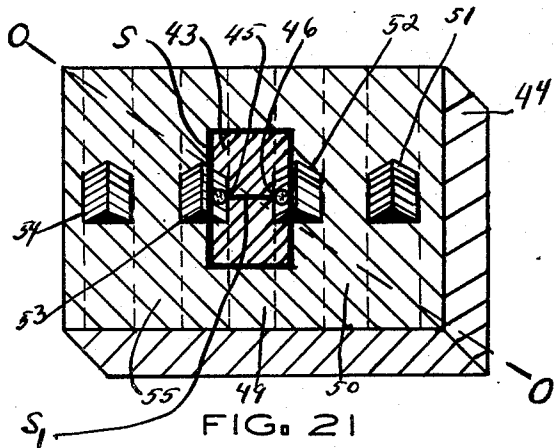


FIG. 21

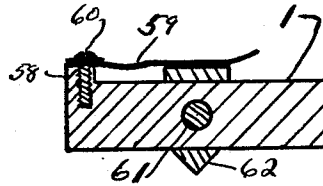


FIG. 24

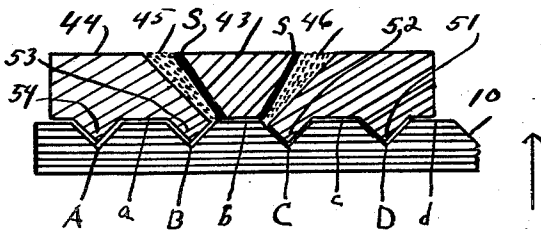


FIG. 22

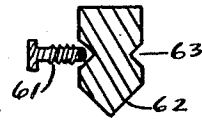


FIG. 25

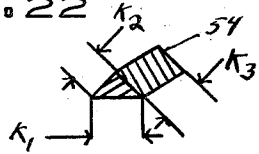


FIG. 23

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UNITED STATES PATENT OFFICE

2,361,752

MAGNETIC RECORDING AND REPRODUCING SYSTEM

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Application February 22, 1943, Serial No. 476,749

17 Claims. (Cl. 179—100.2)

This invention relates to improvements in magnetic recording, reproduction or obliteration, and particularly to magnetic head design for recording, reproduction, or obliteration with a magnetic sound carrier in the form of a flat disk, analogous in shape to the ordinary phonograph record in common use, or a circular drum, analogous in shape to the cylindrical record ordinarily used on well known dictating machines. In either case the magnetic sound carrier is of magnetic material, such as steel, most of the ferric alloys, and certain nickel-aluminum combinations.

This invention also relates to improved methods of record construction, especially where such records are in the form of a circular disk or cylindrical drum.

This invention is more specifically related to methods and means of confining all stray magnetic fields normally associated with the recording, reproducing or obliterating pole pieces or pole piece tips and, also, to methods of preventing wear on such pole piece tips, and the present invention further relates to improvements in the methods and means disclosed by my co-pending patent application entitled Magnetic pole piece, filed Feb. 22, 1943, Serial Number 476,750, and reference should be made to this co-pending application.

The above cited co-pending patent application disclosed methods and means of confining the stray magnetic fields normally associated with a pole piece tip, and of reducing wear on such pole piece tips. The present invention discloses improved methods of design where two pole pieces of opposite polarity are disposed adjacent and opposed to each other in the same plane, both pole pieces, or at least both pole piece tips, being completely enclosed in a non-magnetic metal shoe, said shoe being a good electrical conductor and so designed as to provide total and complete conductive shielding of all stray magnetic fields, at the same time providing a highly concentrated magnetic field dispersed over a relatively small area in the immediate locality of a sound track.

The design of such a non-magnetic metal shoe also disperses the total magnetic head weight over a relatively wide area, so that the pole piece tips, being completely enclosed, are not subject to wear, and the design of the magnetic sound carrier is such that a plurality of magnetic sound tracks, each having a flat surface mating with the lower contacting surface of the non-magnetic

metal shoe provides minimum wear on both sound tracks and shoe.

A further design feature incorporates the use of a magnetic sound carrier having an air gap between each adjacent sound track, the pole piece tips confined within the non-magnetic metal shoe being so disposed that the magnetic flux is confined to the immediate locality of the sound track instantaneously associated with the pole pieces, the air gap between the adjacent sound tracks co-operating to further reduce the possibility of leakage field energy transfer between the pole piece tips and the next adjacent sound tracks.

It is well known in the art that the effective pole piece dimensions in the immediate locality of a magnetic sound track determine the highest frequency that can be recorded, for any given linear sound track speed. It is also well known that the effective pole piece dimensions are often much greater than the actual physical dimensions, due to stray or leakage flux threading the magnetic sound track, or due to spreading of the magnetic flux in or near a magnetic sound track, this effect being commonly referred to as fringing. This fringing limits the recording range to a value much less than would be the case if all fringing were eliminated.

Prior art discloses numerous attempts to correct this fringing effect. By way of example, United States Patent Number 2,089,287 of Molloy, which attempts to correct this fringing effect by shielding the pole piece tip with extensions of the electromagnet core laminations. This, of course, is a form of magnetic shielding, but it is obvious that the shielding itself, in this case, is also magnetized; this must be so, as the pole piece tip per se becomes magnetized only through magnetic contact with the so called shielding, which, as previously stated, is in itself actually part of the pole piece. If this shield were carried into the immediate locality of a sound track, the effect would be to increase the effective pole piece dimensions rather than to decrease these dimensions. The inventor attempts to overcome this by terminating the shield at a distance from the magnetic sound track, thus leaving the pole piece tip exposed, with a resultant effective dimension similar or identical to that which it would have had without such shielding as might be offered by the pole piece extension.

