# United States Patent

[11] 3,553,389

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Ladera, Calif.
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## [54] MAGNETIC TRANSDUCER WITH A LOW RELUCTANCE MASSIVE BACK GAP

5 Claims, 18 Drawing Figs.

[52] U.S. Cl. .......... 179/100.2
[51] Int. Cl. .......... G11b 5/20, G11b 5/22
[50] Field of Search .......... 346/74MC; 340/174.1F; 179/100.2C

[56] References Cited

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 2,431,540 | 11/1947 | Camras | 179/100.2 |
| 2,535,480 | 12/1950 | Begun | 179/100.2 |
| 3,243,521 | 3/1966 | Lock | 179/100.2 |
| 3,244,818 | 4/1966 | Bick et al. | 179/100.2 |


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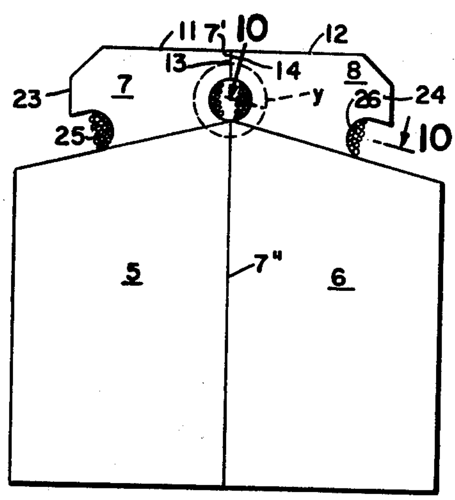
*Assistant Examiner*—Robert S. Tupper
*Attorney*—J. Hanson Boyden

**ABSTRACT:** The improved magnetic transducer is designed particularly for recording and reproducing very high frequencies of between 5 and 20 million cycles per second which includes television video frequencies. The transducer is made up of a pair of similar, separate halves, comprising massive body portions of relatively great width and thickness. The abutting surfaces of these body portions are lapped flat and true, and when assembled in contact with each other, constitute a back joint or back gap of extremely low reluctance. The body portion of each half carries integral therewith a head which is relatively small and thin, or narrow. These heads constitute elongated pole pieces, the tips of these pole pieces, when said halves are assembled, facing each other in closely spaced relation, providing between them a front or scanning gap. The cross section of said massive body portion is at least fifty times that of the pole piece tips adjacent the scanning gap, and the relative areas of said back and front gaps are on the order of at least twenty to one.

The relative thinness or narrowness of the pole pieces results in there being formed on the body portions, at each of the pole pieces, broad shoulders. Each of the heads has at each end, between the pole pieces and said shoulders, a coil-receiving notch, and a coil is wound in these pairs of notches around each head, these coils engaging the shoulders. These coils are relatively small, the effective coil length lying within a range of .005 to .03 inch. The notches at the gap ends of the pole pieces are substantially semicylindrical, and when in registry with each other, form a substantially circular opening extending transversely of the pole pieces, adjacent the gap. This circular opening lies immediately below the scanning gap, so that the shortest flux path through said gap extends circumferentially around said opening. This results in an exceptionally short flux path length ranging from .02 to .05 inch.



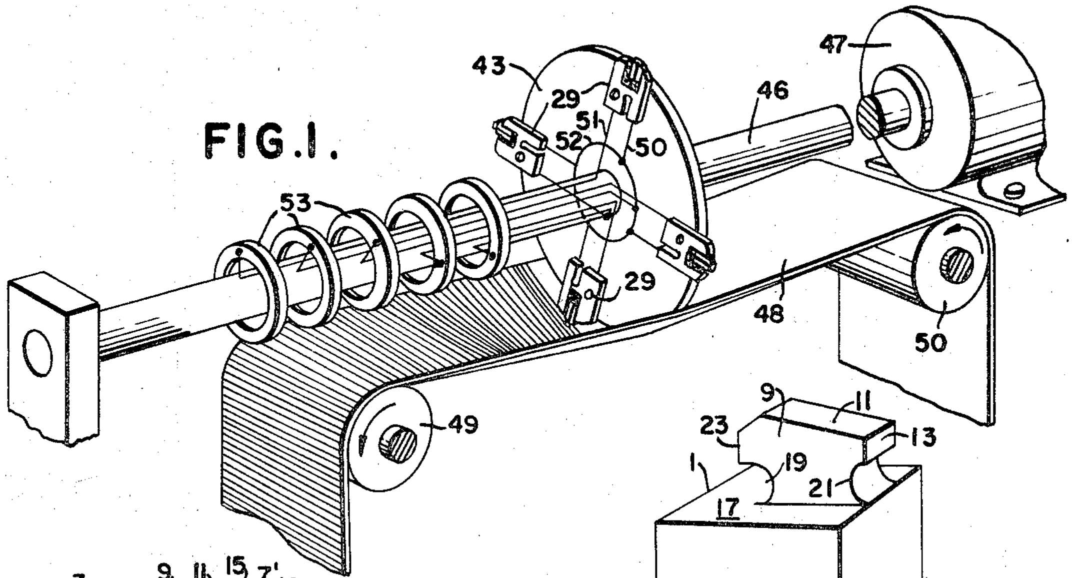


FIG. 1.

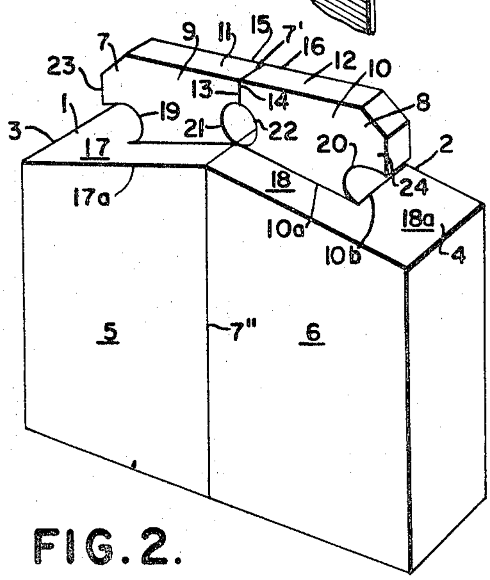


FIG. 2.

