Aug. 1, 1967 M. CAMRAS 3,334,192

CROSS FIELD MAGNETIC TRANSDUCER HEAD

Filed July 24, 1961 4 Sheets-Sheet 1

FIG. 1

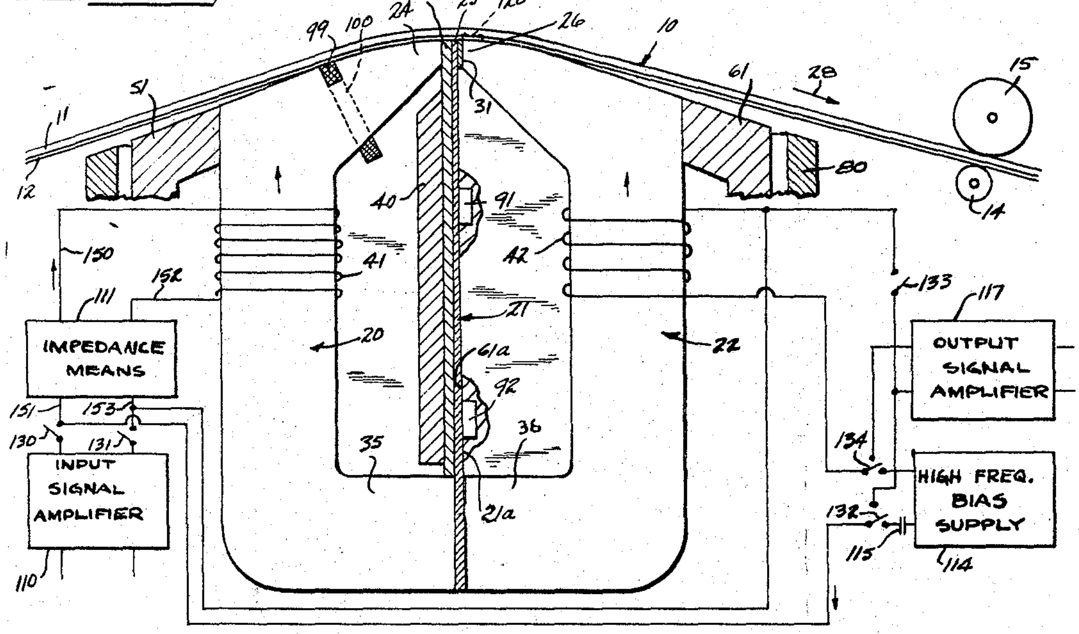


FIG. 2

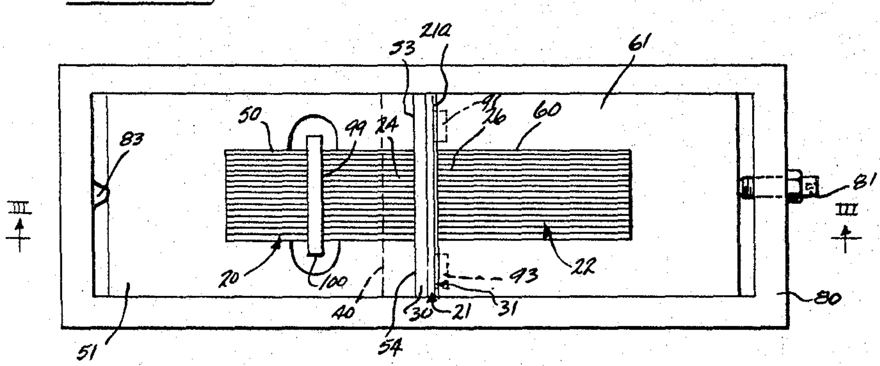
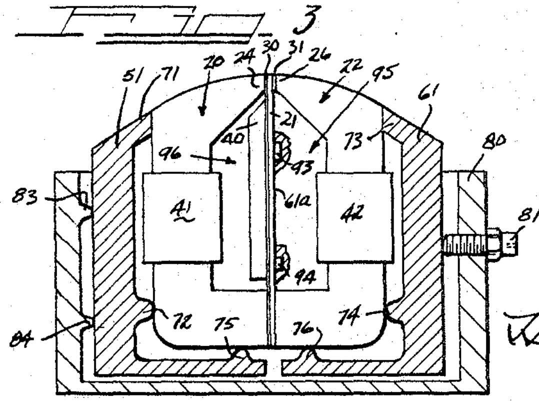


FIG. 3



INVENTOR.
Marvin Camras

BY

Hill, Sherman, Meroni, Gross & Simpson
ATTORNEYS

CROSS FIELD MAGNETIC TRANSDUCER HEAD

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Fig. 4

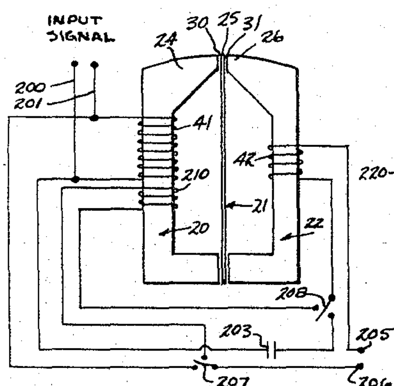


Fig. 5

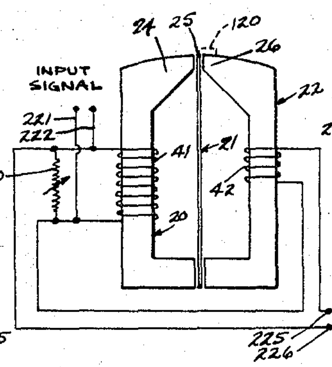


Fig. 6

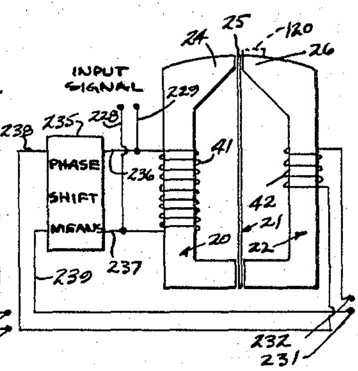


Fig. 7

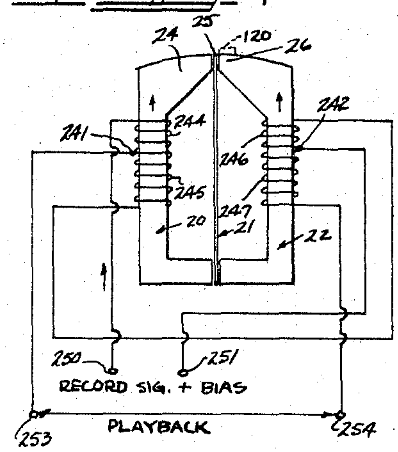


Fig. 8

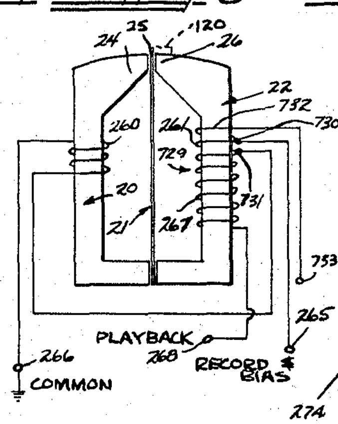


Fig. 9

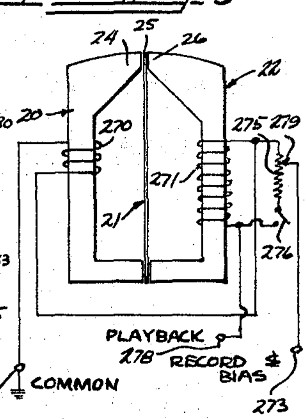


Fig. 10

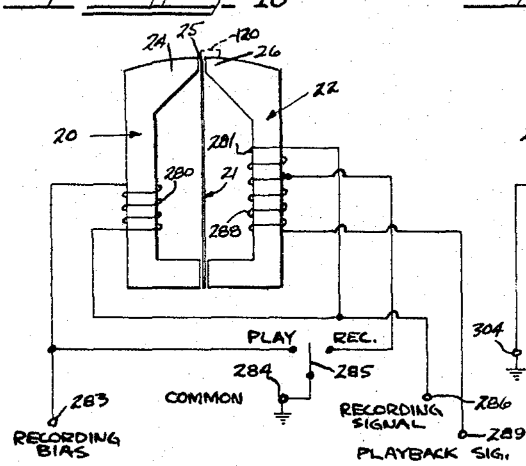
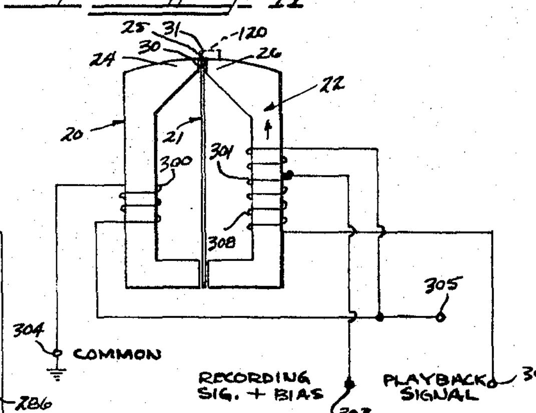


Fig. 11



INVENTOR.
Marvin Camras

BY

Hill, Sherman, Meroni, Gross & Simpson
ATTORNEYS

FIG. 12

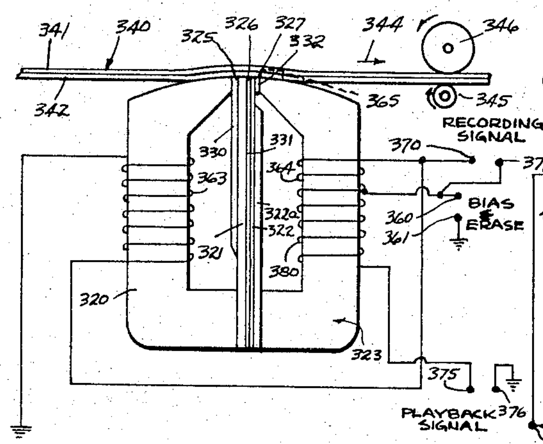


FIG. 14

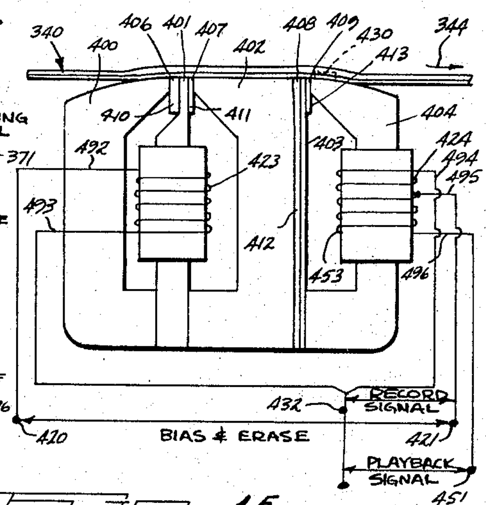


FIG. 13

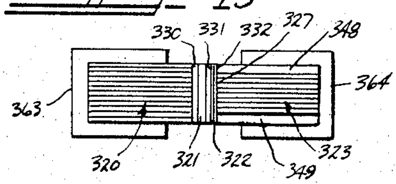


FIG. 15

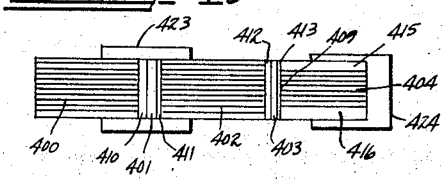


FIG. 16

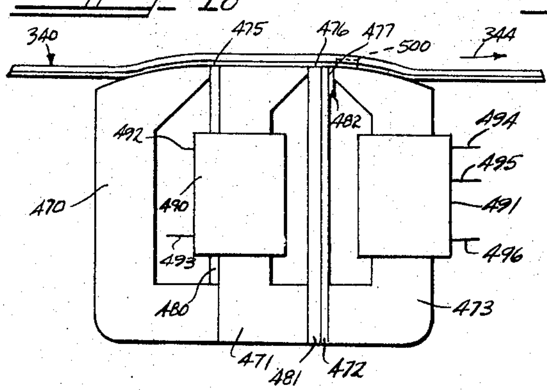


FIG. 18

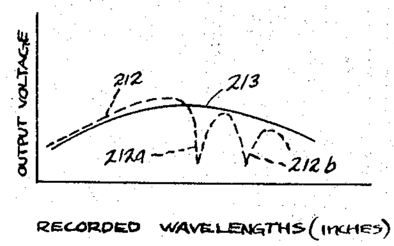


FIG. 17

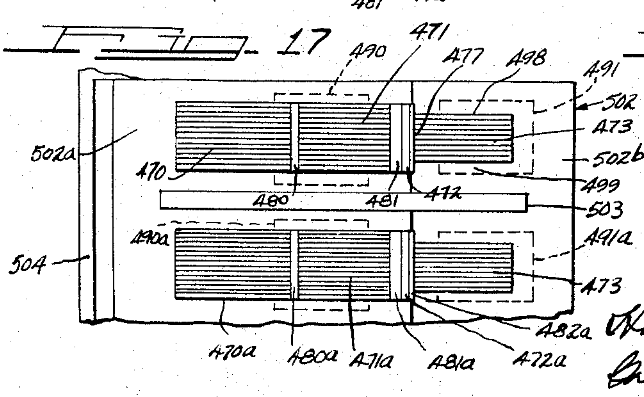
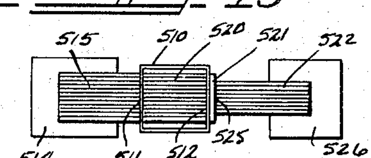