This invention discloses methods, which I have found satisfactory in actual practice, of totally confining all stray or leakage fields, at the same time preventing spreading of the magnetic force lines within a magnetic sound track, so that the

effective pole piece dimension will be exactly equal to the physical dimension, which may be as desired for any particular class of service.

Among the numerous objects of this invention are:

First, to provide a magnetic head assembly for use in magnetic recording, reproduction, or obliteration, which shall be completely shielded and confine all stray magnetic fields.

Second, to provide a magnetic head assembly of the class described in (1) above, which will eliminate or greatly reduce the wear on the pole piece tips.

Third, to provide a magnetic head assembly of the class described in (1) above, which will allow the use of a pole piece material having very low or zero retentivity, such as plasticized powdered iron.

Fourth, to provide a magnetic head assembly of the class described in (1) above, which will concentrate the recorded magnetic field in an extremely small area in the direction of motion of the magnetic sound track.

Fifth, to provide a magnetic head assembly of the class described in (1) above, which will confine the recording or reproducing fields to the immediate locality of the pole piece tips.

Sixth, to provide a magnetic head assembly of the class described in (1) above, which will allow the use of relatively small uniform diameter pole piece tip dimensions.

Seventh, to provide a magnetic head assembly of the class described in (1) above, which will allow the use of pole piece tips whose effective dimensions are exactly the same as the physical dimensions.

Eighth, to provide a magnetic head assembly of the class described in (1) above which will co-operate with a pregrooved recording surface so as to be self guiding laterally over such recording surface, where the magnetic sound tracks are moving tangentially to the pole piece tips:

Ninth, to provide a magnetic head assembly of the class described in (1) above, which will allow the use of closely adjacent magnetic sound tracks.

Tenth, to provide a magnetic sound carrier for the magnetic head assembly referred to in objects one through nine inclusive above, which will provide a plurality of magnetic sound tracks each having a flat surface, to carry the weight of the magnetic head assembly.

Eleventh, to provide a magnetic sound carrier of the class described in (10) above, which will provide an air gap between closely adjacent sound tracks.

Twelfth, to provide a magnetic sound carrier of the class described in (10) above, which shall be in the form of a disk analogous to the ordinary phonograph record with provisions for recording or reproducing both sides of such a record, if desired.

Thirteenth, to provide a magnetic sound carrier of the class described in (10) above, which shall be in the form of a cylinder analogous to the ordinary dictating machine record.

Fourteenth, to provide a method of recording, reproduction, or obliteration with a closed magnetic field where both pole pieces are in the same plane.

Fifteenth, to provide a method of improving signal to noise ratio by the use of a relatively small fixed air gap between the pole piece tips and their associated magnetic sound track, to eliminate noise produced by variable magnetic

contact between said pole piece tips and their associated magnetic sound tracks.

Sixteenth, to provide methods or means of combining any or all of the foregoing objects in a single magnetic head assembly and magnetic sound carrier in combination.

In all forms of magnetic recording it is well known that the pole piece tip dimension must be kept extremely small; in order to record the high audio frequencies at a reasonable linear sound track speed. This pole piece dimension is a product of actual dimension and linear sound track speed, and should not exceed one-half wave length of the highest frequency it is intended to record. As an example, in order to record a frequency of 10 k. c. at a linear sound track speed of 16" per second, which corresponds to the innermost track speed on a disk record traveling at 78 R. P. M., the pole piece dimension in the direction the sound track is moving should not exceed .0008".

A further requirement for such a pole piece is that it have very low magnetic retentivity, and it has been common practice to make such pole pieces from soft iron having relatively low magnetic retentivity, although this has not been found fully satisfactory, as a magnetic sound track, on the other hand, must have relatively high magnetic retentivity, and it has been common practice to use very hard steel or hard magnetic alloys for this purpose, which provides a high rate of wear on the relatively soft pole piece.

It may readily be seen that such pole piece requirements as extremely small tip dimension and soft iron having low magnetic retentivity are contradictory. While it is quite possible to produce a pole piece having the proper tip dimension, such tips wear rapidly, thus increasing their effective dimension.

The present invention discloses methods of constructing a pole piece where a section of the pole piece is confined within a wear resistant non-magnetic metal shoe which serves the dual purpose of protecting the pole piece and completely shielding the pole piece.

It is well known in the art that magnetic shielding may be accomplished in two ways, first, by the use of magnetic material surrounding or enclosing the magnetic field it is intended to shield and, second, by the use of conductive material surrounding or enclosing the magnetic field it is intended to shield. The conductive shield should be a relatively good electrical conductor and of sufficient thickness to dissipate all of the stray magnetic fields as eddy current loss. In the present invention a third requirement is necessary, that the shielding be wear resistant.

There are numerous such materials available. For example, numerous copper silicon alloys having a hardness on the order of B90 Rockwell and electrical conductivity approximately 6.5 times that of copper. Beryllium copper, trade marked alloys such as Everdure and Oilite (an oil bearing bronze) and numerous aluminum bronze alloys are also suitable for this purpose, it being understood that these materials are mentioned here merely by way of example and that any non-magnetic metal having suitable wear resistant qualities and which is a good electrical conductor may be used for the pole piece shoe.