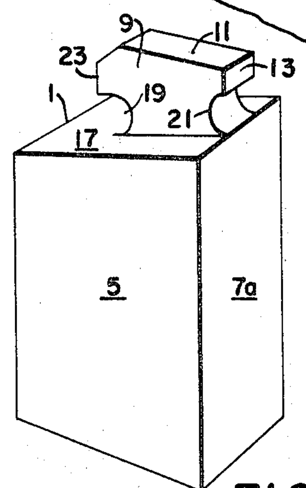


FIG. 3.

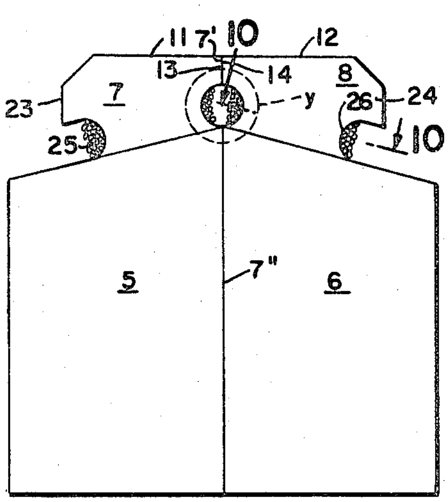


FIG. 4.

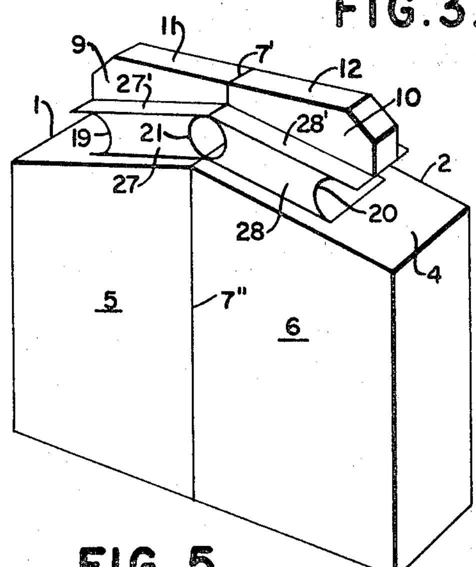


FIG. 5.

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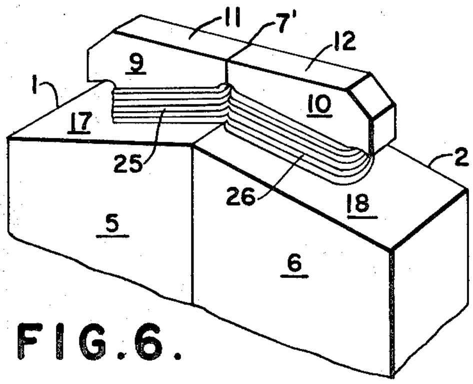


FIG. 6.

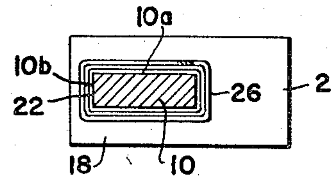


FIG. 10.

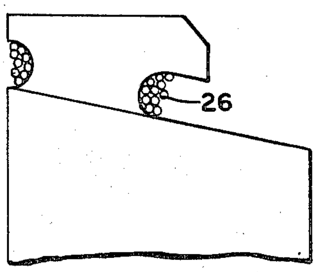


FIG. 7.

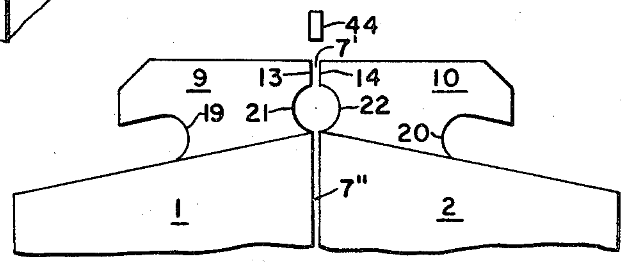


FIG. 11.

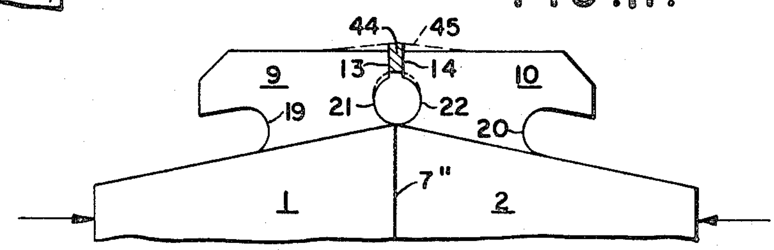


FIG. 12.

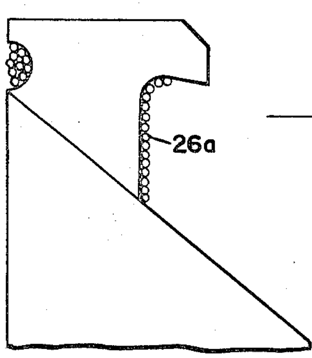


FIG. 8.

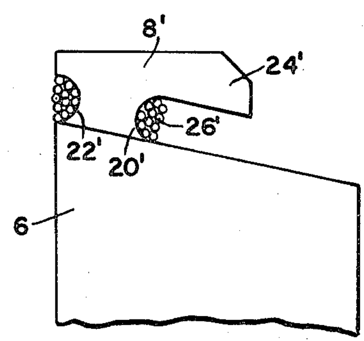


FIG. 13.

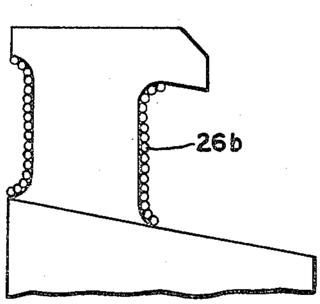


FIG. 9.