FIG. 19



INVENTOR.
Marvin Camras
BY
ATTORNEYS

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Fig. 20

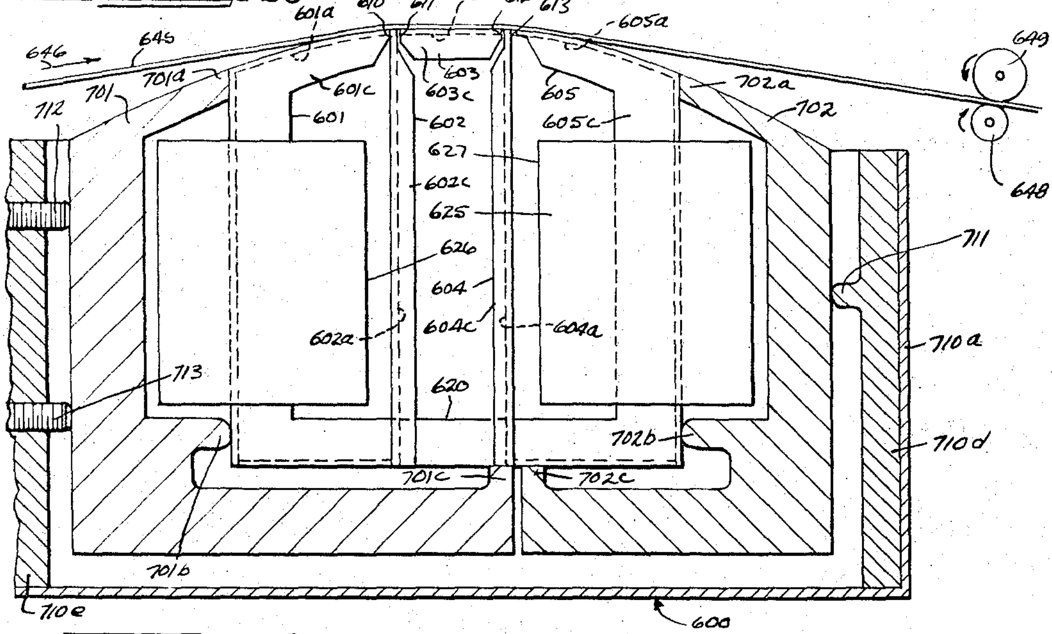


Fig. 21

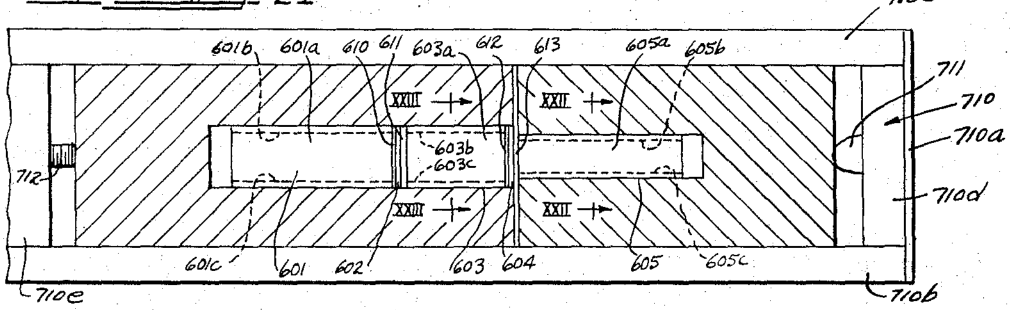


Fig. 24

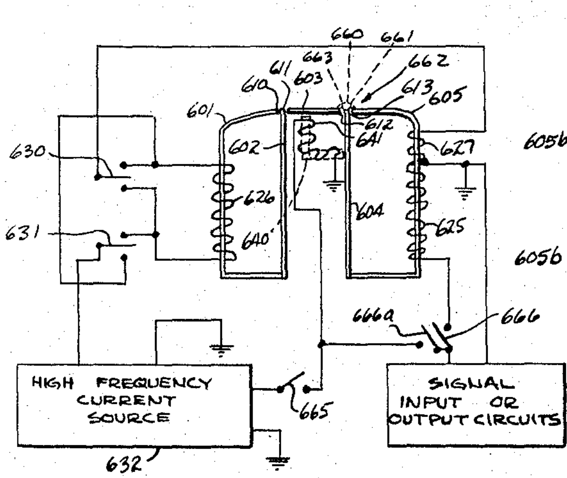


Fig. 22

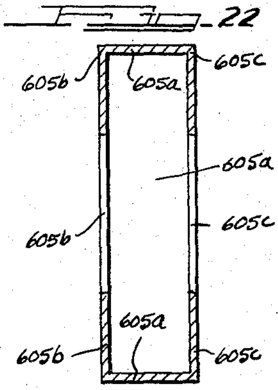
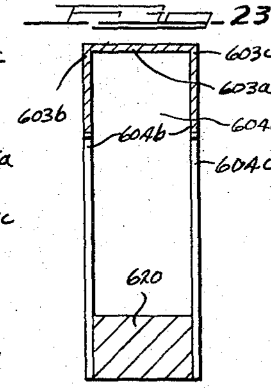


Fig. 23



INVENTOR.
Marvin Camras
BY
Hill, Sherman, Meroni, Gross & Simpson
ATTORNEYS

United States Patent Office

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Patented Aug. 1, 1967

3,334,192

CROSS FIELD MAGNETIC TRANSDUCER HEAD

Marvin Camras, Glencoe, Ill., assignor to IIT Research Institute, a corporation of Illinois

Filed July 24, 1961, Ser. No. 126,121
26 Claims. (Cl. 179—100.2)

Applicant hereby claims the benefit of the filing dates of his copending application Ser. No. 434,281, filed June 3, 1954 (now Patent 3,049,790, issued Aug. 21, 1962), and of his application Ser. No. 249,348, filed Oct. 2, 1951 (now Patent 2,785,232 issued Mar. 12, 1957), pursuant to 35 U.S.C. 120.

This invention relates to a magnetic transducer assembly for recording signals on magnetic record media and/or reproducing signals which have been recorded on such media, and also concerns a magnetic transducer assembly utilizing a single magnetic transducer head construction for both recording and playback functions.

The present invention provides a magnetic transducer assembly giving superior frequency characteristics and less distortion at very low record medium speed or in high frequency applications and particularly relates to improvements over Patent No. 2,803,708, issued Aug. 20, 1957. In accordance with a preferred embodiment as disclosed in said prior patent, the erase gap of an erase-record head assembly is placed sufficiently closely to the record gap so that high frequency flux extends in air from one of the erase poles to the region of the recording gap and is of magnitude adjacent the recording gap to produce a substantially more desirable bias field configuration in the region of the recording gap.

While maintaining the advantages of said previous patent, the present invention provides important new concepts which significantly improve the effectiveness of the recording and playback functions and make possible a simple low cost record-playback head assembly which is practical for use in medium and low priced recording machines. A head assembly in accordance with the present invention gives excellent distortionless low frequency response without the sacrifice of high frequency response at tape speeds of 1⅞ inches per second or lower. It allows the use of extremely short high resolution gaps which could not ordinarily be used for recording, and of relatively thick magnetic tape layers for high output and uniformity at medium and long wavelengths. A preferred construction utilizes a recording-playback assembly with a pair of gaps defined by a series of three poles across which the tape successively travels. Preferably a composite arrangement including outer strips of copper or other non-magnetic material and a center strip of magnetic material define the second or center pole between the two outer poles and the gaps at either side of the center pole. By this construction, the gaps are permanently and accurately located with respect to each other and may be made as close together as desired. The gap defining faces of the poles may be polished to high precision, and the three pole head may be assembled as readily as a conventional head.

The tape or other suitable record medium may travel first over a relatively large non-magnetic gap and then over a relatively fine gap suitable for high density recording or playback. In accordance with one embodiment of the present invention, the high frequency field across the first relatively large gap is not required to perform an erase function and thus may be precisely of optimum configuration and intensity for aiding in the recording function of the head assembly.

A preferred construction further provides means for applying the signal magnetomotive force at the outer pole adjacent the large gap so as to provide a relatively

uniform signal field adjacent the small gap in the region where the bias field has a sharp gradient. Thus the signal field persists at substantially full strength as the bias field intensity falls off along the path of the tape beyond the small gap; this produces a recording of the signal field of greater intensity than is the case where the recording signal field and bias field are both attenuating at the same rate along the path of the tape beyond the small gap.

A further feature of the preferred embodiment resides in the provision of a metal casing for the transducer head made of a material having a thermal expansion coefficient similar to that of the core material of the head to provide a more stable gap configuration.

The present invention also makes possible the provision of an erase gap or gaps in the head assembly which may also be provided by a sandwich type construction for simplicity and so as to place the erase gap or gaps as close as possible to the recording section of the head to insure proper tracking of the tape over all of the gaps. A single head including provision for the erase function is economical and reduces problems of mounting and alignment between the erasing and recording sections. By the present invention the magnetic circuit between the erase and record sections may readily couple an optimum level of high frequency field from the erase section to the recording section.

Stereo or multiple heads may employ the concepts of the present invention. Thus two or more laterally spaced cores may cooperate with a larger area center pole arrangement common to all of the head units. Alternatively, separate center pole assemblies may be used for each head unit with shield members extending longitudinally of the tape path between the successive separate head units.

It is therefore an important object of the present invention to provide a novel and improved magnetic transducer assembly for magnetic record media providing higher resolution, better frequency response and less distortion at very low speeds or in high frequency applications.

A further object of the present invention is to provide a relatively simple and inexpensive transducer head for high density recording or playback applications.

Still another object of the present invention is to provide a novel magnetic recording head structure providing excellent distortionless low frequency response without sacrifice of fidelity at high frequencies and which is particularly adapted to low record medium speeds such as 1⅞ inches per second or less.

A further object of the present invention is to provide a novel magnetic transducer head having a gap configuration of great accuracy and stability.

A still further object of the invention is to provide a novel combined erase record and playback transducer assembly for use with magnetic record media and to provide a novel stereo or multiple head assembly having a common center pole configuration.

Other objects, features and advantages of the present invention will be apparent from the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a somewhat diagrammatic vertical cross sectional view of a magnetic transducer head construction in accordance with the present invention and illustrating suitable circuit components connected to the windings of the head for carrying out recording and playback operation;

FIGURE 2 is a somewhat diagrammatic top plan view of the structure of FIGURE 1;

FIGURE 3 is a somewhat diagrammatic vertical cross sectional view taken along the line III—III of FIGURE 2 and illustrating the manner in which the two halves of the head assembly may be cemented together without detriment to the non-magnetic gap therebetween;

FIGURES 4 through 11 illustrate various circuit modifications for improving playback response in a combined record-playback transducer head assembly in accordance with the present invention;

FIGURE 12 illustrates an erase-record playback head assembly in accordance with the present invention;

FIGURE 13 is a somewhat diagrammatic top plan view of the assembly of FIGURE 12;

FIGURE 14 is a somewhat diagrammatic illustration of a further erase-record-playback transducer assembly in accordance with the present invention;

FIGURE 15 is a somewhat diagrammatic top plan view of the structure of FIGURE 14;

FIGURE 16 is a diagrammatic illustration of an erase-record-playback head assembly representing a modification of the embodiment of FIGURE 14;

FIGURE 17 is a somewhat diagrammatic top plan view of the structure of FIGURE 16;

FIGURE 18 shows in dotted outline a plot of output voltage as a function of recorded wavelength for the case of a multigap playback head having a pair of closely spaced gaps using a playback winding on the trailing pole piece, and shows in solid outline a similar plot for a playback head such as shown in FIGURE 1;

FIGURE 19 is a diagrammatic top plan view of a head such as shown in FIGURES 12 and 13 which has been modified to have a closed electric circuit extending through the erase and cross field gaps;

FIGURE 20 is a diagrammatic vertical sectional view of a further embodiment of magnetic transducer assembly;

FIGURE 21 is a horizontal sectional view of the assembly of FIGURE 20;

FIGURES 22 and 23 are vertical sectional views taken along the lines XXII—XXII and XXIII—XXIII, respectively, in FIGURE 21; and

FIGURE 24 is a diagrammatic view showing an electric circuit for the embodiment of FIGURES 20–23.