The pole piece material may be soft iron, as is common practice, or any of the magnetic materials ordinarily used for this purpose. However, a preferred pole piece material would be plasti-

cized powdered iron, for at least a portion of the pole piece. There are certain disadvantages of using plasticized powdered iron, for the entire pole piece, principally the fact that higher recording power is necessary, due to the relatively low permeability of plasticized powdered iron. However, plasticized powdered iron has certain advantages not found in other materials. First, such powdered iron has zero magnetic retentivity; second, it has a relatively high saturation point; and third, it may be forced into the pole piece shoe under pressure, which is more satisfactory than producing a pole piece from solid metal where the tip diameter is on the order of .001". It is understood that the use of plasticized powdered iron for part of all of the pole piece is not to be deemed restrictive in any sense, it being understood that other magnetic materials may be used without departing from the principles disclosed by this invention.

The design of a pole piece constructed according to this invention may have a uniform diameter for a length great enough that normal wear will not affect the diameter. While prior art teaches numerous methods of supporting a pole piece having small dimensions in one direction only, this invention discloses methods of constructing a pole piece so that it may have small dimensions in two directions, so that it is suitable for recording relatively high audio frequencies on closely adjacent sound tracks. In order to be practical for the purpose intended, such a pole piece tip must be extremely small in diameter, and therefore fragile, and may be compared to a small iron wire having a diameter on the order of .001", or less.

In the past such pole pieces have been possible only by using material having a diameter great enough to be strong mechanically, with a small diameter tip, like the point of a recently sharpened lead pencil. While it is possible to produce a very small diameter pole piece tip by this method, a slight amount of wear increases the diameter. This difficulty will be overcome by my invention, and normal wear will not alter the original pole piece diameter.

A magnetic head assembly constructed according to this invention will be completely shielded, so that no stray fields exist in the region of the magnetic sound carrier, which is important if high audio frequencies are to be recorded on closely adjacent sound tracks. As a leakage field would tend to increase the effective pole piece dimension, irrespective of the actual physical dimension. This is a very important factor if recording is to be accomplished on a disk or cylinder record having sound tracks on the order of .0025" wide, separated by a like distance of .0025", which corresponds to 200 sound tracks per inch. It is understood that these dimensions are given merely by way of example, and that any sound track dimension, sound track spacing, or number of sound tracks per inch giving satisfactory results may be used.

As in all other forms of magnetic field recording, the recording represented by magnetic flux lines in the magnetic sound track may be obliterated preparatory to a new recording, either by exposing the sound tracks to a high frequency alternating current field to completely demagnetize the sound tracks or by exposing the sound tracks to a steady D. C. field of sufficient strength to magnetically saturate the sound tracks. A magnetic head assembly similar to that used for recording or reproduction may, if desired, be also

used for obliteration, so that the field of obliteration is confined to the region of a single sound track, which is important where obliteration is progressive immediately ahead of recording, as is common practice.

The invention will be best understood from a consideration of the following detailed description in view of the accompanying drawings forming a part of the specification; nevertheless, it is understood that the invention is not confined to the disclosure, being susceptible to such changes and modifications as define no material departure from the salient features of the invention as expressed in the appended claims.

In the drawings:

Figure 1 represents a cross section end view of a complete magnetic head assembly constructed according to this invention.

Figure 2 represents a cross section view of the non magnetic metal shoe of Figure 1, with modified pole piece tip arrangement.

Figure 3 represents a cross section view of the non magnetic metal shoe of Figure 1, with further modified pole piece tip arrangement.

Figure 4 represents a cross section view of the non magnetic metal shoe of Figure 1, illustrating magnetic flux distribution in a single sound track.

Figure 5 represents a bottom view of the non magnetic metal shoe of Figure 1.

Figure 6 represents a side view of the non magnetic metal shoe of Figure 1.

Figure 7 represents a view of a modified form of the non magnetic metal shoe of Figure 1, adapted to mate with the recording surface of a cylinder record.

Figure 8 represents a bottom cross section view of the non magnetic metal shoe illustrated by side view in Figure 7.

Figure 9 represents a fragmentary cross sectional view of the magnetic sound carrier of Figures 1, 4, and 6.

Figure 10 represents a cross section end view of a modified form of the non magnetic metal shoe shown by Figures 1, 2, 3, 4, 5, 6, 7, and 8.

Figure 11 represents a bottom view of the shoe piece shown by Figure 10.

Figure 12 represents a top view of the shoe piece shown by Figure 10.

Figure 13 represents a grossly exaggerated pole piece tip for use with the shoe piece shown by Figures 10, 11, and 12.

Figure 14 represents a perspective view of a separate section from the shoe piece shown by Figures 10, 11, and 12.

Figure 15 shows a cutaway perspective view of the separate section shown by Figure 14.

Figure 16 graphically illustrates bending of the magnetic force line in a magnetic sound track.

Figure 17 represents a cross section end view of a further modified form of the non magnetic metal shoe piece of Figure 10.

Figure 18 represents a further modified form of the shoe piece shown by Figure 17.

Figure 19 represents a further modified form of the shoe piece shown by Figure 17.

Figure 20 represents a further modified form of the shoe piece shown by Figure 17.

Figure 21 represents a bottom cross section view of a modified form of the shoe pieces previously illustrated.

Figure 22 represents an end cross section view of the shoe piece shown by Figure 21, including a fragmentary schematic view of the magnetic sound carrier.

Figure 23 represents a grossly exaggerated single guide section as shown by Figures 21 and 22.

Figure 24 represents a cross section side view of the shoe pieces previously illustrated, showing a modified form of guide pin mounting.

Figure 25 represents a cross section view of the guide pin shown in Figure 24.