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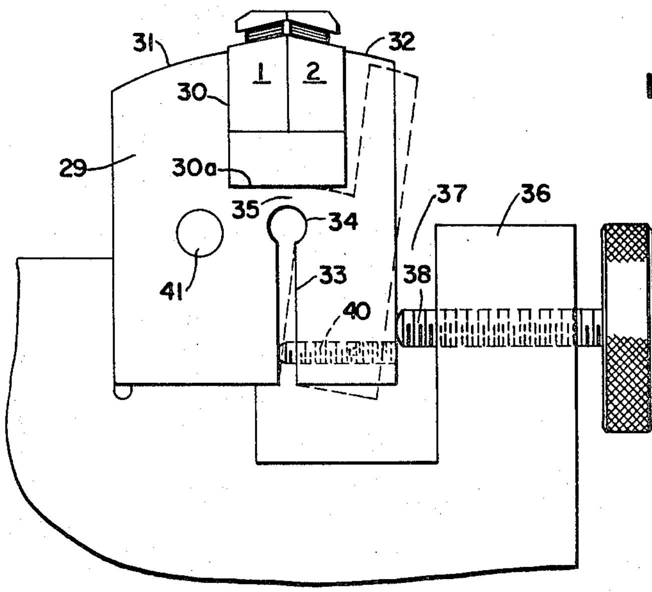


FIG. 14.

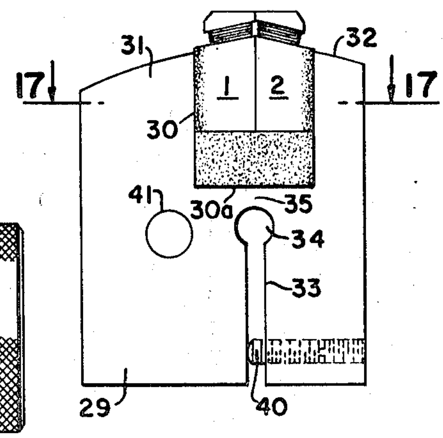


FIG. 15.

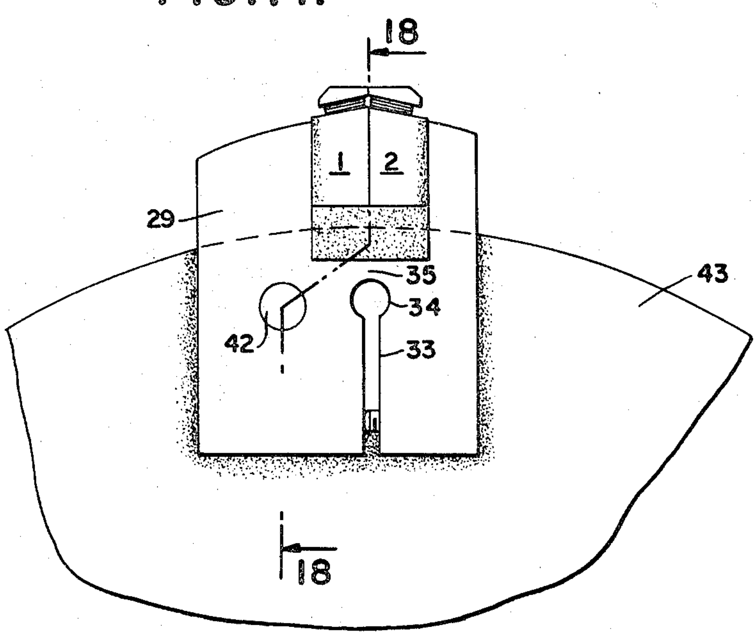


FIG. 16.

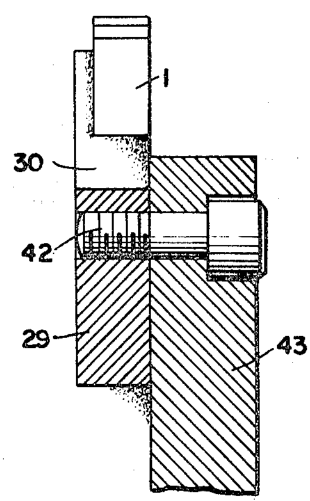


FIG. 18.

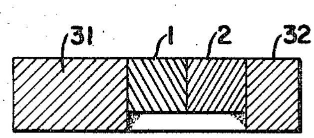


FIG. 17.

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# MAGNETIC TRANSDUCER WITH A LOW RELUCTANCE MASSIVE BACK GAP

This invention relates to transducers for magnetic recording and reproducing on a magnetic tape or other magnetic record media.

While, in its broader aspects, it is also applicable to other types of magnetic recording, such as sound recording, it is particularly designed for use in connection with magnetic record systems utilizing high frequencies of between 5 and 20 million cycles per second, short wave length and high media speeds, including the recording of television video frequencies, high frequency recording of analogue data either directly or through a modulation method and high density and high rate digital data in various formats.

More especially, the invention is outstandingly useful in television recording of the kind in which a plurality of magnetic transducing heads are mounted on the periphery of a rotating wheel and sweep successively across the tape transversely thereof, as the tape travels longitudinally. This type of recording was originated prior to 1940, by Marzocchi, as set forth in his expired U.S. Pat. No. 2,245,286, and is shown in a number of more recent patents, including U.S. Pat. No. 3,046,359, July 24, 1962, to Warren.

Magnetic transducing heads for magnetic recording in common use comprise a substantially closed magnetic circuit having therein a scanning gap, with coil means surrounding parts of such circuit. When used for recording, currents flowing through said coil means will cause a strong concentration of flux in the area of the gap. This flux will vary in intensity as the current in the coil means is varied in intensity, and magnetic media caused to move through the field fringing this gap will retain a magnetic pattern or record corresponding to variations in the flux. When used for reproducing, the magnetic media moving relative to the scanning gap will induce magnetic fields in the face of the pole pieces of the transducer. Where these fields are interrupted by the gap, a portion of the flux will pass through the magnetic circuit threading through the coil means and cause an electromotive force to be developed which corresponds to the rate of change of the flux intensity, and thus to the original variation in current induced in the coil means when the record was made.