As shown on the drawings:

FIGURES 1, 2 and 3 illustrate a magnetic transducer head assembly for recording signals on a magnetic record medium **10** and for electrically reproducing the signals previously recorded on the record medium by the head assembly. By way of example and not of limitation, the record medium **10** may be in the form of a magnetic tape having a non-magnetic base **11** and a magnetizable layer **12** comprising a suitable magnetizable powder dispersed in a suitable non-magnetic binder. By way of example, the tape record medium **10** may be supplied from a supply reel (not shown) moved across the head assembly by means of a capstan roll **14** and pressure roll **15** at a constant speed and then wound upon a take-up reel (not shown). The present head assembly is particularly adapted to provide distortionless low frequency response without the sacrifice of high frequency response at low speeds such as 1⅞ inches per second, or below. Similar benefits are obtained at higher tape speeds, however.

The transducer head assembly comprises a magnetic core with three legs **20**, **21** and **22** having polar extremities **24**, **25** and **26** across which the record medium **10** successively travels as it moves in the direction of the arrow **28**. A relatively long gap between the extremities or poles **24** and **25** may be rigidly defined by means of a strip **30** of copper or other suitable electrically conductive non-magnetic material. A second relatively fine gap between poles **25** and **26** may be provided by a gap spacer **31** which may be of copper or other suitable metallic non-magnetic material. By way of example, the non-magnetic stip **30** may comprise a strip of copper having a thickness of .002 inch in the direction of travel of the record medium, the magnetic center leg **21** may comprise a sheet of "Deltamax" (50% nickel and the remainder iron and minor constituents), "Carpenter 49" (49% nickel and the remainder iron and minor constituents), "4–79 Molybdenum Permalloy" (4% molybdenum, 79% nickel and the remainder iron and minor constituents), or "Supermalloy" (5% molybdenum, 79% nickel and the remainder iron and minor constituents), and the gap spacer **31** may comprise a copper strip of .0001 inch or .00005 inch thickness in the direction of movement of the record medium. Where especially high flux-carrying capacity is desired during recording, leg **21** may be made of a cobalt-iron alloy such as "Supermendur." Where especially good initial permeability is desired during playback, leg **21** may be made of "Supermalloy." It may also be made of layers, some of which impart high flux capacity, and others high initial permeability.

In the illustrated embodiment, the outer legs **20** and **22** of the magnetic core have inturned lower end portions **35** and **36** which are spaced apart to receive the lower end of the sheet **21** of magnetic material. Beryllium copper is preferred for the spacer members **30** and **31**.

A sheet **40** of non-magnetic conductive material may be secured to the gap spacer **30** and extend centrally of the core to provide further shielding between core legs **20** and **21** and may have a thickness in the direction of movement of the tape of .005 inch. A piece of high permeability material, preferably laminated may be placed along and in contact with leg **21** beginning at a point spaced well below pole **26** to increase the flux carrying capacity of leg **21**.

Windings **41** and **42** are wound on the core parts **20** and **22**, and the core part **20** which may be made up of a stack of laminations of magnetic material is inserted in a receiving groove **50** of a casing part **51**. The gap spacer sheet **30** may be suitably secured to the faces **53** and **54** of the casing **51** and to the planar face of pole portion **24**. The center pole sheet **21** may then be suitably secured to the outer surface of the gap spacer member **30** for example by means of a thin layer of a suitable cement. Similarly the leg **22** of the core may comprise a stack of generally C-shaped laminations and may be placed in a suitable recess **60** of a casing part **61**. The casing parts **51** and **61** may be of a suitable non-magnetic material having substantially the same coefficient of expansion as the magnetic material of core legs **20** and **22**; for example, the coefficient of expansion of nickel-iron cores containing 79% nickel is about 12.5×10^{-6}; for cores of 50% nickel content it is about 9.5×10^{-6}. Non-magnetic stainless steel having a coefficient of about 10×10^{-6}, and Monel metal with a coefficient of 14×10^{-6} may be used for the case. A closer match is possible with special alloys. The casing parts **51** and **61** may engage the legs **20** and **22** at boss portions **71–76** for accurate three point positioning of each of the legs.

Thus, in assembling the head construction, a first sub-assembly is formed including the casing part **51** and core legs **20** and **21**, while a second sub-assembly is formed including case part **61** and core leg **22**. The polar faces of poles **25** and **26** are then polished to optical flatness, and the two sub-assemblies are placed in mating relation with spacer strip **31** therebetween. The completed unit may then be placed in a suitable frame **80**, FIGURE 3, which may serve as a shield, with a set screw such as indicated at **81** acting on the casing part **61** and cooperating bosses such as indicated at **83** and **84** acting on the casing part **51** to press the two sub-assemblies toward each other. The polar faces of poles **25** and **26** are thus urged against opposite sides of gap spacer **31**. Alternatively, a wedge may be used instead of set screw **81**.

The two sub-assemblies are preferably cemented together at their mating surfaces such as indicated at ***21a*** and ***61a*** in FIGURE 1 by suitable means such as a cement to prevent side shift between the two sub-assemblies. Where the gap spacer **31** has a thickness dimension of .0005 inch or less, the cement may be placed in a recess or recesses such as indicated at **91** and **92** in FIGURE 1 adjacent mating face ***61a*** of casing part **61**. Further recesses may be located as indicated at **93** and **94** in FIGURES 2 and 3. This prevents the build up of any additional spacing between poles **25** and **26** for extremely fine gap thicknesses.

The present invention further contemplates leaving air spaces at **95** and **96** in the final head assembly so that there is no problem of expansion or swelling with heat or humidity which would open the fine gap between poles **25** and **26** as would be the case if these spaces were filled with epoxy resin or the like. Any cement which is used, for example between the bosses **71–76** and the legs **20** and **22** is in a thin layer which cannot appreciably affect the gap dimension.

An erase gap may be located as indicated at **99** and may be energized by a coil such as indicated at **100** in FIGURE 1 or by a single conductor of cross section corresponding to the gap space **99** and extending therethrough. Such a conductor may form a closed circuit around leg **20** at **100** to obtain its energy from coil **41**.

In the embodiment of FIGURE 1, an input signal amplifier **110** or other input signal supply means is connected to the winding **41** either directly or through a suitable impedance means **111**. The impedance means **111** has particular significance during the playback operation of the assembly but in some instances may be used during recording. It may be desirable to adjust the phase relationship between the cross field and main bias field during recording and this may be accomplished by component **111**. A high-frequency bias supply component **114** is illustrated for connection to the windings **41** and **42** in series during the recording operation. A by-pass capacitor **115** is illustrated for transmitting bias frequency current which may have a frequency of 20 kc. to 300 kc. or higher, for example, while blocking signal frequency current. It will be observed that the windings **41** and **42** are connected in series across the high frequency bias supply component **114** and that the windings are connected in series opposing relation with respect to the magnetic circuit including core legs **20** and **22**. By way of example, the winding **41** may have 250 turns where the winding **42** has 42 turns. The high frequency bias current flowing in windings **41** and **42** may be such as to produce a bias field at the region of pole portion **26** in the path of tape **10** which diminishes much more rapidly as a function of distance from the gap **31** in the direction of tape movement than the bias field produced by winding **42** between poles **25** and **26** considered by itself. This phenomenon has been explained in detail in my prior Patents Nos. 2,628,285, issued Feb. 10, 1953, and 2,803,708, issued Aug. 20, 1957. The field pattern produced with the winding arrangement and connections just described would correspond to that shown in FIGURE 3 of Patent No. 2,803,708 and provide a more uniform bias field through the thickness dimension of the magnetizable layer **12**, a bias field at the trailing pole **26** which is more nearly longitudinal in character with respect to the direction of movement of the record medium and one having a very rapidly decaying magnetic intensity in the region of the trailing pole **26**. In fact, such a field configuration has a null point near the gap **31** above the trailing pole **26** where the leakage field from pole **24** produced by winding **41** effectively cancels the main bias field between poles **25** and **26** which is produced by winding **42**.

While in certain embodiments of said previous Patent No. 2,803,708, the high frequency field between poles corresponding to poles **24** and **25** in FIGURE 1 was of sufficient intensity to erase a saturation signal on the record medium, in the present instance, the high frequency field between poles **24** and **25** ordinarily has an intensity less than the saturation field intensity for the material of the record medium and is not of an intensity to insure erasure of record medium **10**. This is a result of the present construction where the distance between

the X-field gap and the following signal gap is equal to or less than the size of the X-field gap.

In the illustrated embodiment, the lower frequency signal current is supplied only to the winding **41** and serves to provide an effective recording field between poles **24** and **26** which is of substantially constant strength in the effective recording region above pole **26** indicated by the rectangle **120** where the bias field rapidly decays to an insignificant intensity. Thus the recording signal field due to the signal current in winding **41** persists substantially at a full strength value as the bias field falls off in intensity beyond the gap **31** in the path of the magnetizable layer of the record medium **10**. This results in the recording of a signal of greater intensity on the record medium for a given value of signal current in winding **41** than would be the case if the signal current were also supplied to winding **42**, or were supplied to a signal winding on leg **22** only. This recording arrangement with signal current supplied to winding **41** only provides substantially as good resolution as would be obtained where the cross field principle is applied both to the bias and signal frequencies. The arrangement is superior to the case where the signal current is supplied to a winding on leg **22**, since it provides a higher magnetization level on the tape record; a greater recording sensitivity, because a given signal field will magnetize the record more strongly; and freedom from recording demagnetization where the bias field may partially erase a high frequency recording before this recording has left the gap field, and where the signal field does not reinforce the recording.

During playback, in one form of the present invention, one winding **42** only may be directly connected to the output signal amplifier **117**. This corresponds to the case where switch means **130**, **131** are in open condition, switch **132** is in its intermediate open circuit position as shown in FIGURE 1, switch **133** is closed and switch **134** is in its upper position. This arrangement provides an operable playback system utilizing the same head configuration as utilized during recording but under some conditions has been found to provide less than optimum frequency response characteristics since at certain recorded wavelengths, the portion of the magnetizable layer **12** bridging the gap **30** will set up a stray flux in the magnetic circuit including legs **20** and **22** and linking winding **42** in advance of the time when this recorded signal element of the magnetizable layer reaches the correct playback region. The result is that at certain frequencies a cancellation effect is produced reducing the output from the single coil **42** during playback. While this phenomenon might not be detrimental for certain applications and in certain frequency ranges, and while various external circuit expedients could be utilized for compensating for this effect, it has been found preferable to utilize at least a part of the winding **41** for inducing a counteracting voltage in response to stray flux from the record medium and to utilize circuit means for introducing this cancelling voltage at the output signal amplifier **117** so as to counteract the effect on the stray pick-up phenomenon in winding **42**.