Referring now particularly to Figure 1, which represents a cross section end view of a complete magnetic head assembly, where 1 represents the non magnetic metal shoe, 2 the main pole piece assembly which may be of soft iron, either solid or laminated, or alternately, pole piece section 2 may be formed of plasticized powdered iron. The recording, reproducing, or obliterating coil is represented by 3, coil 3 having leads 4, it being understood that leads 4 are connected to a suitable amplifier or other source of voltage. The pole piece tips are represented by 5 and 6, in this case shown as plasticized powdered iron, in magnetic contact with the main pole piece section 2. Section 11 of non magnetic metal shoe piece 1 is between the pole pieces 5 and 6, thus providing complete shielding between these pole piece tips except for insulating gap Q, which prevents the effects of a shorted turn around pole pieces 5 and 6. The bottom surface of section 11 as represented by 19 has, in this instance, a width equal to sound track b of magnetic sound carrier 10. The lower surface of shoe piece 1 is represented by 40, and this lower surface mates with and rests on a plurality of sound tracks shown as a, b, c, etc. Guide pin 7 is normally constructed of some very hard material, such as, carbonyl or nitralloy, or some similar wear resisting material. Guide pin 7 has a tip section 39 conforming to the shape of the guide groove in sound carrier 10, and is held in place by set screw 8 in tapped section 14 of shoe piece 1. The upper part of the magnetic head assembly is completely enclosed in shield 9, which surrounds the entire upper assembly and mates tightly with shoe piece 1. Shield cover 9 is preferably made of nonmagnetic metal which is also a good electrical conductor, with a wall thickness sufficient to confine all stray internal magnetic fields and shield against all external magnetic fields. Shield 9 may be made of copper, which is the best conducting shield material used commercially, it being understood that any similar non magnetic metal may also be used, it being further understood that shield 9 may be alternately made of a magnetic material or magnetic alloy, such as, for example, permalloy, which would also be effective for shielding the upper structure of magnetic head assembly, although in the present design it is believed that non magnetic shielding similar or even identical to the nonmagnetic metal used in shoe piece 1 is preferable for shield section 9. If a dissimilar metal is used for shield piece 9, than was used for shoe piece 1, the thermo-couple effect must be considered, and material so chosen that small DC voltages will not be generated at the junction of two dissimilar metals.

A study of Figure 1 will show that the magnetic recording field (or obliteration or reproduction field, as the case may be) is confined to the surface area of magnetic sound track b. Wedge section 11 prevents leakage field between the pole pieces 5 and 6, and these pole pieces, being completely surrounded with a relatively thick non magnetic metal, will dissipate all stray and leakage fields as eddy current loss. This eddy current loss will be quite high in wedge section 11, 75

which will in turn require increased recording power and, also, will increase the number of ampere turns required. While this amounts to lowered efficiency, as compared to a non shielded magnetic head, this factor is relatively unimportant, in modern practice. That this is so may be readily understood by calculating the eddy current loss for any given mass of wedge section 11 and magnetic field strength in pole piece sections 5 and 6. For average practical dimensions of these components the eddy current loss will not exceed a value which requires a power ratio greater than 20:1, where the ratio is taken between the recording power required in a totally unshielded head as a ratio of the power required to make a recording with a fully shielded magnetic head similar to that shown by Figure 1.

While a power ratio of 20:1 i. e., the maximum requirement will be a recording power, with the magnetic head design of Figure 1, of 20 times the power which might be required with a totally shielded design, might seem excessive, this is not actually the case in consideration of the fact that a good magnetic recording may be made, with a totally unshielded magnetic head, with a recording power on the order of .1 watt. At the 20:1 power ratio, 2 watts of recording power would be required in a totally shielded magnetic head designed according to Figure 1. However, with careful design and selection of materials, this power ratio may be reduced to approximately 10:1, where 1 watt would represent the maximum useable recording power. It may readily be understood that the difference between .1 watt and 1 watt is of no importance in modern amplifier practice.

In reproduction, the eddy current loss factor would be considerably less, as the ratio of eddy current loss is in part a function of magnetic field strength and while the recording field strength would be relatively high, the reproduced field strength would be relatively low. In general, the eddy current loss in reproducing would be very small, on the order of $\frac{1}{50}$ to $\frac{1}{100}$ of the eddy current loss during recording.

The insulated gap Q may be air or any other non conducting material. This is not a gap in the magnetic circuit, but in the electrical circuit around the pole pieces. This gap may be very small in cross section, on the order of, for example, .001", or less. If insulated gap Q were omitted, the high frequency response would be greatly reduced. It is understood that insulated gap Q need not necessarily be located directly between the pole pieces, this arrangement being shown only for reasons of clarity in the drawings.

Magnetic sound carrier 10, which is shown in fragmentary view, is moving in the direction indicated by arrow, or away from the point of viewing, or, alternately, in the opposite direction, toward the point of viewing. The action of guide pin 7 is evident, it being understood that the guide grooves follow a helical or spiral pattern, so that the magnetic head assembly is guided laterally over the recording surface, it being further understood that magnetic sound carrier 10 may be either in disk or cylinder form, and, if desired, may be pregrooved and recorded on both sides.

In Figure 2, a modified pole piece arrangement is shown for use with non magnetic metal shoe piece 1, where pole piece tips 12 and 13 are formed from soft iron, or other solid magnetic material.

In Figure 3, a further modified pole piece ar-

rangement is shown, where 15 and 16 are formed of plasticized powdered iron, as were the pole pieces 5 and 6 of Figure 1, except that in the modification shown by Figure 3, a small gap is left at points 17 and 18, to form two relatively small air gaps in the magnetic circuit. The purpose of this is to eliminate any stray field effects which may be evident during reproduction, due to a variable magnetic contact between the pole piece tips and their associated sound track, either during recording or reproduction, or both, where the pole piece tips were normally in magnetic contact with their associated sound track.