The performance of magnetic recording apparatus is principally limited by the quality of the tape or other magnetic media, the quality of the reproduce amplifiers, the resolution and sensitivity of the magnetic transducing head, and the relative velocity of the record media. The magnetic media have been continuously improved in quality. Amplifier components and design have greatly reduced the threshold noise level. Apparatus for providing the precise speed of relative movement of magnetic media required have been improved and new methods devised whereby very high velocity can be attained. The magnetic transducing head remains the limiting factor in most magnetic record apparatus.

The electromotive force developed when a magnetic transducer head is reproducing a record is, in theory, proportional to the number of turns in the pickup coil. The limit to the number of turns that may be used is determined by the point at which the inductance of the coil resonates with the capacitance in the circuit. The amplitude of the frequencies above the resonant frequency will suffer an increasing attenuation.

It has been established practice of present designers to adjust the turns so as to place this resonant point near the highest frequency to be recorded and reproduced, and by allowing the circuit to be under damped, to achieve a gain in output amplitude in the resonant area. This practice does provide improved amplitude output at the higher frequencies when related to the broad band noise threshold of the system, but the true dynamic range is not enhanced, as the individual noise components in this same area are also subject to amplitude gain from this circuit. In addition, there will be a change in phase at the resonant point that will be most rapid for the undamped condition. This phase characteristic will cause a differential delay between frequency components at different points in the range of frequencies to be recorded and reproduced that will distort the faithful reproduction of complex wave forms. Where the magnetic record is to be interchanged between different recording and reproducing equipments or where data is to be compared between several of many parallel records, the uncertainty of the results of the comparison is thus increased.



In the recording of color television the color hue information is contained in the phase difference between a chroma signal and a reference frequency while the picture detail is contained in the amplitude of a luminance signal. Broadcast television magnetic recorders in general use are of the rotary head type with the record made up of the output of four separate circuits combined in serial fashion. If the four serial circuits have differences in their phase characteristic there will be slight differences in the hue of the color produced.

The human eye is not adept at absolute measurement. The eye, however, is exceptional in its capability to detect slight relative variations in hue. These differences in hue, although they are individually pleasing, will produce a subjectively displeasing color picture as the differences will stand out at the places where the signals are recombined and create a banding of the picture. When in accordance with the present practice the resonant frequency is placed within the band of frequencies to be recorded and reproduced the four circuits must be carefully matched in regard to the resonance frequency and the degree of damping. In my improved design, I can obtain sufficient sensitivity with a reduced inductance per turn, which allows the placement of the resonant frequency well above the highest frequency to be recorded.

Once the number of turns in the coil has been determined by the aforesaid usual practice, a minimum wave length on the magnetic record media is established as a compromise between the desired playing time, the capability to move the magnetic media at a suitable relative velocity, life of the transducing head, and the required signal output.

The minimum wave length that can be resolved is related to the length of the scanning gap in the face of the transducing head. The shorter this gap, the shorter the wave length and hence the higher the frequency, for a fixed magnetic media velocity, that can be resolved. As this gap is made shorter the sensitivity of the transducer decreases, as an increasing amount of flux is being shunted through the gap decreasing the flux that links the pickup coil, thus reducing the electromotive force developed.

To restore the sensitivity thus lost, the gap area can be reduced to increase the reluctance of this shunting path. This is accomplished by reducing the depth of the abutting portion of the two pole tips making up the gap. This, in turn, reduces the life of the transducer which is determined by the rate at which material is worn away from the intimate mechanical contact maintained between the transducing head and the magnetic media which is characteristically abrasive.

The final parameter affecting output is the width of the track. This parameter may be adjusted to provide a compromise between the amount of magnetic media surface to be used, and the desired output level.

Although it is the established practice to employ a smaller number of turns in a transducing head to be used for recording, as distinguished from reproducing, so as to reduce the impedance and increase the frequency response, particularly when AC bias recording is utilized, there are certain magnetic recording apparatus where it is most convenient to utilize the same transducing head for both purposes. This is the case in the rotary head magnetic recording equipment used for broadcast television. This compromise following present practices has not been entirely satisfactory.

The principal object of this invention is to provide an improved magnetic transducer having greater sensitivity over an extended band of high frequencies, longer life, proper damping, and greater resolution of short wave lengths, and having a point of resonance beyond the range of frequencies to be recorded and reproduced.

Specifically an object of this invention is to provide a more efficient magnetic circuit whereby the flux induced into the pole pieces when reproducing a magnetic record will flow principally through that part of the magnetic circuit where it effectively threads a pickup coil and with little irreversible power conversion; and to provide a mechanical design whereby the scanning gap may be accurately and uniformly established and maintained and where the joints in the magnetic circuit are made with a very low reluctance per unit area.

Another object is to provide a coil means so constructed and disposed that the frequency response may be greatly increased without loss of output or sensitivity.

In magnetic transducers of this general type, higher frequencies normally result in loss of output. With my improved design, however, I am able to provide coil means which will respond to much higher frequencies than heretofore employed, without loss in sensitivity.

Several factors enter into the production of such a design, including the shape and size of the pole pieces, the length, width and depth of the scanning gap, the location and disposition of the coil means, and the materials used for the pole pieces, and other portions of the magnetic circuit.

The induced flux in the pole pieces of the transducer during reproduction of a magnetic record passes along three principal paths; one, through the core around which the pickup coil is wound; two, through the scanning gap; three, through leakage paths not linking the pickup coils. The efficiency of the transducer is related directly to the ratio of the amount of flux that links the coils relative to that flux that does not link the coils in passage through the transducer.

Another specific object is to devise means for reducing to a minimum the reluctance of all parts of the magnetic circuit other than that of the scanning gap, so that the greater portion of flux passing through the transducer will link the pickup coils. This is achieved by placing the coil means closely adjacent the pole pieces, by causing the flux path through the coil means to be as short as possible, by properly shaping the pole tips, and by constructing the parts of the magnetic circuit remote from the scanning gap in such manner as to provide a back joint having a low reluctance per unit area so that it will allow the major portion of the flux to pass through a small area of the said joint adjacent the scanning gap; this reduces the reluctance and the irreversible power conversion that directly affect the sensitivity of the transducer.