In one approach to this problem windings **41** and **42** are connected in series opposing relation across the terminals of the output signal amplifier **117**, this condition being produced by opening switch **133** and placing switches **132** and **134** in their upper positions. If the impedance means **111** is omitted and lines **150** and **151**, and **152** and **153** are directly connected respectively, perfect cancellation may not result since the number of turns for winding **41** has been selected to optimize the recording function rather than for best cancellation. On the other hand, optimum cancellation may also be achieved utilizing a winding **41** of the proper number of turns for recording by proper selection of the impedance means **111**. By way of example, impedance means **111** may take the form of a potentiometer having its outer fixed terminals connected to lines **150** and **152** and having its movable contact connected with line **151**, line **153** connecting directly with line **152**, for example. With this arrangement, adjustment of the potentiometer adjusts the value of voltage supplied from winding **41** to the output signal amplifier **117** for optimum cancellation of the spurious voltage induced in winding **42**. During recording, the potentiometer may be bypassed and not used. Another way to use the head of FIGURE 1 for playback is to connect coil **41** in series aiding relation with respect to coil **42** through a low pass filter at **111**. The long wavelengths will then generate additive voltages in windings **41** and **42** to give enhanced low frequency response. At higher frequencies represented by shorter wavelengths, only the output from winding **42** is effective so that a minimum of interference results. This mode of operation is especially desirable where stray coupling between gap **30** and winding **42** is low. The low pass filter at **111** may also be used during the recording to enhance low frequency recording by coil **41**.

In the embodiment of FIGURE 1, the non-magnetic strip **30** may terminate above the confronting lower end portions **35** and **36** of legs **20** and **22**, the legs **20** and **21** then being placed in magnetic contact with each other in this region. Filler strips of non-magnetic material may be inserted between end portion **35** and the low part of magnetic sheet **21** to vary the reluctance of the magnetic circuit including legs **20** and **21** and its coupling to the leg **22**.

With respect to the embodiment of FIGURE 1, assuming the impedance means **111** comprises a potentiometer having its outer fixed terminals connected to lines **150** and **152** and having its movable contact terminal connected to line **151** and one of its outer terminals connected to line **153**, the potentiometer may be adjusted to a value during playback which will minimize the discontinuities which occur when only the winding **42** is utilized to generate the playback signal.

FIGURE 18 shows a curve **212** representing the output voltage from winding **42** as a function of recorded wavelength on the tape **10** in the absence of any circuit means for compensating for the stray flux interference effect. It will be observed from FIGURE 18, that when a recorded half wavelength is approximately equal to the separation between the magnetic centers of gaps **30** and **31**, the signal at gap **31** of the head will generate a voltage of one polarity in the winding **42**, while the signal at gap **30** may produce a stray flux linking winding **42** and producing a voltage of opposite polarity at the winding **42**. The stray voltage induced in winding **42** in this manner produces a cancellation effect at this value of recorded wavelength as indicated by dip **212*a*** in the response curve **212**. Similar but less significant dips occur at sub-multiples of this critical recorded wavelength, a further dip being indicated at **212*b*** in the response curve **212** of FIGURE 18.

Since the stray flux linking winding **42** which produces these discontinuities also links winding **41**, it is possible to utilize a voltage divider across winding **41** during playback to select a correct value of voltage to exactly cancel the effect of the stray flux in the winding **42**. It is evident that the correct adjustment of the voltage divider can be determined by experiment by first obtaining a response curve such as indicated at **212** in FIGURE 18, then observing the critical recorded wavelength where the main discontinuity occurs, and by then adjusting the voltage divider to restore normal output from the head while a tape having the critical recorded wavelength travels across the head. When the first dip **212*a*** in the original curve has been eliminated in this manner, the setting of the voltage divider then obtained is found to provide a frequency response curve such as indicated at **213** in FIGURE 18. It will be observed that for recorded wavelengths greater than the critical wavelength illustrated in FIGURE 18, flux is produced in the circuit including legs **20** and **22** predominantly, and an opposing voltage is thus induced in winding **41** at these low frequencies. This opposing voltage, however, does not substantially affect the frequency response characteristics of the head as will be apparent from a comparison of curves **212** and **213**. At substantially higher recorded wavelengths, it will be understood that the gap **30** is relatively ineffective to produce a voltage in winding **41**, and thus it will be understood that connection of the winding **41** in series opposing relation to the winding **42** during playback will not appreciably affect the high frequency response of the head.

Thus, it is possible to smooth out the frequency response characteristics of the head by the utilization of an opposing winding on leg **20** during playback. Various additional circuits for accomplishing this same result are illustrated in FIGURES 4 through 11 and will now be described to illustrate additional examples of circuitry for accomplishing a smooth frequency response characteristic as illustrated by curve **213** in FIGURE 18.

With reference to the embodiment of FIGURE 1, for example, if impedance means **111** takes the form of a low pass filter, windings **41** and **42** may be connected in series aiding relation during playback whereupon the two windings will produce aiding voltages in response to low frequency magnetic signal flux linking the magnetic circuit including legs **20** and **22**. The head will thus provide increased output at low frequencies. At higher frequencies including those corresponding to the critical recorded wavelengths, the voltage induced in winding **41** will be blocked in the low pass filter **111** and will not appear at output signal amplifier **117**.

During recording, the low frequency components of the input signal from amplifier **110** will be transmitted through low pass filter **111** to winding **41** while higher signal frequency and bias frequency will be blocked and not reach winding **41**. If desired, during recording, bias supply **114** may be connected directly to winding **41** so that bias frequency is supplied to windings 41 and 42 in series as in previously described alternatives.

The core constructions for the embodiments of FIGURES 4 through 11 may be identical to that described in connection with FIGURES 1 through 3, and the description of FIGURES 1 through 3 is incorporated by reference with respect to each of the embodiments of FIGURES 4 through 11. The parts shown in FIGURES 1 through 3, but not shown in FIGURES 4 through 11 have been omitted simply for clarity of illustration and it is intended that the embodiments of FIGURES 4 through 11 include such parts.

In the embodiment of FIGURE 4, during recording, signal current corresponding to the signal to be recorded is supplied at leads **200** and **201** to the winding **41** but is illustrated as being blocked from winding **42** by means of capacitor **203**. High frequency bias current is supplied to the windings **41** and **42** in series from terminals **205** and **206** with switch **207** in its lower position and switch **208** in its lower position so that the high frequency bias field above pole **26** due to winding **41** instantaneously is 180° out of phase with respect to the bias field produced in the recording region by winding **42**, as in the embodiment of FIGURE 1.

During playback with the embodiment of FIGURE 4, switches **207** and **208** are placed in their upper positions to connect a winding **210** on leg **20** in series opposing relation to winding **42** on leg **22** across terminals **205** and **206** which in this case constitute the signal output means and would be connected to an output signal amplifier such as component **117** in FIGURE 1. The winding **210** has the correct number of turns for generating a cancelling voltage equal and opposite to the spurious voltage generated in winding 42 by stray flux linking the circuit including legs **20** and **22** at the frequencies where such stray flux otherwise produces an interference effect and introduces irregularities in the frequency response characteristics of the head.

By way of example, in designing a head as illustrated in FIGURE 4, the playback response may first be observed with the winding **42** only connected to the playback amplifier. This response curve will be generally as indicated in FIGURE 18 at **212** and will include discontinuities such as indicated at **212*a*** and **212*b***. A further winding may now be placed on the leg **20** with a number of suitable taps so as to provide outputs from numbers of turns more than adequate to compensate for the effect and intermediate numbers of turns. The number of turns providing a smooth output curve as illustrated at **213** in FIGURE 18 may then be determined by experiment. It is found that the additional winding **210** does not change the shape of the frequency response of the head to recorded wavelengths greater than the interference wavelength, and it is further found that the high frequency response of the head for wavelengths shorter than the interference wavelength also remains satisfactory. At long recorded wavelengths greater than the interference wavelength, the signal voltage in coil **210** due to pickup at gap **30** is in phase opposition to the signal voltage in coil **42** due to pickup at gap **31**, and their summation produces a slight reduction in output. At very short wavelengths, the long gap **30** is inefficient (and may be made even more so by rounding its edges, or not having the gap edges straight and parallel); thus the opposing voltage generated in winding **210** is of such a low value as to have little effect on the overall response of the head. Further, the voltage generated in the winding **210** by flux generated in the circuit including legs **20** and **21** has been found not to substantially distort the output signal.

The embodiment of FIGURE 5 illustrates the use of a variable resistor **220** as the impedance means represented by block **111** in FIGURE 1. An input signal may be supplied from an input signal amplifier such as **110** in FIGURE 1 via lines **221** and **222** during recording. Suitable switch means such as indicated at **130** and **131** in FIGURE 1 may disconnect the input signal amplifier **110** from lines **221** and **222** during playback. The input signal to be recorded may be blocked from winding **42** by means of a capacitor in series with the bias supply such as capacitor **115** in FIGURE 1, suitable switch means connecting the bias supply to terminals **225** and **226** during recording to supply high frequency bias current to the windings **41** and **42** in series and to produce high frequency magnetic fields in the recording region **120** which are 180° out of phase as in FIGURE 1. By way of example, during recording, variable resistor **220** may set to its maximum value so as to be effectively eliminated from the high frequency bias circuit.

During playback as in the previous embodiments, the bias supply and its capacitor **115** are effectively eliminated from the circuit, and the windings **41** and **42** are connected in series opposing relation across the terminals **225** and **226** which then constitute the signal output means and may be connected to the input of a suitable output signal amplifier such as **117** in FIGURE 1. During playback, the variable resistor **220** is adjusted to the value which provides optimum frequency response of the head as indicated by curve **213** in FIGURE 18 and eliminates the discontinuities such as indicated at **212*a*** and **212*b*** which are experienced when only the winding **42** is utilized during playback. It will be understood that once the correct value of variable resistor **220** has been determined for optimum playback response, a fixed resistor may be substituted of this optimum value and the resistor may be permanently connected across the winding **41**. Alternatively, a fixed resistor of the optimum value may be connected across the winding **41** by means of a switch during playback and the switch may be opened to disconnect the resistor from across the winding **41** during recording. Where a variable potentiometer or other voltage divider is substituted for element **220**, terminal **226** would be connected to the movable tap of the potentiometer instead of the upper fixed terminal of **220** in FIGURE 5, during playback. Once the optimum setting has been determined for playback, two fixed resistors in series may be substituted for the potentiometer, and switch means incorporated for connecting the resistor corresponding to the desired voltage fraction in circuit with the winding **42** during playback. During recording, the fixed resistors may be switched out of the circuit, or may have such a total value as to have a negligible effect on the recording characteristics of the head. In the latter case, during recording, the winding **42** would be connected in series with a network including both resistors of the voltage divider in parallel with the winding **41**.

In FIGURE 6, during recording, the input signal is supplied by lines **228** and **229** to winding **41** only and bias frequency current is supplied from terminals **231** and **232** to windings **41** and **42** in series. As in the previous embodiments, the high frequency bias fields produced by windings **41** and **42** may be 180° out of phase at the recording region **120**. During playback, winding **41** is again connected in opposing relation with respect to winding **42** and a phase shift device **235** is interposed between lines **236**, **237** and **238**, **239** to introduce an optimum value of cancelling voltage at the output signal means **231**, **232** as in the previous embodiments. The phase shift device **235** may be adjusted to give an optimum magnitude and phase of voltage at **238**, **239** at the critical recorded wavelength to counteract the voltage component in **42** which produces dip **212*a*** in FIGURE 18. By way of example, the phase shifting network may comprise an RC or an RL circuit. In either case, the values of the components of the network are selected for optimum cancellation to provide a smooth frequency response curve as indicated at **213** in FIGURE 18.

The impedance means **111** of FIGURE 1 may represent a potentiometer, a variable resistor such as **220** in FIGURE 5 or a phase shift device such as **235** in FIGURE 6 and may comprise components of fixed predetermined value which may be left in the circuit during recording, as well as during playback where their function is actually required.

In the embodiment of FIGURE 7, the windings on legs **20** and **22** have taps as indicated at **241** and **242** which divide the windings into sections **244**, **245** and **246**, **247**. During recording, the signal to be recorded together with the high frequency bias superimposed thereon is supplied to input terminals **250** and **251** to supply high frequency bias current to windings sections **244** and **245** on leg **20** and to winding section **246** on leg **22**. The field produced by winding sections **244** and **245** is substantially 180° out of phase with the field produced by winding section **246** at the recording region **120** as in the previous embodiments. In this case, however, a sharp gradient is produced in the recording region **120** both for the signal field and the high frequency bias field. During playback winding section **245** on leg **20** is connected in series opposing relation to winding sections **246** and **247** on leg **22** to provide the compensated frequency response characteristic indicated at **213** at FIGURE 18. Thus, recording winding section **246** may have 42 turns where winding sections **244** and **245** provide a total of 250 turns. Winding section **247** together with winding section **246** may provide an optimum number of turns for playback operation, as for example 1000 to 3000 turns when operated in the grid circuit of a vacuum tube amplifier, and winding section **245** may have a number of turns selected experimentally to properly compensate for the interference effects such as indicated at **212*a*** and **212*b*** in FIGURE 18 exactly in the manner previously described for FIGURE 4, for example. Terminals **250** and **251** constitute the signal and bias supply means in FIGURE 7 while terminals **253** and **254** constitute the signal output means in this embodiment.