This feature represents a known practice, which has not been widely used in magnetic recording, due to the extreme difficulty that has been previously encountered in attempts to maintain a relatively small air gap at a constant length. However, in the present invention such an air gap (the term "air gap" as here used is intended to mean the total air gap, which is the sum of the two separate air gaps shown clearly by Figure 3) may be maintained relatively constant in length, due to the improved magnetic head design and magnetic sound carrier design, this being readily apparent in Figure 1.

The use of air gaps 17 and 18 introduces a power loss but this is small for a relatively small air gap and may readily be calculated for any given length of air gap by the well known equation:

$$A_t = A_1 - (A_1 \cdot 8a) \quad (1)$$

where A_t represents the total ampere turns per unit length, A_1 the ampere turns per unit length without an air gap in the magnetic circuit, 8 is a constant, and a represents the air gap per unit length.

As a practical example, air gaps 17 and 18 may each have a length on the order of .002". Substituting in Equation (1) above, and assuming, for example, 10 ampere turns per inch in a closed magnetic circuit, the increased ampere turns would become .0032 ampere turns for a total air gap of .004", it being understood that this increase in ampere turns may be either an increase in the number of turns per unit length, the current flowing in the coil, or both, it being understood that the use of any air gap is optional and in the event such air gap is used that the length of such air gap may be as desired, or as necessary in any particular magnetic head design.

In Figure 4, the flux concentration in a single magnetic sound track is indicated by 22, it being readily apparent that the total flux must be confined to the region indicated by 22, which represents a very high density of magnetic flux in a very small area. It is understood that magnetic sound track 10 is moving in the direction indicated by arrow, or the directly opposite direction. From Figure 4 it is evident that the magnetic flux distribution represents a form of cross magnetization, which is the preferred method according to this invention, it being further understood that magnetic sound track 10 may also be caused to move in a direction opposite to that indicated, in which case the magnetic flux distribution would represent a form of longitudinal recording.

In Figure 5 a bottom view of non-magnetic metal shoe 1 is shown, where 20 and 21 represent the pole piece tips, 7 the guide pin and 27, 28, and 29 represent alternate positions for guide pin 7, which may also be interpreted as a plu-

ality of guide pins, which may be desirable in certain applications. Insulating slot Q is represented as shown by Figures 1 through 4 inclusive. Alternately, two such insulating slots may be used as represented by Q_1 and Q_2 , the electrical effect being the same as a single insulating slot between the pole pieces, as represented by Q.

In Figure 6, a side view of shoe 1 is shown, which is believed to be self explanatory.

Figure 7 represents a modified form of shoe piece 1, now designated as 23, with the lower surface 26 designed to mate with a cylindrical record 25. In this instance, it is assumed that cylindrical record 25 is pregrooved in a manner similar to magnetic sound carrier 10 and that guide pin 7 serves the same function as previously explained.

Figure 8 represents a bottom cross section view of the shoe illustrated by side view in Figure 7, except that guide pin 7 and set screw 24 have been omitted. An alternate and preferred method of guiding shoe 23 is shown where the raised threads 32, 34, 36, and 38 are designed to engage the guide grooves of the magnetic sound carrier 25, and flat sections 31, 33, 35, and 37 are each designed to rest on an equal number of magnetic sound tracks, it being understood that any desired number of guiding threads may be used, and that it is not considered necessary that the entire mating surface of shoe 23 be threaded as shown, although this may be done if desired. In any event, the weight of the entire magnetic head assembly will be carried on the flat surface sections 31, 33, etc., resting on their associated flat surface magnetic sound tracks. It is readily apparent that the arrangement illustrated by Figure 8 will not wear rapidly, and that such wear as might take place on shoe 23 would tend to seat the guiding threads, this being a progressive and continuous effect which would not impair the operation of the magnetic head assembly or the magnetic sound carrier. Due to the relatively greater hardness of the magnetic sound carrier, as compared to the non magnetic shoe, maximum wear will take place on the shoe. Pole piece tips are represented by 41 and 42, which may represent any of the pole piece structures previously described, or those described further below, an air gap being represented by points 41 and 42 if that is desirable.

In Figure 9 a fragmentary cross section view of magnetic sound carrier 10 is shown as a disk record pregrooved on both sides, having guide grooves A, B, C, etc., and sound tracks a, b, c, etc., on one side and guide grooves A_1 , B_1 , C_1 , etc., and sound tracks a_1 , b_1 , c_1 , etc., on the opposite side. It is understood that the actual dimensions of these guide grooves and sound tracks may be anything desired or necessary, that the record may be pregrooved on one side only if desired, that the overall record thickness may be as desired and that the design shown may be readily adapted to a cylinder record (not shown), which would normally be pregrooved on the outer surface only. It is further understood that the design shown may be reversed so that the flat surface magnetic sound tracks a, b, c, etc., may be lower than the main surface with separating guide ridges or threads, although this design would eliminate the desirable factor of an air gap between adjacent sound

tracks, and the preferred design is as shown in Fig. 9.