In magnetic transducers, it is the common practice to interpose a nonmagnetic shim between the pole tips to fix the length of the scanning gap and maintain it constant. This shim is some cases is separate or it may be fused to one or both of the pole tips. Low resistivity metals will develop eddy currents that increase the effective gap reluctance. Such metals are available in shim forms. The present invention employs such a shim separate from and not fused to the pole tips, and a still further object of the invention is to devise improved means for securely holding the shim in place, so that it will not be thrown out by centrifugal force generated by the rotation of the headwheel used in some apparatus, or be pulled out by contact with the magnetic tape.

For proper resolution of short wave lengths when reproducing a magnetic record the scanning gap must be precise. The two faces of the gap must be parallel. Another object of this invention is therefore to provide a design in which the body of the transducer is made so massive and the abutting surfaces of the back joint are so large and fit together so closely that the body and back joint possess sufficient mechanical rigidity to absolutely ensure the proper positioning and stability of the pole tips adjacent the scanning gap.

The frequency response of the transducer is limited by the irreversible power conversion of the magnetic circuit which increases with increasing frequency, and by the circuit bandpass of the coil where the inductance and the capacitance of the coil, with the circuit elements of its transmission line and amplifiers, resonate and frequencies higher than the resonant frequency are suppressed. Still another object of this invention is to so place and wind the coils as to maintain a low inductance and capacitance per turn, whereby either more turns with a corresponding greater sensitivity may be used, or fewer turns with a satisfactory sensitivity may be used over a much higher band of frequencies.

Another object of this invention is to provide proper damping whereby the phase response may be improved. This involves designing the core and the coil means so that the amount of energy stored per cycle and the amount of energy lost through irreversible power conversion per cycle is approximately equal.

Yet a further object of the invention is to provide a magnetic transducer head of exceptionally simple construction, and comprising a minimum number of parts, whereby less cost of labor and material results, and the manufacturing process is greatly facilitated so that a large number of standard units of uniform characteristics and performance can be readily produced.

With the above and other objects in view, and to improve generally on the details of such equipment, the invention consists in the construction, combination and arrangement of parts hereinafter described and claimed, and illustrated in the accompanying drawings, forming part of this specification, and in which:

**FIG. 1** is a diagrammatic view showing a rotary head wheel for recording and reproducing transversely of a traveling tape;

**FIG. 2** is a perspective view of one form of my improved transducer head, the coil means being omitted;

**FIG. 3** is a perspective view of one of the similar halves making up the transducer shown in **FIG. 2**;

**FIG. 4** is a side elevation of the complete transducer, including the coil means, the latter being shown in section;

**FIG. 5** is a perspective view, similar to **FIG. 2**, but showing a slightly modified construction;

**FIG. 6** is a fragmentary perspective view similar to **FIG 2**, but showing the coil means in place on the pole pieces;

**FIGS. 7, 8,** and **9** are fragmentary side elevations of parts of one of the similar halves of the transducer, showing various shapes of the pole piece, and various ways in which the coil means may be wound;

**FIG. 10** is a transverse section substantially on the line **10–10** of **FIG. 4**, looking in the direction of the arrows;

**FIG. 11** is a fragmentary side elevation of the unassembled halves, showing the relation between the length of the front or scanning gap and the thickness of the shim (greatly exaggerated);

**FIG. 12** is a similar view showing the shim in position and, in broken lines, the pole tips distorted or deformed by reason of the lateral pressure used in assembling;

**FIG. 13** is a fragmentary side elevation of one of the transducer halves illustrated in **FIG. 4**, but showing a smaller coil designed especially for very high frequencies;

**FIG. 14** is an elevation of a clamping device which I may advantageously use for assembling and mounting my improved transducer, this view also showing a jig for manipulating the clamping device;

**FIG. 15** is a similar view, omitting the jig, and showing the transducer firmly fixed in the clamping device;

**FIG. 16** is a view of the clamping device showing it attached to the head wheel illustrated in **FIG. 1**;

**FIG. 17** is a transverse section on the line **17–17** of **FIG. 15**, looking in the direction of the arrows; and

**FIG. 18** is a substantially radial section on the line **!8–18** of **FIG. 16**, looking in the direction of the arrows.

## DEFINITIONS

Where the terms listed below occur in the following specification and claims, they shall be understood as having the meaning given in these definitions:

Shim thickness defines "gap length."

Width of track at gap is called "track width." It is the dimension across the face of the head at 90° to the gap length dimension.

Pole piece "thickness" is the same as "width."

"Pole depth" is the dimension mutually at 90° to the first two, and is a measure of the depth of the pole piece at the gap.

By "thickness" of the body portions is meant the dimension parallel with the "track width."

The "width" of body portions means the distance from the back joint (or gap) to the outer side.

"Face" of pole piece is the outer surface which engages the tape.

Referring to the drawings in detail, and first more particularly to FIGS. **2**, **3** and **4**, the improved transducer is made up of a pair of similar, separate halves **1** and **2**. These halves comprise body portions of relatively great thickness, as indicated at 3 and 4, and also having sides 5 and 6 of relatively great width. The abutting surfaces, such as *7a* in FIG. **3**, are lapped flat and true, and when assembled in contact with each other, as in FIGS. **2** and **4**, constitute a back joint or back gap **7**''. The body portion of each half carries integral therewith a head **7**, **8**, which is relatively small and thin or narrow, as compared with the thickness of the body portions. The sides **9** and **10** of these heads preferably lie in the same plane, and this plane is parallel with, but, at least at one side, offset from, that of the sides **5** and **6** of the body portions. The heads **7** and **8** constitute elongated pole pieces **11** and **12**, the tips **13** and **14** of these pole pieces, when said halves are assembled, facing each other in closely spaced relation, providing between them a front gap **7**'. As shown in FIGS. **2** and **4**, this front gap **7**' and the back gap or joint **7**'' lie in a common plane, and this plane is at right angles to that of the faces **15** and **16** of the pole pieces which engage the tape.