In the embodiment of FIGURE 8, winding section **260** on leg **20** may have 250 turns where winding section **261** has 42 turns and these two winding sections may be connected in series aiding relation between terminals **265** and **266** with respect to the recording region **120**. Both recording and bias frequency may be supplied to terminals **265** and **266** during recording to produce effective recording and bias fields in the recording region **120**.

When connected for playback, the coils **260** and **267** are in series opposition, so that coil **260** generates a voltage that counteracts interfering pickup in winding **267** from the left hand gap. The number of turns on coil **267** may be chosen for proper matching to the playback amplifier. The turns on coil **260** are then chosen to minimize playback interference, and finally the coil **261** is chosen to have the number of turns relative to **260** so that adequate biasing action is obtained. Alternatively, coil **261** may be wound oppositely to the direction shown in FIGURE 8 (opposite the direction of coil **267**) in which case the main bias and recording fields will have a different phase relative to the cross fields from winding **260**. Terminals **265** and **266** constitute the recording and bias supply means in this embodiment and terminals **268** and **266** constitute the signal output means. This embodiment is simple with regard to switching, head winding, and auxiliary components.

In the embodiment of FIGURE 9, winding sections **270** and **271** are connected between the recording and bias supply terminals **273** and **274** under the control of a potentiometer **275** during recording. In this embodiment, winding sections **270** and **271** may have the correct numbers of turns to provide optimum playback operation as illustrated by curve **213** in FIGURE 18 with switch **276** opened to disconnect potentiometer **275** from the circuit. The output signal is taken from playback terminals **278** and **274**. During recording, the movable contact **279** of potentiometer **275** is moved to the position providing optimum recording operation. It will be understood that where winding **270** has 250 turns, winding **271** will have substantially more than the 42 turns which would provide optimum bias field configuration. The potentiometer **275** serves to effectively adjust the bias field produced by winding **271** to correspond to that which would be produced by a winding of a lesser number of turns directly in series with winding **270**. The winding turns are illustrative only, since the number and proportion depend on gap sizes, pole piece dimensions, etc.

In the embodiment of FIGURE 10, winding sections **280** and **281** are connected in series opposing relation with respect to recording region **120** between recording bias terminals **283** and **284** when switch arm **285** is in the record position. The recording signal applied to terminals **286** and **284** is applied only to the winding section **281** on leg **22** of the core. Where winding section **280** has 250 turns, for example, winding section **281** may have 42 turns to provide an optimum bias field configuration in the recording region **120**.

During playback, winding section **288** is in series with winding sections **281** and **280** between playback terminals **289** and **284** with switch **285** in the play position. As in the previous embodiments, the total number of turns of sections **281** and **288** is related to the number of turns of section **280** to provide the response characteristics indicated at **213** in FIGURE 18.

In the embodiment of FIGURE 11, winding sections **300** and **301** are connected in series opposing relation between terminals **303** and **304** during recording and receive the signal to be recorded together with a superimposed high frequency bias to provide a sharp gradient in the longitudinal component of both the signal field and the bias field in the recording region **120** of the head. Alternatively, only the high frequency bias may be supplied between terminals **303** and **304**, and the signal current may be supplied between terminals **303** and **305** to energize the winding section **301** only. As a further alternative, the recording signal may be supplied between terminals **305** and **304** to energize winding section **300** while the high frequency bias is supplied between terminal **303** and **304**. In this latter instance, the signal field will not fall off with distance from gap **31** as rapidly as the high frequency bias field in the recording region **120**.

During playback, the output amplifier may be connected between terminals **307** and **304** wtih winding section **308** added in series with winding section **301** on the leg **22** and with winding section **300** in series opposing relation to provide the desired frequency response characteristic indicated at **213** in FIGURE 18.

In the embodiment of FIGURE 11 winding section **300** is proportioned with respect to the total number of turns of winding sections **301** and **308** to neutralize the effect of stray magnetic flux from the record medium at gap **30** which is coupled into the magnetic circuit including leg **22** during playback. Coil section **301** is proportioned with respect to coil **300** to give the desired cross field at the bias frequency so that both the low frequency and high frequency signals can be recorded with the same optimum value of bias. This is achieved by producing a resultant bias field which is relatively uniform throughout the cross section of the magnetizable layer **12**.

As a further alternative, it will be noted that the bias supply may be connected to terminals **305** and **304** in FIGURE 11 and the signal supply connected between terminals **303** and **304** to produce a sharp gradient in the resultant signal field in the recording region **120** while providing a relatively uniform bias field in the recording region **120** which does not fall off in intensity as rapidly as the signal field.

A preferred recording embodiment in FIGURE 11 is with the bias supplied to terminals **303** and **304**, and the signal applied to **304** and **305**, so that the signal field persists at substantial amplitude beyond the biased regions in the tape.

FIGURES 12 and 13 illustrate an embodiment combining erase, record and playback functions in a single head construction wherein the erase gap is directly adjacent the record-playback gap to facilitate tracking of the tape over the successive gaps.

The head assembly of FIGURE 12 includes a pair of C-shaped outer legs **320** and **323** and inner legs **321** and **322** defining successively an erase gap **325**, a cross field gap **326** and a record playback gap **327**. The gaps **325**, **326** and **327** have respective electrically conductive non-magnetic strips **330**, **331** and **332** therein.

By way of example, the erase gap spacer may have a thickness of .002 inch and be of copper strip material, pole member **321** may be of a laminated construction with the laminations extending transversely relative to the laminations making up the legs **320** and **323**. The strip **321** may be of "Permalloy" and may comprise 78.5% nickel and the remainder iron and minor constituents. The gap spacer member **331** defining gap **326** may have a thickness of .001 inch and be of copper strip material. The next inner leg **322** may have a thickness of .0005 inch and be of "Permalloy" or other suitable magnetic material, and the gap spacer strip **332** defining gap **327** may have a thickness of .00005 inch and also be of copper, preferably beryllium copper. Several additional shorter pieces of magnetic material such as "Permalloy" are indicated at **322***a* which lie against the leg **322** along the length thereof below the gap spacer **332**, but do not extend up to the level of gap **327**. The magnetic pieces **322***a* thus do not increase the spacing between gaps **326** and **327**, but increase the flux carrying capacity of the magnetic circuit including legs **322** and **323**.

A tape record medium is indicated at **340** having a non-magnetic base layer **341** and a magnetizable layer **342** consisting of a powdered magnetic material in a suitable non-magnetic binder. The tape may be driven in the direction of the arrow **344** by means of a capstan **345** and pressure roller **346** and be unwound from a supply reel (not shown) and wound upon a take-up reel (not shown) after travel across the successive gaps **325**, **326** and **327**. As seen in FIGURE 13, the legs **320**, **321** and **322** may have a width dimension transversely to the direction of movement of the tape substantially equal to the width of one channel on the tape **340**, while the trailing leg **323** defining gap **327** has a reduced width and has a non-magnetic filler member of substantial thickness at each side thereof as indicated at **348** and **349** in FIGURE 13. It will be noted that the spacing between the erase gap and the cross field gap in this embodiment may be only .002 inch so as to minimize the possibility of tracking errors as the tape moves from the erase gap **325** to the cross field gap **326** and record-playback gap **327**. The close spacing of the gaps together with the reduced width of the effective record-playback gap insures that the erase gap **325** will erase all of the record medium which is coupled to the record-playback gap **327**.

During recording, a high frequency bias and erase supply is connected between terminals **360** and **361** to energize winding sections **363** and **364** in series opposing relation with respect to the recording region **365**. The high frequency current supplied to windings **363** and **364** is operative to produce an erasing magnetic field across gap **325** for insuring complete erasure of the record medium **340** before it reaches the record gap **327**. Additionally, winding section **363** produces a high frequency field across gap **326** which may insure more complete erasure in conjunction with erase gap **325**. Winding **363** also produces a high frequency field in the recording region **365** which effectively modifies the bias field produced by winding section **364** to provide a sharp gradient of bias field intensity in the recording region **365** as in the previous embodiments. The signal to be recorded may be supplied to terminals **370** and **371** to energize winding section **364**.

During playback, a playback amplifier is connected between signal output terminals **375** and **376**. Winding section **380** on leg **323** is in series with winding **364** during playback, and winding **363** is in series opposing relation with respect to winding sections **364** and **380** during playback as in the previous embodiments to provide the desired smooth frequency response curve indicated at 213 in FIGURE 18.

FIGURES 14 and 15 illustrate a combined-erase record-playback head utilizing two gaps in the erase head section. The head comprises a series of legs **400**, **401**, **402**, **403** and **404** providing successive erase gaps **406** and **407**, a cross field gap as indicated at **408** and a record-playback gap as indicated at **409**. Gap spacers of electrically conductive non-magnetic material are indicated at **410**, **411**, **412** and **413** defining the successive gaps **406–409**. By way of example, gap spacer **406** may comprise a strip of copper having a thickness of .003 inch, gap spacer **411** may comprise a copper strip having a thickness of .002 inch. The cross field gap spacer **412** may comprise a strip of copper having a thickness of .001 inch, leg **403** may comprise a sheet of "Permalloy" having a thickness of .0005 inch and gap spacer **413** may comprise a strip of copper having a thickness of .0001 inch. As in the embodiment of FIGURE 12, the trailing leg **404** in FIGURE 14 may have substantially less width than the other legs to define a narrower effective record-playback gap **409**, and filler strips as indicated at **415** and **416** may be provided at each side of the leg **404** and are of substantial thickness in the direction transverse to the direction of tape movement indicated by arrow **344**.

During recording, bias and erase high frequency current is supplied between terminals **420** and **421** to energize winding section **423** on leg **401** and winding section **424** on leg **404** in series opposing relation. This produces high frequency erase fields at gaps **406** and **407** and produces a high frequency field impinging on leg **404** at the recording region **430** opposing the bias field pro-

duced by winding **424** in this region. The recording signal may be supplied between terminals **432** and **421** to energize coil **424** with the signal to be recorded. The high frequency bias field component from winding **423** acts to modify the bias field to provide a sharp gradient of bias field intensity in the recording region **430** as in the previous embodiments.

During playback, an output amplifier is connected between terminals **432** and **451** so as to connect a winding section **453** in series with winding section **424**. In this case the winding **423** is not used during playback.

In the embodiment of FIGURE 16, the combined erase-record-playback head has legs **470**, **471**, **472** and **473** defining an erase gap **475**, a cross field gap **476** and a record-playback gap **477**. Erase gap spacer member **480** may comprise .0015 inch thick copper, cross field gap spacer **481** may comprise .004 inch thick copper, leg **472** may comprise .0005 inch "Permalloy," "Supermalloy," "Deltamax" or "Supermendur," and gap spacer **482** defining gap **477** may comprise a strip of copper having a thickness of 0.00005 inch. Windings **490** and **491** on legs **471** and **473** may be connected in an electric circuit identical to that for the windings **423**, **424** and **453** in FIGURE 14 and corresponding reference numerals have been affixed to the respective leads in the two figures to indicate this fact. Thus leads **492** and **493** in FIGURE 16 may connect to terminal **420** and terminal **432** of FIGURE 14, respectively. Line **494** in FIGURE 16 may connect to terminal **432**, line **495** may connect to terminal **421** and line **496** may connect to terminal **451** of FIGURE 14. As in the embodiments of FIGURES 13 and 15, the trailing leg **473** may have substantially less width than the other legs and may have filler members **498** and **499** of substantial thickness at the opposite sides thereof. The operation of the circuit for the embodiment of FIGURES 16 and 17 is the same as that for the circuit of FIGURES 14 and 15 with an erasing field being produced across the gap **475** for erasing the record medium **340** and the recording and playback functions taking place as in the embodiment of FIGURES 14 and 15.