Figure 10 represents a modified construction of the non magnetic shoe, the main construction being identical with that previously shown, except that wedge shaped section 43 is now shown as a separate section, which may be machined separately and inserted into shoe 44. This is an improved and preferred method having two advantages. First, it makes possible a separate machining operation on wedge section 43 to provide the necessary openings for the pole piece tips. It is normally simpler to mill slots in wedge section 43 than it would be to drill such pole piece tip openings in a solid piece, considering the extremely small dimension of the pole piece tips, which are on the order of .001", or less. Second, use of a separate wedge section 43 allows the use of a softer material, such as copper, which is a much better electrical conductor than any material suitable for the main surface of shoe piece 44. Substitution of a better electrical conductor as material for wedge section 43 would improve the conductive shielding between the pole piece tips 45 and 46, increase the flux density at these pole piece tips, and lower the eddy current loss, all of which are desirable.

It is necessary that an insulated gap be provided in the electrical circuit around the pole pieces, to prevent the effect of a shorted turn, which would considerably reduce the high frequency response. Such an insulated gap is indicated by S, which completely insulates wedge section 43 from main shoe section 44. Insulated gap S may be any non conductor which would serve to break the electrical circuit, such as, for example, mica, Bakelite, paper, etc.

The electrical resistivity of the main section may be considerably greater than that of copper and still offer complete shielding, due to the relatively less magnetic field intensity and relatively great mass. As previously set out, some of the oil bearing bronzes, or graphite bronzes would be ideal for the main section of this shoe, as the action between the shoe mating surface and the magnetic sound carrier may be compared to the action between a bearing and a shaft, and a desirable feature would be maximum slidability at this point, with minimum friction, and some lubrication at this point would be desirable, both to reduce friction and to control corrosion of the magnetic sound carrier, which must be considered in the case of ordinary high carbon steel, although rust proof magnetic materials may be used for the magnetic sound carrier. A thin film of oil or graphite on the magnetic sound carrier would have no appreciable effect on recording or reproduction.

Figure 11 is a top view of Figure 10, all reference numbers being the same.

Figure 12 is a bottom view of Figure 10, all reference numbers being the same. It is believed that both Figures 11 and 12 are self explanatory.

Figure 13 represents a grossly exaggerated view of pole piece tip 45 or 46, as formed in the milled slots in wedge section 43. For a clearer understanding and by way of example, the dimensions of such a pole piece tip may be similar to the following: T₁ and T₂, 1/8"; P₁ and P₂, 8/10,000"; L, 1/2". It is understood that these dimensions are merely suggestive of practical dimensions which may be used, and are not to be deemed restrictive in any manner, it being understood that any other practical dimensions may be used. It is further

understood that Figure 13 may also represent any of the pole piece tips previously shown, except that those previously shown, being circular, would have circular end dimensions analogous to the rectangular dimensions given by way of example for the pole piece tip shown by Figure 13.

Figure 14 is grossly exaggerated perspective view of wedge section 43, which clearly shows the construction of the pole piece slots and is believed to be self explanatory.

Figure 15 is a sectional cutaway view of the wedge section 43 shown by Figure 14, taken through the line RR, which will further clarify the construction of wedge section 43.

Figure 16 is a schematic diagram illustrating bending of the magnetic force lines in magnetic sound carrier 10, where such bending is due to the great difference in permeability between pole piece tip sections 45 and 46, and magnetic sound carrier 10. This may be likened to the refraction of light in translucent material. The amount of this bending is determined by the permeability ratio between the material of the pole piece tip and the material of the magnetic sound carrier, and by the angle of pole piece inflection, represented by Z in Figure 16. If plasticized powdered iron is used as pole piece tip material, the maximum permeability, at audio frequencies, may be on the order of 30, while the permeability, of the magnetic sound carrier may be on the order of 6,000 to 10,000 or even higher, depending upon the specific material and the magnetic flux density. From this it may be seen that the permeability ratio between pole piece tips and magnetic sound carrier will be on the order of 200:1, or greater.

This permeability difference results in bending of the magnetic force lines so that, for the single pole piece 46, the magnetic force line path VV which would result with two materials having the same permeability is distorted or bent along the axis XX, due to the great difference in permeability. The same is true for pole piece 45, where the normal axis WV will be deflected along the axis YX.

Assuming a permeability ratio of 200:1, the axis XX or YX will be parallel with the surface of the magnetic sound track within .2°, where the angle Z is 45°. Assuming a soft iron pole piece tip with a permeability of 100, and a permeability ratio of 60:1, an angle Z of 45°, then the axis XX or YX will lie at an angle of 6° from the horizontal sound track surface. From the foregoing, it may be seen that depth of field or focal point will be extremely close to the horizontal surface of the sound track. In no event can the maximum depth of field or focal point exceed the width of the magnetic sound track, and it would be necessary to assume a permeability ratio of 1:1 and an angle Z of 45° for the depth of field to be as great as the width of the magnetic sound track.

The foregoing magnetic force line defraction which occurs does not taken into account the further bending which occurs as a result of the normal attraction between the North pole and the South pole. This normal bending, due to opposite pole attraction, added to the defraction bending gives a very desirable condition where the entire magnetic flux is concentrated very close to the sound track surface, and in no event can the focal point of this magnetic flux concentration be at a depth in the magnetic sound carrier greater than the width of the magnetic sound track. In a practical case of 200 sound tracks per inch and a guide groove

having a width at the throat equal to the sound track width, the width of each sound track, and consequently the maximum magnetic field depth in the sound track, cannot exceed .0025". From the foregoing it is evident that the overall thickness of a magnetic disk to be pregrooved and recorded on both sides will be determined only by the mechanical requirements, as the maximum overall thickness needed for recording both sides will, in a practical case, by way of example, be less than .005".