The relative thinness or narrowness of the pole pieces as compared with the body portions results in there being formed on the body portions, at each of the heads or pole pieces, broad shoulder **17** and **18**, and the width of the body portions is also greater than the length of the pole pieces, so that the body portions extend laterally beyond the pole pieces, as shown in the drawings.

Each of the heads has at each end, between the pole piece and said shoulders, a coil receiving notch **19**, **20**, **21**, **22**, and a coil **25**, **26** is wound in these pairs of notches around each head as clearly shown in FIG. **4**, these coils engaging the shoulders **17**, **18**.

By reference to FIG. **10**, it will be understood that the heads **7** and **8** are of rectangular cross section, when viewed in substantially horizontal section, having relatively long sides **10a** and relatively short ends **10b**. The long sides have a length lying within a range of .017 to .025 inch, and the short sides or ends have a length lying within a range of .01 to .02. This means an effective diameter of about .015 to .025 inch.

Where, in the specification and claims, I use the term "effective diameter," I mean the diameter of a circle having approximately the same area as the above mentioned rectangular cross section.

The coils **25** and **26**, wound around these heads and lying in the notches are relatively small, compared with prior designs, but have greater effective length due to the use of two coils in series. The effective coil length lies within a range of .005 to .03 inch.

The notches **21**, **22** at the gap ends of the pole pieces are substantially semicylindrical and are in registry with each other, forming a substantially circular opening extending transversely of the pole pieces, adjacent the gap, so that the outer surfaces of the two coils are in substantial contact. The wire has a diameter on the order of .001 inch and the number of turns on each pole piece may run as high as 100 or as low as 4. The size of the notches is determined by the number of turns to be used.

This circular opening lies immediately below the scanning gap, so that the shortest flux path through said gap follows a circular course concentric with said opening, as indicated by the dotted line *y* in FIG. **4**. In other words, the shortest flux path through the gap extends circumferentially around said opening.

This results in an exceptionally short flux path. In commercially available video magnetic head designs made by two well known manufacturers, the minimum flux path for one is .085 inch and for the other, .065 inch, while magnetic heads made in accordance with the design of the present invention have been successfully produced having a minimum flux path length ranging from .020 to .050 inch.

It is known that the sensitivity is inversely proportional to the average length of the flux paths through the metallic pole pieces. This depends not only on the minimum path length above referred to, but also on the provision of a back joint with large and intimate contact. Hence, a very low reluctance back joint can be provided even over a small area, that can pass relatively high flux density satisfactorily, and result in short average path lengths.

Thus, by virtue of the short minimum flux path, in combination with the improved single back joint, I have achieved sensitivity at 3,000,000 cycles per second which is several times greater than that of prior designs.

Furthermore, I have obtained usable output up to 20,000,000 cycles, while the output of prior video transducer designs falls away rapidly above 8,000,000 cycles.

By virtue of the notches **19**, **20**, the outer ends **23**, **24** of the pole pieces may be said to "overhang" the upper surfaces of the body portions. And these upper surfaces are shown as lying at an acute angle to each other and to the plane of the back joint with the axes of the coils at right angles to such upper surfaces.

In FIG. **5**, I have shown a slightly modified construction in which the coil receiving notches **19**, **20** are made in portions **27**, **28**, thicker than the pole pieces so that shoulder **27**', **28**' are formed on each side of the pole pieces.

In FIG. **13**, I have shown a modified construction in which the length of the head portion between the coil receiving notches **20**', **22**' are formed on each side of the pole pieces. is somewhat less than in FIG. **4**, so that the rectangular core cross section may be made smaller. This reduces the effective diameter of the coil, which will result in a lower inductance per turn and increasing the upper limit of frequencies that may be passed through the coil. This construction also reduces the irreversible power conversion in the core.

In producing the improved transducer, the coil is first wound on each half and the halves then assembled under pressure by means of a suitable clamping device. The preferred type of clamping device is that devised by Anore Hofmann, and described and claimed in his patent application Ser. No. 684,811 filed Nov. 21, 1967 and now abandoned. As shown in said application, this clamping device consists of a flat block **29** of strong, nonmagnetic material, such as a suitable alloy. The block has a notch **30** extending inwardly from one end, and of such width as to snugly receive the two halves **1**, **2**, of the transducer. The parts of the clamp on either side of this notch may be referred to as "jaws" **31** and **32**.

Extending inwardly from the end of the clamping block opposite the notch **30** is a slot **33** having a rounded inner end **34**. Between the bottom **30a** of the notch **30** and the inner end **34** of the slot **33** is a band or zone of material **35**. This material is highly resilient, so that it can bend, within its elastic limit, when the slot **33** is compressed, to permit the jaw **32** to move outwardly to the position shown in dotted lines in FIG. **15**. This compression of the slot **33** can be produced by means of an assembly jig **36**, having a recess **37** to receive the clamping block. A load screw **38**, having a hand wheel by which it may be turned, works through the side of the jig, with its point **39** bearing against the edge of the clamping block below the jaw **32**. A set screw **40** works through a threaded opening adjacent the slot **33**, and bears against the far wall of this slot.

The jaw **32** is moved to open position as shown in dotted lines, by means of the screw **38**, the transducer halves inserted between the jaws, and then the screw **40** is backed off, permitting the resilience of the zone of material **35** to move the jaw back to closed position, as indicated in full lines, thus clamping the transducer halves between the jaws. To maintain the jaws in closed position, and, if desired, to increase the pressure on the transducer, the set screw **40** is turned up.

A threaded opening **41** extends transversely through the clamping block to receive a screw **42** for fastening the clamping block to the periphery of the head wheel **43** (see FIG. **1**), all as shown in detail in said Hofmann application.

As already mentioned, it is highly desirable to so design the transducer as to provide a major portion of the reluctance of the magnetic circuit at the front gap. There are two critical factors controlling the reluctance of this gap, namely, (1) the length of the gap; and (2) the area of the pole tips. For a given track width the area can be varied by changing the depth of the pole tips. One of the problems involved is that, while striving for a gap area as small as practicable, it is necessary (commercially) to make the pole depth large enough to insure a reasonable life. That is, that the time required for the face of the pole pieces to wear away to an inoperative extent, due to abrasion against the tape, be reasonably long.