As indicated in FIGURE 17, a housing **502** may receive a succession of head units such as shown in FIGURE 16 with a shield of electrically conductive and/or magnetic material between successive head units as indicated at **503**. The housing may be of electrically conductive non-magnetic material having a coefficient of expansion corresponding to that of the magnetic core material as in FIGURE 1 and may be in two parts **502*a*** and **502*b*** similar to parts **51** and **61** in FIGURE 1. A surrounding casing of magnetic shielding material may be provided as indicated at **504** similar to casing **80** in FIGURE 3 and which clamps housing parts **502*a*** and **502*b*** together in the same way as illustrated in FIGURE 3. Corresponding reference numerals followed by the letter *a* designate parts of the second head unit corresponding to the respective parts of the head unit of FIGURE 16.

FIGURE 19 shows a head which may be identical to that of FIGURES 16 and 17, for example, except that a loop electric circuit **510** extends through erase gap **511** and cross field gap **512** and an erase-bias coil **514** is on an outer leg **515**. The head includes legs **515**, **520**, **521** and **522** defining erase gap **511**, cross field gap **512** and record-playback gap **525** with a bias and signal winding assembly **526** on leg **522** which may be connected with erase-bias coil **514** in the same way as indicated for windings **423** and **424**, **453** in FIGURE 14. By way of example, the loop electric circuit may have a width or height dimension of .020 inch and a thickness dimension of .002 inch. The loop electric circuit serves to increase the coupling of the erase-bias coil **514** to the cross field magnetic circuit including legs **520** and **522** which correspond to legs **471** and **473** in FIGURE 16 during recording.

FIGURES 20 through 24 represent a preferred embodiment of the present invention wherein a magnetic transducer head **600** comprises a series of magnetic core parts **601, 602, 603, 604** and **605** defining erase gaps **610** and **611**, a cross field gap **612** and a record-playback gap **613**. A non-magnetic spacer **620** is interposed between the lower portions of core legs **602** and **604** to introduce a substantial reluctance in the magnetic circuit including legs **602, 603** and **605** and cross field gap **612** to tend to minimize the coupling of magnetic signal flux from the record medium at gap **612** to winding **625** during playback. It has been found that with a construction as in FIGURE 20, distortion of the output from the signal winding **625** as a function of recorded wavelength (such as indicated in FIGURE 18) is avoided. Thus the compensating means of the preceding embodiments is not required during playback with the embodiment of FIGURE 20.

An erase frequency energizing coil **626** is on the leg **601** of the core and a bias winding **627** is on leg **605** along with signal winding **625**. As indicated in FIGURE 24, during recording switch arms **630** and **631** are closed in a downward position to supply high frequency current to erase winding **626** and bias winding **627** in series. A high frequency current source is indicated at **632** and a signal input or output circuits component is indicated at **633** connected with the signal frequency winding **625**. The high frequency current is of course of a substantially higher frequency than the highest signal frequency component to be recorded. A further optional source of bias frequency magnetic field is indicated in FIGURE 24, in dash outline as including a magnetic core part **640** and a winding **641** for producing a cross field in the region of recording gap **613**. Winding **641** may be a coil on either leg of the L-shaped core **640**. The spaces between the ends of core **640** and the adjacent core pieces **603** and **604** may be adjusted to minimize interference from pick-up at gap **612**, and also to set the level of the X-field relative to the small-gap field.

As indicated in FIGURE 20, a tape record medium **645** may have its magnetizable layer in sliding contacting relation to the surfaces of legs **601, 602, 603, 604** and **605** which extend adjacent the tape path and the tape may be driven in the direction of the arrow **646** by means of a suitable constant speed drive including capstan member **648** and pressure roll member **649** so that the tape travels successively across the erase gaps **610** and **611**, across cross field gap **612** and then across the record gap **613**.

In this embodiment, rather than using laminated core parts which are relatively expensive and difficult to assemble to form a magnetic head, the core parts **601–605** may be formed from a flat sheet by a die into a U cross section as indicated in FIGURES 22 and 23 and annealed after mechanical operations are completed. Each of the core parts thus has a generally planar body portion such as indicated at **603***a* and **605***a* in FIGURES 22 and 23 and has right angle flange portions such as indicated at **603***b* and **603***c* and **605***b* and **605***c* in FIGURES 22 and 23. The thickness of sheet material from which the core is formed depends on the head dimensions and on the allowable eddy current losses. For a quarter track head, 0.043 inch wide, "Permalloy" stock 0.006 inch thick has proved very satisfactory. Heads of this construction have been used with bias frequencies of 100 kc. and have given satisfactory response to signals of 50 kc. and higher. Thicker material is siutable for lower frequencies or larger heads. The body portions of the respective core parts have the widths indicated in FIGURE 21, core parts **601, 602, 603** and **604** having a width substantially equal to the channel of the record tape **645** cooperating therewith while core part **605** has a substantially reduced width to insure complete erasure of the portion of the channel travelling across the record gap **613**. A nominal width dimension for each recorded trace on four track stereo tapes is 0.043 inch. As seen in FIGURE 20, the width of the side flanges **601***b*, **602***b*, **603***b*, **604***b* and **605***b* and **601***c*, **602***c*, **603***c*, **604***c* and **605***c* may taper at the regions of the gaps **610–613** so as to tend to concentrate flux in the path of the record medium **645**. The configuration of the side flanges of core parts **603** and **604** adjacent gap **612** provides a very sensitive and convenient adjustment of the magnitude of the cross field component extending from core part **603** to the trailing side of the record gap **613**. Thus, the more extended the area and the closer the reatlionship between the side flange parts **603***b* and **604***b* and **603***c* and **604***c*, where they meet at the gap **612**, the smaller the magnitude of the cross field component adjacent gap **613**.

By way of example, the polepieces **601–605** may be of .005 inch thick "Permalloy" and may have an overall height in the plane of FIGURE 20 of 0.5 inch. Polepiece **605** may have a width of .043 inch while polepieces **601–604** may have a width of about .047 inch after forming into U cross section. Erasing gaps **610** and **611** may have a length in the direction of tape movement of .002 inch, each; cross field gap **612** may have a length in the direction of tape movement of .001 inch; and gap **613** may have a length in the direction of tape movement of .00005 inch. The magnetic tape layer thickness may be .0003 inch to .0005 inch. The body part **604***a* of polepiece **604** adjacent the tape path may be reduced in thickness compared to the remainder of the body portion and may have a thickness dimension in the direction of tape movement of .0005 inch, for example. Core parts **601–604** may have a width 10% to 20% greater than the width of core part **605**, for example. It will be understood that the relatively intense high frequency field between core parts **603** and **604** across gap **612** may assist in the erasure of the record medium. Winding **626** also provides a cross field component in air between core parts **603** and **605**. Coil **626** may have 1000 turns and coils **625** and **627** may comprise 1000 turns tapped at 48 turns and at 144 turns from the top. A high frequency bias current of 3.5 milliamperes at 100 kc. may be used to energize coil **626** and 96 turns of coil **625, 627** in series opposed connection with **626**. A recording signal of 20 cycles to 20 kc. at 0.1 milliampere may be fed through coil **626** plus 144 turns of **625, 627**, also series bucking. The channel construction described gives a self-supporting polepiece having increased cross section by virtue of the lateral flanges, and low eddy current loss. The gap defining portions may be the same as the sheet thickness (for example 0.005 inch), requiring no machining. The core material is in an unstressed condition compared to laminations which are glued and clamped after anneal.

As indicated in FIGURE 24, the embodiment of FIGURE 20 includes the case where switch arms **630** and **631** are in their upper positions to supply a cross field component between core parts **603** and **605** in opposing relation at the trailing side of gap **613** and the case where the switch arms **630** and **631** are in their lower positions to generate a cross field component between core parts **603** and **605** which is substantially in aiding relation to the main bias field across gap **613** at the trailing side of the gap **613**. The additive cross field arrangement with switch arms **630** and **631** in their lower positions provides results which under certain conditions compare quite favorably with the results obtained for an opposing cross field (with switch arms **630** and **631** in their upper positions). The signal cross field may also be additive in conjunction with opposing or additive bias cross field. It is believed that an important advantage achieved by the cross field is in providing a relatively uniform bias field intensity throughout the thickness of the magnetizable layer of the tape and either the additive or opposing cross field provides this advantage. Thus, an important concept is to provide a cross field component such as indicated at **660** in FIGURE 24 bridging in air between core parts **603** and **605** and of magnitude in the recording region at the trailing side of the recording gap **613** approximating the bias amplitude required for optimum recording. Where there is a main bias field as indicated at **661** between core parts **604** and **605** produced by a winding such as indicated at **627**, the cross field component as indicated at **660** produced by erase winding **626** should be at least of a substantial magnitude in comparison with the main bias field **661** in the recording region which has been indicated at **662**. One suitable value in this case has been found to be a value of cross field component **660** equal to approximately ⅔ of the main field component **661** whether the cross field component is aiding or opposing the main field at the recording region **662**. A further embodiment for the head of FIGURE 20 involves the omission of the bias winding section **627**. In this case, the erase winding **626** will produce a first generally semi-circular field configuration **663** across gap **612**, a second generally semi-circular field configuration **661** across gap **613** and a cross field component such as **660** between core parts **603** and **605**. In this case, of course, the cross field component **660** and the main field component **661** are additive in the recording region **662**. Winding **627** may be omitted as a bias frequency winding by connecting the signal circuits component **633** across winding sections **625** and **627** together with the upper terminal of winding section **627** grounded rather than the upper terminal of winding **625** being grounded as shown in FIGURE 24.

Of course, if winding **627** is omitted, a winding such as indicated at **641** may be energized by closing switch **665** during recording to increase the strength of the cross field component **660** and the main field component **661**. In each of the above cases, switch **666** may be in its right hand position to supply recording signal current to winding section **625**.

As a further alternative represented by the embodiment of FIGURE 20, switch arm **666*a*** may be in its left hand position to supply signal recording current to winding **641** only (switch **665** being open or closed as desired) while the bias field components may be provided in any of the manners described. This configuration has the advantage of providing a more uniform signal field throughout the cross section of the magnetizable layer of the tape at low frequencies particularly. In effect, energization of winding **641** with signal current produces field components such as indicated at **660**, **661** and **663** with the cross field component **660** additive with the main field component **661** in the recording region **662** the same as with a bias field configuration omitting winding **627**. In any of the embodiments, playback may be obtained by moving switch **666** to its right hand position and leaving switch means **665**, **666*a***, **630** and **631** in their intermediate open positions shown in FIGURE 24.

As another alternative, switch arms **666** and **666*a*** may both be closed to provide a signal field at gap **613** due to winding **625** as well as a signal cross field from winding **641**. These fields may be additive or opposing in region **662**. Bias from source **632** is then supplied to both winding **641** and winding **625** with winding **627** omitted, and the bias cross field may be additive or opposing to the main bias field in region **662**.

While A.C. bias has been mentioned in the above explanation because it is widely used, similar advantages are obtained with these structures when D.C. bias is used. The structures are also applicable where bias is not used.

While in FIGURES 20–24, a channel or U cross section has been specifically shown for core parts **601–605**, other cross sections will produce the advantages of larger flux carrying capacity with low eddy current loss. For example, the core parts may have an L cross section. A generally spiral cross section may also be formed in an initially flat sheet by bending the sheet at right angles at successively increasing intervals. In this case the sheet would be flat between successive right angle bends. The adjacent parallel portions of the sheet are suitably insulated to avoid forming a closed loop electric circuit for eddy currents.

The core parts **601–605** may also have a generally O cross section with flat sides similar to one convolution of the spiral type cross section. The free edges of the magnetic sheet formed into an O cross section would have a non-conductive gap therebetween to avoid a closed loop electric circuit for eddy currents.

An O cross section may also be formed by nesting the lateral flanges of a pair of oppositely directed strips of channel cross section. The adjacent overlapping lateral flanges of the respective strips would be insulated from each other to avoid forming a closed loop electric circuit for eddy currents above the perimeter of the O cross section.

As a further example, a series of channel cross section strips of different size and all oriented in the same way may be nested one within the other to form a large area C cross section. A channel or C cross section type core leg may have a solid cross section non-magnetic filler nester therein to rigidify the leg. The filler may be non-conductive or insulated from the core leg to avoid formation of an electrically conductive loop path about the perimeter of the square or rectangular cross section defined by the leg and filler.

The spiral and O cross sections just described are advantageous over conventional laminated core parts because of their ease of assembly and relatively unstressed magnetic condition as finally assembled. The spiral and O cross section core parts are advantageous over solid cross section parts of comparable flux carrying capacity because of their reduced eddy current loss. The spiral and O cross sections provide more flux carrying capacity than a simple channel cross section, but are somewhat more difficult to fabricate and assemble. The non-magnetic filler provides increased rigidity over the simple channel cross section core part.

