



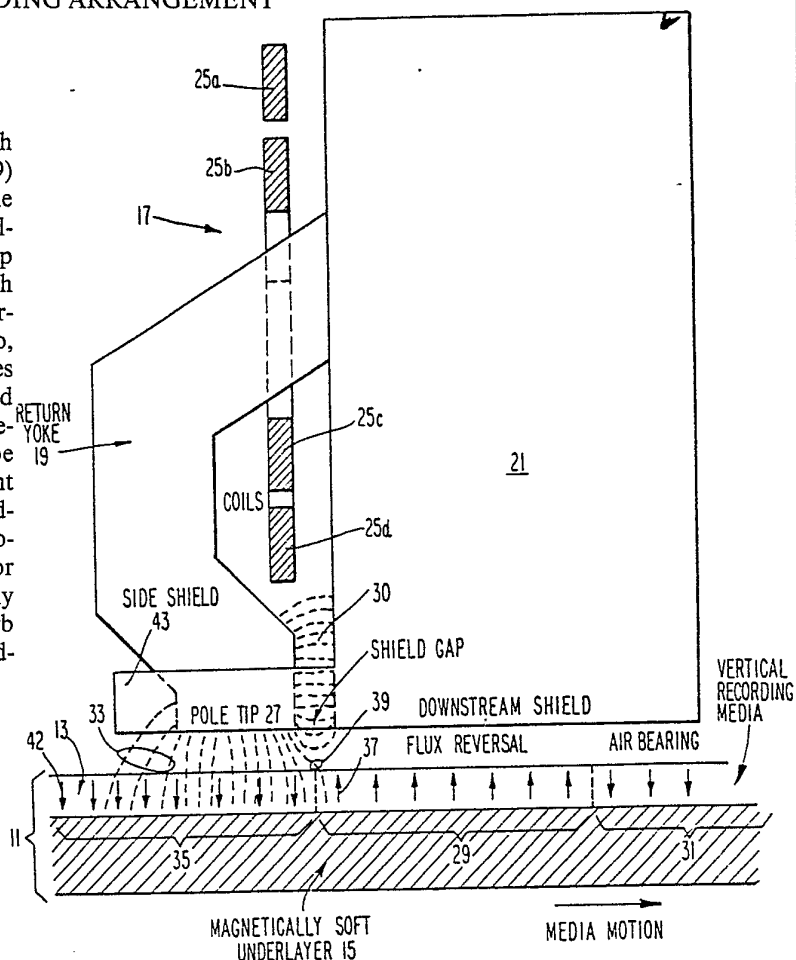
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(54) Title: VERTICAL MAGNETIC RECORDING ARRANGEMENT

(57) Abstract

A downstream magnetic shield (21) which is integrally formed with a write pole section (19) to make up a magnetic recording head. The shield and the write pole tip (27) are located relatively close together, providing a small gap there between, so that magnetic flux (39) which fringes from the magnetic write pole tip is intercepted by, or has an incentive to pass directly to, the shield. Accordingly such fringing flux does not pass through the recording medium, and hence if a data bit has been written into the recording medium its dipole identity will not be weakened by the fringing flux of a subsequent data bit being written into the magnetic recording medium. In addition the present device provides magnetic flux shielding means (43, 53) for the tracks along side of the track being presently written so that the fringing flux does not disturb the dipole identity of the bits recorded in the adjacent tracks.



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Vertical Magnetic Recording Arrangement

While magnetic recording of information is enormously successful, it has been found that in the prior art there is a limitation with respect to recording density. In the present state of the art the popular method of magnetic recording has been longitudinal recording. Magnetic recording systems to date generally recognize recorded bits of information by detecting pulse peaks within certain timing windows. Unfortunately systems often inadvertently shift pulse patterns, in time, with respect to the timing of the windows and this of course results in errors. It follows that when linear density is increased, the time windows in which the peak must be detected necessarily narrows and the systems become more sensitive to noise and there are resulting errors.

Magnetic recording techniques have turned to considering vertical recording as compared to longitudinal recording as a means for vastly improving the linear density of recorded information. Vertical magnetic recording has been accomplished by having the recording medium pass between two mirror image recording heads. The magnetic flux from a first recording head passes vertically from a first write tip through the magnetic recording medium to a second write tip (the write tip of a second recording head). The shape of the tips concentrate the flux and hence effect a magnetic polarization within the recording medium to provide recorded information. The magnetic flux having passed through the second tip is routed upstream to a flux return path of the second write head. The flux return head is designed to have a face which is many times

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larger than the write tip so that the flux passing into the flux return head is disbursed therealong and hence the flux density is low. The low density flux passes through the recording medium, upstream, to the flux
5 return path of the first magnetic write head and therealong to complete a magnetic flux circuit. Because the density of the flux passing through the recording medium upstream is low, there is very little effect by way of reversing or weakening any patterns in the
10 recording medium upstream.

In the prior art vertical recording technique there has been a prerequisite in that there has been required a relatively large distance between the write tip and the flux return path to prevent leakage flux cross-over. In
15 other words in such techniques the full strength of the write flux is desired to effect a desired recording. However, in such arrangements, as the described in U.S. Patent 4,317,148 the downstream fringing flux, which is ignored, acts to reverse or weaken, the magnetic polarity
20 of information having been previously recorded and to compensate therefor the packing density has had to be reduced.