Referring now to Figure 17, a modified arrangement of the shoe shown by Figures 10, 11, and 12 is illustrated, where a small quantity of loose powdered iron, not plasticized, is inserted at 56 and 57, to provide a better magnetic contact between plasticized iron pole piece tips 45 and 46 and the main pole piece section 9. Wedge section 43D is similar to section 43, except that in the present instance pole piece tips 45 and 46 are shown as having a uniform diameter, and space is provided for loose powdered iron at points 56 and 57.

Figure 18 represents a further modification, where pole piece tips 45 and 46 are designed to terminate directly over their associated sound track, to provide tolerance for a slight lateral shift between magnetic head assembly and the magnetic sound carrier.

In Figure 19, wedge section 43B is modified so that it does not occupy the full space, i. e., the thickness of section 43B is less than the main thickness of section 44. This results in less shielding, and lowered eddy current loss, which may be permissible or desirable in specific designs.

In Figure 20, wedge section 43C occupies a greater space than the thickness of section 44. This results in more complete shielding and higher eddy current loss, which may also be permissible or desirable in specific designs.

Figure 21 represents a bottom cross section view of shoe piece 44, illustrating improved guiding means, similar to the guiding means shown by Figure 8, except that the present design is adapted for use on a magnetic sound carrier in the form of a disk record, where the radius of the helical guide grooves becomes progressively less (or greater, as the case may be), which does not permit using guide sections having any considerable length. Raised thread sections 51, 52, 53, and 54 are designed to engage their respective guide grooves, while flat sections 50, 49, 55, etc. rest on their respective magnetic sound tracks, it being understood that any desired number of raised guiding threads may be used and that the axis of these threads may be at any desired angle, rather than parallel with one edge of shoe 44, as shown. For example, the axis of these guide sections may follow any desired angle, such as the line 00, or, the axis may be circular, or elliptical.

Figure 22 is an end cross section view of Figure 21 and a fragmentary schematic view of sound carrier 10, showing the relationship between these two mating sections in a clear manner.

Figure 23 is a grossly exaggerated view of a single guide section, here designated as 54. Dimension K₁ will approximate the dimension of the guiding groove throat, dimension K₂ will approximate the dimension of the guiding groove depth, and dimension K₃ will approximate dimension K₁, although in any given design it may

be permissible for dimension K₃ to exceed dimension K₁ by a small amount.

In Figure 24, a modified arrangement of guide pin mounting is shown, for use with any of the designs previously shown, where guide pin 62 is held in mating contact with its associate guide groove, and at the same time automatically compensated for wear by pressure from spring 59, mounted on pillar 58 and held in place by screw 60.

Figure 25 further clarifies the modification shown by Figure 24. Guide pin 62 has a slightly elongated groove 63, which is lightly engaged by set screw 61, which allows a small vertical travel of guide pin 62, but prevents the pin from falling out when the magnetic head assembly is lifted from the magnetic sound carrier.

Summarizing, a complete invention has been disclosed, which may be separated into two main parts. First, improvements in design and construction of a magnetic head for use in magnetic recording, reproduction or obliteration, which incorporates complete shielding of the magnetic field, improved methods of guiding the magnetic head laterally over the magnetic sound carrier, improved methods of concentrating the magnetic field in an exceedingly small area of a magnetic sound track, improvements in pole piece tip design and material, elimination or great reduction of fringing in the immediate locality of the pole piece tips, and numerous other advantages. Second, a magnetic sound carrier having a plurality of closely adjacent magnetic sound tracks, each having a relatively flat surface and each separated from the next adjacent sound track by an air gap. The flat surface feature of the sound tracks makes possible dispersing the magnetic head weight over a large area, without weight on the pole piece tips per se, thus eliminating or greatly reducing wear on the totally enclosed pole piece tips. The air gaps between closely adjacent sound tracks co-operating with the magnetic head design to allow the use of closely spaced sound tracks. The improvement of using a flat sound track over that of using a substantially V pitch sound track is evident, as such a V pitch track would tend to increase the wear between the magnetic head assembly and the magnetic sound carrier, and would not allow the use of closely spaced sound tracks separated by air gaps.

While the magnetic sound carrier guide grooves have been shown throughout as having a substantially V pitch, separated by flat surface magnetic sound tracks, it is understood that other shape guide grooves, such as, for example, U shaped, or rectangular shaped, or any desired modification may also be used, this factor not being considered of major importance in the practice of this invention.

While numerous modified and alternate designs have been shown and described, it is understood that all of these features are to be considered interchangeable or useable in combination and it is anticipated that other alternate and modified arrangements will occur to those skilled in the art.

The use of a nonmagnetic electrically conductive wedge section between the pole piece tips offers numerous advantages, several of which have been explained in detail. Further advantage may be taken of the fact that eddy current loss in this wedge section will vary with magnetic field strength (also with frequency and

other factors) so that, if desired, a true form of volume compression-expansion may be utilized. By proper choice of mass and material for this wedge section, eddy current loss may be so reduced as to be negligible, even though serving its primary function of shielding and magnetic field concentration.

If desired, however, by proper choice of mass and material this eddy current loss may be so increased as to compress the higher recording levels according to a definite ratio, and this initial volume compression may be later expanded, utilizing well known methods of volume compression-expansion. The effect of this would be to greatly increase the effective recording volume range, in terms of total DB between minimum and maximum volume levels recorded. This would be done by greatly raising the upper recording level, the lower level being determined by the permissible signal to noise ratio, as in any recording system.

From the foregoing it is evident that a further advantage offered in the practice of this invention would be the increase in DB recording range, and that by proper design the total range may be made much greater than that possible with known methods.