It will be understood that the housing shown in FIGURES 20 and 21 is substantially identical to that illustrated in FIGURE 3 and comprises casing parts **701** and **702** engaging the respective core sections at points **701*a***, **701*b***, **701*c*** and **702*a***, **702*b*** and **702*c***, respectively. As in the embodiment of FIGURES 1–3, the casing parts **701** and **702** may be made of a non-magnetic metal having substantially the same thermal coefficient of expansion as the core parts **601–605**. The casing parts **701** and **702** have interior air spaces so that there is no problem of expansion or swelling with heat or humidity which would tend to open the fine gap **613** as would be the case if these spaces were filled with epoxy resin or the like. Any cement which is used, for example between bosses **701*a*–701*c*** and **702*a*–702*c*** and the core, is in a thin layer which cannot appreciably affect the gap dimension.

The casing parts **701** and **702** may have closely confronting mating surfaces with recesses therein such as indicated at **91–94** in FIGURES 1–3 for receiving a cement to retain the two sub-assemblies against relative lateral displacement. A housing **710** including plates **710*a*–710*c*** of magnetic shielding material may surround the casing parts **701**, **702**. A housing plate **710*d*** may have a boss portion **711** engaging one of the casing parts and a housing plate **710*e*** may have set screw means such as indicated at **710** and **713** engaging the opposite casing part to press the casing parts together. The arrangement is such that the polar portions defining the gap **613** are pressed toward each other against the gap material intervening therebetween to precisely determine the gap spacing.

It will be apparent that a number of head units including core parts such as **601–605** may be associated with respective unitary housing parts such as indicated at **502*a*** and **502*b*** in FIGURE 17. Magnetic or electrically conductive shielding members or both may be interposed between the successive head units in the same manner as indicated at **503** in FIGURE 17. Further, one or more of the core legs, particularly those which do not require windings, in FIGURES 17 or 20, may be common to all of the head units and extend through gaps in the shield members such as indicated at **503** in FIGURE 17. Thus, in FIGURE 17, the core leg **472** may be common to all the head units and the portions **472** and **472***a* in FIGURE 17 would then be part of a single common core member which would extend through a suitable gap in the shield member **503**.

It will be apparent that the various circuit arrangements illustrated in any of the various figures generally may be applied to any of the core structures illustrated herein, and that the features of core configuration and mounting described with respect to any embodiment generally may be applied to the other illustrated embodiments. It is further noted that the specific numerical examples of gap spacings, numbers of turns for windings and the like are generally applicable to any of the embodiments and are given simply by way of illustration and not of limitation.

With respect to each of the embodiments, it is preferable to have the pole between the cross field and recording gaps as thin as possible in the direction of tape movement thereacross subject to practical limitations of a mechanical nature and the need to avoid saturation of the pole during recording or inadequate flux carrying capacity during playback; for example, it is preferable to have the pole thickness equal to or less than two mils (.002 inch).

In each of the embodiments, the cross field gap may be defined by a gap spacer of beryllium copper having a thickness of .001 inch and the recording gap may be defined by a gap spacer of beryllium copper having a thickness of .00005 inch. The tape may have a magnetizable layer .0003 to .0005 inch thick in sliding contact with the successive poles. The pole between the cross field and erase gaps may have a thickness dimension in the direction of tape movement where it contacts the tape of .0005 inch.

By way of a further specific example and not of limitation, each of the embodiments may utilize an electric circuit as indicated in FIGURE 8 with a winding **260** coupled to the cross field magnetic circuit including legs **20** and **21** having 1000 turns and a winding **729** having 1000 turns coupled to the record-playback magnetic circuit including legs **21** and **22**. The winding **729** coupled to the record-playback magnetic circuit may be tapped at 48 turns from the top as indicated at **730** and may be tapped at 144 turns from the top as indicated at **731**. Thus winding section **732** has 48 turns, winding section **261** has 96 turns and winding section **267** has 856 turns. During recording a high frequency bias current of 3.5 milliamperes at a frequency of 100,000 cycles per second is supplied to winding **260** and winding section **261** in series. Thus the bias supply would be connected between terminals **265** and **266** in FIGURE 8. A recording signal having frequency components between 20 cycles per second and 20,000 cycles per second at 0.1 milliampere may be supplied between terminals **733** and **266** to energize winding **260** and winding sections **732** and **261** in series. Bias current would then flow in 96 turns of winding **729** while recording signal current would flow in 144 turns of winding **729**. While in FIGURE 8, the windings **260** and **729** are shown in aiding relation with respect to recording region **120**, the example applies where the direction of winding **260** is reversed to provide signal and bias fields in region **120** which are in phase opposition to the signal and bias fields produced by winding **729**. With the present example, the playback amplifier would be connected to winding **729** only.

When the circuit just described is applied to the embodiment of FIGURES 20–24, winding **260** would be placed on core part **640** and winding **729** placed on leg **605**, for example.

As a further modification which will be practical in many instances, the winding **42** in FIGURES 1–6, the winding sections **246** and **247** in FIGURE 7, **261** and **267** in FIGURE 8, **271** in FIGURE 9, **281** and **288** in FIGURE 10, **301** and **308** in FIGURE 11, and **364** and **380** in FIGURES 12 and 13 may be used alone for playback. This arrangement may be preferred for simplicity, especially where the head is proportioned and adjusted so that interference is negligible without the use of a compensating winding linking the cross field magnetic circuit.

It will be apparent that many modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

I claim as my invention:

1. A magnetic head comprising a magnetic core having cross field core means defining a first pole and recording core means defining second and third poles, means for defining a path of travel of a record medium successively across said first, second and third poles, signal magnetic field producing means for coupling to said cross field core means to produce a signal magnetic field between said first and third poles varying in accordance with a signal to be recorded, bias field producing means coupled to said cross field core means for producing a bias magnetic field between said first and third poles, and bias field producing means coupled to said recording core means for producing a bias magnetic field between said second and third pole means having a magnitude comparable to the magnitude of the bias magnetic field between said first and third poles.

2. A magnetic head for coupling to a magnetic record medium comprising a magnetic core having a cross field magnetic circuit and a recording magnetic circuit with a cross field gap and a recording gap respectively therein across which the record medium successively travels, means for coupling to said cross field circuit for establishing a magnetic field bridging said cross field and recording gaps in series, and means for introducing a reluctance in said cross field circuit for signal recorded wavelengths comparable to the spacing between the cross field and recording gaps, of the order of the reluctance of an air path equal to the width dimension of the core to reduce the coupling of said signal recorded wavelengths to a magnetic circuit including the cross field and recording gaps in series during playback.

3. A magnetic head comprising a magnetic core having cross field core means defining a first pole and recording core means defining second and third poles, means defining a path of travel of a record medium successively across said first, second and third poles, magnetic field producing means coupled to said cross field core means for establishing a magnetic field between said first and third poles and coupled to said recording core means for establishing a magnetic field between said second and third poles, said cross field core means comprising at least two separate core parts one extending generally along the path of the record medium and terminating in said first pole and a second core part having one end adjacent said one core part and having its opposite end more remote from said one core part with a substantial non-magnetic gap between at least one of the ends of said second core part and other portions of said core of length comparable to the length of said one of said core parts.

4. A magnetic head comprising a magnetic core having cross field magnetic core means defining a first magnetic pole and recording magnetic core means defining second and third magnetic poles, means defining a path of travel of a magnetic record medium successively across said first, second and third magnetic poles, means for establishing a signal magnetic field between said first and third magnetic poles varying in accordance with an input signal to be recorded on the record medium and for establishing a second magnetic field across said second and third magnetic poles for acting on the record medium during recording, and the length of the second pole in the direction of travel of the record medium being not greater than the spacing between said first and second poles.

5. A magnetic head comprising a magnetic core having a pair of oppositely directed C-shaped core members each

having at one end thereof a polar extremity directed toward the polar extremity of the other C-shaped core member, a pair of substantially straight core members extending generally across the extremities of the respective C-shaped core members and having polar extremities disposed in spaced confronting relation to the polar extremities of the C-shaped core members, a further core member interposed between the substantially straight core members and extending generally between the polar extremities of the straight core members and having polar extremities at the opposite ends thereof in spaced confronting relation to the respective polar extremities of the substantially straight core members, the polar extremities of said core members defining in succession along a path of travel for a record medium across said core first and second erase gaps, a cross field gap and a recording gap, said further core member having separate core means adjacent thereto for defining a portion of a magnetic circuit including said further core member and said cross field gap, and winding means on said separate core means for producing a magnetic field which extends across the cross field gap and recording gap in series during recording operation.

6. A magnetic head comprising a magnetic core having first, second and third magnetic poles past which a magnetic record medium is to successively travel, the second and third poles being substantially more closely spaced than said first and second poles, and winding means coupled to said core for producing the entire magnetic signal field which is to produce a recording on the record medium, said winding means in its entirety being substantially closer to said first pole than to said third pole.

7. A magnetic head comprising a magnetic core having first, second and third magnetic poles past which a magnetic record medium is to successively travel, winding means coupled to said core for producing the entire magnetic signal field which is to produce a recording on the record medium, said winding means in its entirety being substantially closer to said first pole than to said third pole, and means coupled to said core for producing a resultant bias magnetic field in the region of said third pole having a substantially sharper gradient in field intensity with respect to the direction of movement of the record medium through said region than the signal field gradient in said region.

8. A magnetic head comprising a magnetic core having a cross field magnetic circuit and a recording magnetic circuit with respective cross field and recording non-magnetic gaps across which a record medium is to successively travel, a first winding coupled to said cross field magnetic circuit, a second winding coupled to said recording magnetic circuit, and signal input means for energizing said first and second windings during recording to produce respectively first and second signal magnetic fields having components of the same frequency in the region of the recording gap which are in aiding relationship at the trailing side of the recording gap with respect to the direction of travel of the record medium.

9. A magnetic head comprising a magnetic core having a cross field magnetic circuit and a recording magnetic circuit with respectively a cross field gap and a recording gap across which a record medium is to successively travel, and means for applying a signal magnetomotive force exclusively to the cross field magnetic circuit to produce a net relatively diffuse signal magnetic field in the region at the trailing side of the recording gap as the sole magnetic field of signal frequency active on the record medium in said region.

10. In a magnetic transducer assembly, a magnetic transducer head comprising magnetic core means having first, second and third core parts of magnetic material, said core parts having polar extremities disposed in spaced series relation along and to one side of a path of a magnetic record medium with a first non-magnetic gap between the polar extremities of the first and second core parts and with a second non-magnetic gap between the polar extremities of the second and third core parts for coupling of the head to a magnetic record medium travelling along said path and successively across said first and second gaps, first winding means coupled to said first core part across which said record medium first travels as it moves along said path, second winding means coupled to said third core part across which said record medium last travels as it moves along said path, input signal supply means for supplying an input signal to be recorded, and input signal connecting means for connecting said input signal supply means to said first winding means only to generate an input signal magnetic field in the recording region at the trailing side of said second gap dependent in configuration and magnitude substantially only on the signal magnetomotive force produced by said first winding means.

11. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first and third poles and said cross field air path therebetween, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path with the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said first pole being substantially less than the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said third pole, said system further comprising

signal input means for supplying a signal current varying in accordance with a signal to be recorded,

means for connecting said signal input means with said magnetomotive force source for exerting a signal magnetomotive force in said cross field magnetic circuit in accordance with a signal to be recorded and at a point having a separation from said first pole of substantially lesser reluctance than that of its separation from the third pole to produce a signal magnetic cross field component extending in air along said cross field air path between said first and third poles and having a substantial magnitude in said recording region,

the first pole being disposed on the same side of the record medium path as said second and third poles and being in alignment with and preceding said second and third poles with respect to the direction of movement of the record medium along said record medium path,

essentially the entire signal magnetomotive force being applied to said magnetic core having a separation from the first pole with a magnetic reluctance substantially less than that of its separation from the third pole, and

means coupled to said magnetic core for producing a magnetic biasing field in said recording region which decays in intensity more rapidly than does the complete signal field in said recording region with respect to said direction of said record medium path away from said recording gap.

12. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first and third poles and said cross field air path therebetween, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path with the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said first pole being substantially less than the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said third pole, said system further comprising

input means for supplying a signal current varying in accordance with a signal to be recorded,

means for connecting said signal input means to said magnetomotive force source for exerting a signal magnetomotive force in said cross field magnetic circuit at a point having a separation from the first pole with a magnetic reluctance substantially less than that of its separation from the third pole to produce a signal magnetic cross field component varying in accordance with a signal to be recorded extending in air along said cross field air path between said first and third poles and having a substantial magnitude in said recording region,

a further magnetomotive force source coupled to said recording magnetic circuit, and

means for connecting said signal input means to said further magnetomotive force source to establish a signal field component between said second and third poles and having a magnitude in said recording region comparable to the magnitude of the signal magnetic cross field component in said recording region to produce a composite signal field in said recording region capable of effectively producing a recording of said signal on the record medium moving along said record medium path,

said first pole being disposed on the same side of the record medium path as said second and third poles and being in alignment with and preceding said second and third poles with respect to the direction of movement of the record medium path and being separated from said second pole by a cross field gap,

said second pole having a dimension in the direction of movement of the record medium comparable to the dimension of the cross field gap in the direction of movement of the record medium, and

the recording gap between said second and third poles being of substantially less length than said cross field gap in the direction of movement of the record medium.

13. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first and third poles and said cross field air path therebetween, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path with the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said first pole being substantially less than the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said third pole, said system further comprising

said first pole being disposed on the same side of the record medium path as said second and third poles and being in alignment with said first and second poles with respect to the direction of movement of the record medium along said record medium path,

said magnetomotive force source comprising an electrical conductor extending transversely to the record medium path adjacent said first pole and on the side of said first pole toward said third pole, and

means for supplying a recording current to said electrical conductor to establish a recording magnetic cross field extending in air along said cross field air path and having a substantial magnitude in said recording region, said electrical conductor being substantially closer to said first pole than to said third pole.

14. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first and third poles and said cross field air path therebetween, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path with the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said first pole being substantially less than the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said third pole, said system further comprising

said first pole being disposed on the same side of the record medium path as said second and third poles and being in alignment with said first and second poles with respect to the direction of movement of the record medium along said record medium path,

said magnetomotive force source comprising an electrical conductor extending adjacent said first pole and substantially closer to said first pole than to said third pole,

means for energizing said conductor with bias frequency electric current to establish a bias frequency magnetic cross field along said cross field air path and having a substantial magnitude in said recording region, and

means coupled to said recording circuit for producing a magnetic signal field between said second and third poles and of substantial magnitude in said recording region.

15. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said record and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first and third poles and said cross field air path therebetween, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path with the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said first pole being substantially less than the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said third pole, said system further comprising

said first pole being disposed on the same side of the record medium path as said second and third poles and being in alignment with said first and second poles with respect to the direction of movement of the record medium along said record medium,

said magnetomotive force source comprising an electrical conductor extending adjacent said first pole and substantially closer to said first pole than to said third pole,

means for energizing said conductor with bias frequency electric current to establish a bias frequency magnetic cross field along said cross field air path and having a substantial magnitude in said recording region,

means coupled to said recording circuit for producing a further bias frequency magnetic field between said second and third poles and having a magnitude in said recording region comparable to the magnitude of said bias frequency magnetic cross field in said recording region, and

means coupled to said recording circuit for producing a signal magnetic field between said second and third poles and having a substantial magnitude in said recording region.

16. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first pole with parallel branches thereof including said first and second poles in series, and said first and third poles and said cross field air path in series, respectively, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path and to establish magnetic flux components in the same direction and in parallel through said parallel branches of said cross field magnetic circuit, said system further comprising

said first pole being disposed on the same side of the record medium path as said second and third poles and being in alignment with and preceding said first and second poles with respect to the direction of movement of the record medium along said record medium path,

signal input means for supplying essentially all of the signal current varying in accordance with a signal to be recorded to said system, and

means for connecting said signal input means essentially exclusively to said magnetomotive force source and for applying essentially the entire signal magnetomotive force varying in accordance with the signal to be recorded to said cross field magnetic circuit to establish magnetic signal flux components having the same instantaneous polarity with respect to both said second and third poles and in said parallel branches of said cross field magnetic circuit.

17. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first pole with parallel branches thereof including said first and second poles in series, and said first and third poles and said cross field air path in series, respectively, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path and to establish magnetic flux components in the same direction and in parallel through said parallel branches of said cross field magnetic circuit, said system further comprising

signal input means for supplying essentially all of the signal current varying in accordance with a signal to be recorded to said system, and

means for connecting said signal input means essentially exclusively to said magnetomotive force sources and for applying essentially the entire signal magnetomotive force varying in accordance with the signal to be recorded to said cross field magnetic circuit to establish magnetic signal flux components having the same polarity with respect to both said second and third poles and in said parallel branches of said cross field magnetic circuit.

18. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first pole with parallel branches thereof including said first and second poles in series, and said first and third poles and said cross field air path in series, respectively, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path and to establish magnetic flux components in the same direction and in parallel through said parallel branches of said cross field magnetic circuit, said system further comprising

signal input means for supplying essentially all of the signal current varying in accordance with a signal to be recorded to said system,

means for connecting said signal input means essentially exclusively to said magnetomotive force source and for applying essentially the entire signal magnetomotive force varying in accordance with the signal to be recorded to said cross field magnetic circuit to establish magnetic signal flux components having the same polarity with respect to both said second and third poles and in said parallel branches of said cross field magnetic circuit,

said first pole being disposed on the same side of the record medium as said second and third poles and being in alignment with and preceding said second and third poles with respect to the direction of movement of the record medium along said record medium path,

first bias means coupled to said cross field magnetic circuit and exerting an alternating current high frequency bias magnetomotive force on portions of the magnetic core substantially closer to said first pole than to said third pole for establishing an alternating current high frequency bias magnetic cross field component along said cross field air path and in said recording region, and

second bias means coupled to said recording magnetic circuit for exerting an alternating current high frequency bias magnetomotive force on portions of the magnetic core at least as close to said third pole as to said first pole for establishing an alternating current high frequency bias magnetic field between said second and third poles and in said recording region and having a magnitude in said recording region comparable to the magnitude of said high frequency bias magnetic cross field component in said recording region.

19. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first pole with parallel branches thereof including said first and second poles in series, and said first and third poles and said cross field air path in series, respectively, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path and to establish magnetic flux components in the same direction and in parallel through said parallel branches of said cross field magnetic circuit, said system further comprising

alternating current high frequency bias input means for supplying essentially the entire high frequency bias current to said system and having a frequency substantially higher than the highest signal frequency component to be recorded,

means for connecting said high frequency bias input means essentially exclusively to said magnetomotive force source so that the entire high frequency bias magnetomotive force applied to said core is applied predominantly to said cross field magnetic circuit and to said branches thereof in parallel, and

means coupled to said magnetic core for producing a magnetic signal field in said recording region varying in accordance with a signal to be recorded.

20. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed ajacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first and third poles and said cross field air path therebetween, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path with the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said first pole being substantially less than the magnetic reluctance along said cross field magnetic circuit between said magnetomotive force source and said third pole, said system further comprising

signal input means for supplying essentially the entire signal current varying in accordance with a signal to be recorded by said system,

alternating current high frequency bias input means for supplying essentially the entire high frequency bias current to said system having a frequency substantially higher than the highest signal frequency component to be recorded, and

means for connecting said signal input means and said high frequency bias input means essentially exclusively to said magnetomotive force source for exerting a signal magnetomotive force and an alternating current high frequency bias magnetomotive force on portions of the magnetic core substantially closer to said first pole than to said third pole for establishing a signal frequency magnetic cross field and a bias frequency magnetic cross field of substantial magnitude in said recording region.

21. In a magnetic recording system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first pole with parallel branches thereof including said first and second poles in series, and said first and third poles and said cross field air path in series, respectively, a magnetomotive force source coupled to said cross field magnetic circuit for exerting a magnetomotive force in said cross field magnetic circuit to produce a magnetic cross field component extending along said cross field air path and to establish magnetic flux components in the same direction and in parallel through said parallel branches of said cross field magnetic circuit, said system further comprising

said first pole being disposed on the same side of the record medium path as said second and third poles and being in alignment with and preceding said second and third poles with respect to the direction of movement of the record medium along said record medium path,

signal input means for supplying a signal current varying in accordance with a signal to be recorded on a record moving along said record medium path, and

means for connecting said signal input means with said magnetomotive force source for exerting a signal magnetomotive force varying in accordance with the signal to be recorded in said cross field magnetic circuit and in said branches of said cross field magnetic circuit in parallel.

22. A magnetic recording system comprising a magnetic core having first, second and third poles, with a cross-field gap between the first and second poles and with a recording gap between said second and third poles, a magnetic record medium traveling successively across said first, second and third poles in the order named with said first, second and third poles all being on the same side of said magnetic record medium, signal input means coupled to said magnetic core for producing a predetermined maximum recorded amplitude on the magnetic record medium, said magnetic recording system further comprising

an electric winding coupled to the magnetic core at location closer to the first pole than to the third pole, and

means for supplying an electric bias current to said winding for establishing a magnetic bias field between said first and third poles,

the magnetic field incidentally produced between the first and second poles being inoperative by itself to act as an effective erasing field for erasing said predetermined maximum recorded amplitude from the record medium, and

means for completely erasing said record medium prior to the time the record medium reaches said cross field gap.

23. In a magnetic transducer system comprising a magnetic core having a record medium path along which a record medium is to travel and having first, second and third poles for coupling with a channel of a magnetic record medium in a recording region of said record medium path, said second and third poles being disposed adjacent and on the same side of the record medium path and being disposed in alignment with respect to a direction of movement of a magnetic record medium along said record medium path and having a recording gap therebetween, said magnetic core having a recording magnetic circuit of closed loop configuration including said second and third poles and said recording region, said first and third poles having a cross field air path therebetween intersecting said recording region of said record medium path, said magnetic core having a cross field magnetic circuit of closed loop configuration including said first and third poles and said cross field air path therebetween, said system comprising

means coupled to said core for producing a recording magnetic cross field component extending along said cross field air path and having a substantial magnitude in said recording region and for producing a further recording magnetic field component extending between said second and third poles and having a substantial magnitude in said recording region, and operative to record a signal on said record medium as it travels along said record medium path during a recording operation,

said first pole being disposed on the same side of the record medium path as said second and third poles and being in alignment with and preceding said second an third poles with respect to the direction of movement of the record medium along said record medium path and being separated from said second pole by a cross field gap,

said second pole having a dimension in the direction of movement of the record medium comparable to the dimension of the cross field gap in the direction of movement of the record medium, and

the recording gap between said second and third poles being of substantially less length than said cross field gap in the direction of movement of the record medium,

playback circuit means for coupling to said recording magnetic circuit during a playback operation to generate an electric signal varying in accordance with a signal recorded on a record medium moving along said record medium path and across said cross field gap and then across said recording gap, and

means for substantially isolating said playback circuit means from signal magnetomotive forces applied by the portion of a magnetic record medium bridging said cross field gap and said recording gap in series.

24. The transducer system of claim 23 wherein

said substantially isolating means comprises a nonmagnetic gap between said first pole and said recording magnetic circuit having a reluctance substantially greater than the reluctance of said cross field gap.

25. The method of operating a magnetic core having first, second and third poles on the same side of a record medium path which comprises

moving a magnetic record medium along the record medium path and across the first, second and third poles in the order named,

establishing a signal magnetic field varying in accordance with a signal to be recorded along an air path between said first and third poles and having a substantial magnitude in a recording region of the record medium path adjacent said third pole, and

establishing a further recording magnetic field between said second and third poles and having a substantial magnitude in said recording region for contributing to the recording of the signal on the record medium.

26. The method of transducing signals by means of a magnetic core having first, second and third poles on the same side of a record medium path, which comprises

relatively moving a magnetic record medium along the record medium path and across said first, second and third poles in the order named,

establishing a signal field in accordance with a signal to be recorded at a recording region of the record medium path adjacent the third pole,

establishing a magnetic bias field between said first and third poles having a substantial amplitude in said recording region effective to substantially contribute to the recording of said signal on the record medium, with the incidental effect of producing a magnetic field between said first and second poles of amplitude less than that required to insure erasure of a previously recorded signal on the record medium, and

effectively erasing said previously recorded signal from the record medium immediately prior to the record medium passing through said incidentally produced magnetic field, whereby the bias field amplitude may be selected independent of any requirement that the field between said first and second poles act as an erasing field.

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BERNARD KONICK, *Primary Examiner.*

L. G. KURLAND, *Assistant Examiner.*