With my improved design, I have been able to successfully employ pole tips having a depth up to .006 inch, while prior designs will not give results with pole tips having a greater depth than .003, with a correspondingly shorter life. The width of the pole face, at the same time, lies within a range of .005 to .050 inch.

Ferrite has been used in many designs of magnetic transducers, but this material has not proven entirely satisfactory. Ferrites have very high resistivity and thus low irreversible power conversion due to eddy currents even at high frequencies. The present ferrite materials commercially available tend to be structurally unsuitable for defining a precise scanning gap. They tend to crumble and erode producing a scanning gap ill-defined and wider than desired. When used in recording, they tend to saturate easily and produce a magnetic fringing flux that is not sharply and properly defined. These problems are discussed by Kornei in his U.S. Pat. No. 2,711,945.

Other designs have utilized ferrite materials in combination with ferrous alloy pole faces. These designs tend to have relative high reluctance flux paths due to the air gaps between the ferrite and alloy portions which offsets the advantages of the ferrite material and hence do not improve the overall sensitivity.

No ferrite is employed in my improved design, but instead, I prefer to make use of suitable ferrous alloys having high permeability and high flux densities at saturation. They are, of course, magnetically "soft," that is, show little magnetic remanence. They should also be somewhat hard physically. By selecting materials of suitable hardness, they provide sufficient resistance to abrasion for a practical operating life, with pole depths small enough to obtain a satisfactory reluctance in the gap.

Materials especially suitable are alloys of iron, silicon and aluminum near the compositions $Fe_3Si$ and $Fe_3Al$ and ternary alloys lying between them.

It has been the practice to utilize laminations in the magnetic structure to reduce the eddy current losses, a practice developed in the designs of transformers. Where very high frequencies are encountered, eddy current losses are the major source of irreversible power conversion and the chief cause of reduced sensitivity. In one case, for example, the sensitivity of a transducer of a particular design was reduced by 74 percent at a frequency of 3,000,000 cycles due to eddy current losses, even where laminations .002 inch thick were employed.

For the high frequencies utilized in the magnetic record apparatus to which my invention is particularly applicable, the thinness of the laminations required to materially reduce eddy current losses is impractically small, so I do not use laminations.

My new design provides a much lower reluctance in the flux path through the coil. This total reluctance is so low that the reluctance of the gap may be decreased while still obtaining improved sensitivity. Thus, the pole depth may be increased to provide added life.



In other words, I have substantially reduced the total reluctance of the flux path through the coil to a point well below that ever reached in known transducers, with the result that the sensitivity far exceeds that heretofore achieved. I can then utilize this increased sensitivity in a transducer having the usual pole depth and life, or I can reduce the sensitivity down to what is considered normal in the industry by increasing the pole depth, thus substantially increasing the life. Or, I may compromise by increasing the pole depth and life to some extent, and correspondingly reducing the sensitivity, while maintaining it well above that of prior transducers.

The lower reluctance in the flux path through the coil is due, first to the unusual shortness of the minimum flux path, through the coil on each pole piece, and second, to the configuration of the body design which provides a back joint of low reluctance per unit area as well as low total reluctance. The short path length results in low irreversible power conversion, which is directly related to the path length of the flux through the circuit.

The area of the meeting faces *7a* of the body portions (FIG. 3) constituting the back joint 7″, is very much greater than the area of the pole tips at the scanning gap, the ratio between the areas of the front or scanning gap and the back joint or gap, being within a range of 20 to 400 to one. The two surfaces of the back joint are lapped flat and true in a common plane and when assembled are held together under pressure. The effective air gap is very small as the joint is in intimate surface contact. There is a low reluctance per unit area under these circumstances and the flux density through the back joint can be relatively high at a point adjacent the coil notches, so the flux need not fan out over the whole area of the joint, causing a longer average flux path, greater irreversible power conversion and lower sensitivity.

Furthermore, this large contact surface, extending in both the vertical and lateral direction in reference to the scanning gap, provides excellent mechanical stability when the halves are assembled. The extent of the lateral surface is on the order of 5 to 10 times the track width, and the extent of the vertical surface is on the order of 10 to 20 times the pole depth, while the extent of both the lateral and vertical surfaces is on the order of 1000 times the gap length. This stability against shifting laterally or angularly is critical in maintaining a precise scanning gap. No glue or cement is used in the assembly of the parts of the magnetic circuit.

Thus, the low values of the reluctance in the rest of the flux path have allowed decreasing the reluctance at the front gap while providing the small gap length necessary for resolving short wave lengths, and, at the same time, the retention of sufficient pole depth for satisfactory life, while also providing greatly improved performance. The efficiency improvement is in both recording and reproducing, where a much better compromise has been achieved.

Transducers of my design have been tested in an existing commercial broadcast television tape recorder of the rotary head type. This recorder embodied a magnetic transducer having a scanning gap length of 90 micro inches and a coil of 48 turns. The pole depth was the standard .003 inch. The substitute transducer of my design being tested had a scanning gap length of .55 micro inches (as compared with 90) and a coil of 36 turns (as compared with 48). The pole depth was substantially greater than the standard .003 inch. The resulting inductance in my design was approximately one-third of that of the commercial recorder, and with the capacitance in the system, the resonance frequency was increased by a factor of three times to over 15 megacycles per second. This places the resonance frequency beyond the range of the usual frequencies to be recorded and reproduced. The output exceeded that of the existing design at all frequencies. Where the higher inductance and longer gap length of the existing design caused rapid reduction in output past 6 megacycles per second, my transducer produced a usable output up to 17 megacycles per second, producing up to five times as much signal output at 10 megacycles per second. The irreversible power conversion per cycle was very nearly equal to the power stored per cycle.

The utilization of my novel transducer on standard commercial video tape recorders has demonstrated improved reproduction of pictures in color. Most noticeable was the absence of banding, even where the output level of the four circuits was not the same. The improvement at 10 to 12 megacycles and above, is due, among other factors, to the shorter scanning gap and higher resonant frequency.