The separate parts of this invention all cooperate to produce a magnetic recording, reproduction, and obliteration system, which, in terms of performance, will give a better high frequency response, better fidelity, lowered sound track linear speed, longer magnetic head and magnetic sound track life, longer playing time and greater volume range than was possible heretofore.

In all of the foregoing examples a recording, reproducing or obliterating bi-polar electromagnet having a single coil is referred to, and such a single coil is shown in the drawings. It is understood that a separate coil may be used to furnish a polarizing flux while recording, as is common practice, or, the signal voltage may be superimposed on a D. C. voltage used to produce such a polarizing flux, as is also common practice.

It is understood that the use of the term "plasticized powdered iron" throughout this specification shall be construed to mean any plasticized magnetizable powder or plasticized magnetizable dust, other than plasticized powdered iron, such as, for example, plasticized powdered permalloy, it being understood that plasticized powdered iron is used only by way of example and is not to be deemed restrictive in any manner.

The above examples are for the purpose of illustrating some of the methods and means by which the broad purposes of this invention may be carried out and are not to be deemed as restrictive in any manner. Other modifications and alternatives will occur to those skilled in the art without departing from the scope of this invention as defined by the following claims.

I claim:

1. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a non magnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having a face mating with and resting on a

plurality of said sound tracks with said polar extremities instantaneously disposed in magnetic relation to part of one of said sound tracks.

2. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks separated by guiding grooves with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a non magnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having a face mating with and resting on a plurality of said sound tracks and engaging at least one of the grooves separating said sound tracks, said shoe guiding said magnetic head assembly laterally over said magnetizable record carrier so that said polar extremities are instantaneously disposed in magnetic relation to part of one of said sound tracks.

3. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks separated by guiding grooves with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a non magnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having a face mating with and resting on a plurality of said sound tracks and having a guide pin engaging at least one of the grooves separating said sound tracks, said pin guiding said magnetic head assembly laterally over said magnetizable record carrier so that said polar extremities are instantaneously disposed in magnetic relation to part of one of said sound tracks.

4. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks separated by air gaps, each sound track having a relatively flat face section, with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a non magnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having a face mating with and resting on a plurality of said sound tracks with said polar extremities instantaneously disposed in magnetic relation to part of one of said sound tracks.

5. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks separated by grooves, each sound track having a relatively flat face section, with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a non magnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having a face mating with and resting on a plurality of said sound track face areas and engaging at least one of the grooves separating said sound tracks, said shoe

guiding said magnetic head assembly laterally over said magnetizable record carrier so that said polar extremities are instantaneously disposed in magnetic relation to part of one of said sound tracks.

6. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks separated by grooves, each sound track having a relatively flat face section, with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a non magnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having a face mating with and resting on a plurality of said sound track face areas and having a guide pin engaging at least one of the grooves separating said sound tracks, said pin guiding said magnetic head assembly laterally over said magnetizable record carrier so that said polar extremities are instantaneously disposed in magnetic relation to part of one of said sound tracks.

7. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a nonmagnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having means for preventing a closed electrical circuit around said polar extensions.

8. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions formed of plasticized magnetizable powder and having a nonmagnetic metal shoe enclosing and separating at least part of said polar extensions.

9. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a nonmagnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having as a separate section of different electrical conductivity than the balance of said shoe at least that part interposed between at least part of said polar extensions.

10. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions

and having a nonmagnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having as a separate section differing at least in part in thickness from the thickness of the remainder of said shoe at least that part interposed between at least part of said polar extensions.

11. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a nonmagnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having as a separate section at least that part interposed between at least part of said polar extensions, at least part of said polar extensions being formed as an integral part of said separate section.

12. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a nonmagnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having as a separate section at least that part interposed between at least part of said polar extensions, at least part of said polar extensions being formed of plasticized magnetizable powder as an integral part of said separate section.

13. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a nonmagnetic metal shoe enclosing and separating at least part of said polar extensions, said shoe having as a separate section at least that part interposed between at least part of said polar extensions, said separate section being electrically insulated from the remainder of said shoe to prevent a closed electrical circuit around said polar extensions.

14. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions as separate sections having a nonmagnetic metal shoe enclosing and separating at least part of said polar extension sections and having non-plasticized magnetizable powder interposed between one extremity of each of said separate sections and a respective extremity of said bi-polar electromagnet.

15. In a magnetic recording or reproducing system, a magnetic head assembly as defined in claim 3 including a spring for maintaining the

guide pin in intimate contact with the guide groove.

16. In a magnetic recording or reproducing system including a magnetizable record carrier having on at least one surface a plurality of closely adjacent sound tracks with means for moving said magnetizable record carrier tangentially to the polar extremities of a recording or reproducing magnetic head, a recording or reproducing magnetic head assembly including a bi-polar electromagnet having polar extensions and having a nonmagnetic metal shoe enclosing and separating at least part of said polar extensions and a lead screw acting on and so guiding said magnetic head assembly laterally over said magnetizable record carrier that said polar extremities are instantaneously disposed in magnetic relation to a part of one of said sound tracks.

17. In a magnetic recording or reproducing system including a magnetic recording or reproducing head assembly having a nonmagnetic metal shoe mating with and resting on a magnetizable record carrier having a plurality of closely adjacent sound tracks moving tangentially to the mating surface of said shoe, the method of reducing wear on the mating surface of said shoe and said magnetizable record carrier which comprises the steps of forming each of said sound tracks in said magnetizable record carrier with a relatively flat mating surface, separating each of said sound tracks from the next adjacent of sound tracks with an air gap and causing the mating surface of said shoe to rest on a plurality of said flat sound track mating surfaces.

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