Transducers of my design have also been tested in tape recorder apparatus of existing commercial design in which the transducer head is located in a fixed position and the record media, such as magnetic tape, is moved across the said head. The test transducer showed a relative life of four times that of the units of existing designs supplied with the usual equipment. The test transducer with coil turns of a number to achieve a similar inductance provided up to four times the output with one-half the track width. Noise in the area of the resonant frequency was greatly reduced.

Usually, I employ a scanning gap ranging in length from 20 to 100 micro inches. (Gap lengths as large as 200 micro inches are used for record only transducers.)

In order to properly define and maintain the front or scanning gap, I may employ a nonmagnetic shim **44** between the pole tips. As shown in FIG. **11**, the space between the pole tips is not as great as the thickness of the shim.

When the two halves are assembled, with the shim in place between the pole tips, the extra thickness of this shim prevents the lapped, flat faces *7a* of the body portions from coming truly into intimate contact. Pressure is then applied to the side edges of the transducer, as indicated by the arrows in FIG. **12**, as by means of the above described clamping device **27**, to force the meeting faces of the body portions into intimate contact over their entire area.

As a result, the pole tips at the front gap are actually strained or distorted to an extent of 1 percent or less, as indicated at **45** in FIG. **12**, thus effectively gripping the shim between them so firmly as to insure the shim being held against being thrown out by centrifugal force or pulled out by contact with the tape. It has been found that an actual pressure of one-half to one pound is sufficient for this purpose.

Referring now to FIG. **1**, I have diagrammatically illustrated a head wheel **43**, mounted on a shaft **46**, driven by an electric motor **47**. Four clamping devices, such as shown in FIGS. **12** to **16**, are secured at equal angular distances apart around the periphery of said wheel, and a transducer such as described is mounted in the outer end of each clamping device. The pole pieces of the transducer extend radially beyond the clamping devices, so that these pole pieces, with the scanning gap between them, sweep transversely across a magnetic tape **48**, carried by supporting rollers **49** and **50**, in contact with the faces of the pole pieces. This tape is caused to travel longitudinally by suitable means (not shown).

The coils on the transducer are connected in series, and two leads **51** and **52** from the coils are brought out from each transducer. One of these leads is connected with a common terminal **52**, and each of the other leads is carried along the shaft to slip rings **53**, on which bear suitable brushes (not shown). The common terminal **52** is also connected with one of these slip rings, so that the circuit from the transducer coils may be completed.

My new design employs coils of unusually small effective diameter, with proportionally lower inductance. Several variations can be used to further reduce the inductance as by varying the length to diameter ratio of the coils.

Thus in FIG. **7**, I have shown a coil quite similar to that in FIG. **4**, having a length to diameter ratio of .5.

In FIG. **8**, by making the average length to diameter of the coil **26***a* equal to 1, the inductance can be reduced by a third.

And, in FIG. **9**, by making the ratio of the length to diameter of the coil **26***b* equal to 1.5, the inductance can be reduced by a half.

I claim:

1. A transducer for use in a rotating head apparatus for recording and reproducing information on a magnetic medium, said transducer being formed of two similar, separate halves of magnetic material, each half comprising a massive body portion and a head integral therewith, said body portion being many times thicker than said head and having relatively broad shoulders on which said head is carried, and said head being relatively narrow and constituting an elongated pole piece, the tips of said pole pieces, when said halves are assembled, facing each other in closely spaced relation, providing between them a front gap, each of said heads having at each end a coil receiving notch, a coil wound around each head in said notches, the coil receiving notches at the gap ends of said pole pieces being in registry with each other, the mating surfaces of the massive body portions being lapped true and flat and in contact with each other, and the joint between them constituting an intimate back gap of relatively low reluctance per unit area as well as low total reluctance, the relative areas of the back and front gaps being on the order of at least 20 to 1.

2. A magnetic transducer in accordance with claim **1** in which the coil receiving notches are each substantially semicylindrical in cross section, so that when the halves are assembled, with the said notches in registry with each other, they form a substantially circular opening extending transversely of the plane of said pole pieces immediately below said gap, the shortest flux path through said gap extending circumferentially around said opening.

3. A magnetic transducer in accordance with claim **2** in which the shortest flux path through said gap follows a circular course concentric with said opening and has a total minimum length substantially no greater than .05 of an inch.

4. A transducer for use in a rotating head apparatus for recording and reproducing information on a magnetic medium, said transducer being formed of two similar, separate halves of magnetic material, each half comprising a massive body portion and a head integral therewith, said body portion being many times thicker than said head and having relatively broad shoulders on which said head is carried, and said head being relatively narrow and constituting an elongated pole piece, the tips of said pole pieces, when said halves are assembled, facing each other in closely spaced relation, providing between them a front gap, each of said heads having at each end a coil receiving notch, a coil wound around each head in said notches. the coil receiving notches at the gap ends of said pole pieces being in registry with each other, so that the outer surfaces of the two coils are in substantial contact at a point immediately adjacent said front gap, the mating surfaces of the massive body portions being lapped true and flat, and the joint between them constituting an intimate back gap of relatively low reluctance per unit area as well as low total reluctance, the cross section of said massive body portion being at least 50 times that of the pole piece tips adjacent said gap.

5. A transducer for use in a rotating head apparatus for recording and reproducing information on a magnetic medium, said transducer being formed of two similar, separate halves of magnetic material, each half comprising a massive body portion and a head integral therewith, said body portion being many times thicker than said head and having relatively broad shoulders on which said head is carried, and said head being relatively narrow and constituting an elongated pole piece, the tips of said pole pieces, when said halves are assembled, facing each other in closely spaced relation, providing between them a front gap, each of said heads having at each end a coil receiving notch, a coil wound around each head in said notches, the coil receiving notches at the gap ends of said pole pieces being in registry with each other, so that the outer surfaces of the two coils are in substantial contact at a point immediately adjacent said front gap, the mating surfaces of the massive body portions being lapped true and flat, and the joint between them constituting an intimate back gap of relatively low reluctance per unit area as well as low total reluctance, both the width and the depth of the back joint surfaces being on the order of 1,000 times the length of the front gap.