The present device employs a two layered recording medium, places the flux return section downstream and by
25 specifically locating the write tip close the flux return path, uses the flux return path as a magnetic shield to intercept downstream fringing flux and thus prevent reversal or weakening, of the magnetic polarity at the trailing edge of a recorded bit of information. As
30 mentioned above the prior art is exemplified by the structure described in U.S. Patent 4,317,148.

The present device includes a two layered recording medium. The upper layer is comprised of a material having perpendicular uniaxial anisotropy, such as cobalt

chromium, while the underlayer is comprised of material having a low magnetic reluctance such as nickel iron. In addition the present device includes a write pole section of a single write head (no mirror image write head is included) which is formed in a partial loop configuration, away from the downstream flux return section, so that there is no leakage along the height dimension of the write pole section. However, the partial loop configuration is designed to place the write tip X micro inches away from the flux return section. Where X is in the range from $G/2$ to $2G$ and where G is the distance from the write tip face to the beginning of the low reluctance layer. The gap X is a small gap and hence most of the downstream fringing flux is intercepted by the flux return section so that the flux return section acts as a magnetic shield. The interception of the downstream fringing flux by the magnetic shield reduces the undesirable effect of reversing, or weakening, a previously recorded bit of information. The present device further provides magnetic shielding means which lie parallel to the tracks on the recording medium so that tracks which lie adjacent to the track being presently written do not suffer from magnetic polarity reversals or weakening of dipole identification by flux fringing in a side direction or orthogonally to the track presently written.

The objects and features of the present invention will be better understood by considering the following description taken in conjunction with the drawings wherein:

Figure 1 is a side view of the write head depicting the write pole section formed in a partial loop and with the coils in sectional view form;

Figure 2 is a view of the write head as seen looking at the excursion direction of the recording medium; and

Figure 3 is an underside view of Figure 2.

Consider Figure 1. In Figure 1 there is shown a
5 section of the magnetic recording medium 11 which is made up of an upper layer 13 and a lower layer 15. The upper layer 13 in a preferred embodiment is cobalt chromium but it should be understood that any material which has perpendicular uniaxial anisotropy could be employed. The
10 lower layer 15 in a preferred embodiment is nickel iron but it should be understood that any material which has a low magnetic reluctance could be employed. While it is not shown in Figure 1, it should be understood that there is means to move the magnetic recording medium in a
15 downstream direction, i.e. a disk drive or the like. As can be seen in Figure 1, located in close proximity but with an air space in between, there is shown the write head 17. The write head 17 is made up of a write pole section 19 and downstream shield 21. The write pole
20 section 19 is formed integrally with the shield 21 and is formed to extend upstream into a partial loop as can be gleaned from Figure 1. By forming the write pole section 19 into a partial loop there is provided a bay or open section 23. By having the write pole section separated
25 from the shield section 21 by the bay 23 there is little fringing magnetic flux passing from the write pole section 19 to the shield 21 through the bay 23, i.e. along the height dimension of the write head.

As can be readily understood from the examination of
30 Figure 1 there is a coil 25 shown with four sections in Figure 1 and its configuration can be better understood by examining Figure 2. While it is not shown in Figure 1 it should be understood that the coil 25 is connected to a source of electrical power so that when the coil 25 is

energized there is a magnetic flux generated in the write pole section 19. It should be further understood that by forming write pole section 19 into a partial loop, the pole tip portion 27 comes into close proximity to the downstream shield section 21. Accordingly there is a gap 30 which is labeled in the drawing as the shield gap located between the pole tip 27 and the lower portion of the downstream shield section 21. The selection of the width (X) of the gap 30 is important. It has been determined that if the distance between the bottom of the face of the pole tip 27 and the start of the lower layer 15 of the magnetic recording medium has a dimension of G then the width (X) of the shield gap 30 should not be any smaller than $G/2$. This concept is set forth in the drawing wherein the drawing depicts the width of the shield gap as being equal to $G/2$. In the preferred embodiment the shield gap is equal to $G/2$ because at that dimension virtually all of the fringing flux passes directly into the downstream shield 21 while there is still a sufficient amount of flux emanating from the pole tip 27 to effect a vertical magnetization in the layer 13. However, in order to obtain sufficient write field it may be necessary to increase the gap from $G/2$ to as much as $2G$.

It should be borne in mind that the magnetic recording medium is moving from a left to right in Figure 1 and that the data bit recorded in the section 29 of the layer 13 has been recorded and the user wants that data bit to remain recorded on the magnetic recording medium 11. Accordingly the system does not want fringing flux to disturb or weaken or even reverse the dipole identification of the data recorded in section 29. As depicted for purposes of illustration (and not with any scientific exactness) the flux passes from the pole tip

27, through the hard layer 13 and through the soft layer 15 and is concentrated, or sufficiently dense, to align the dipoles of the layer 13 so as to effect a vertical recording of information in sections along the layer 13, such as sections 29 and section 31. It should also be noted in Figure 1 that fringing flux 33 is shown emanating from the left hand side from the pole tip 27. Such fringing flux indeed may disturb the dipole identification of a section of the magnetic recording medium entering under the write head but since that section is going to be rewritten it makes no difference that it is being disturbed. It is the downstream fringing flux that is the undesirable fringing flux and in accordance with the present device such fringing flux on the write end of the pole tip is intercepted by the shield section 21.

In order to have the magnetic flux emanate from the pole tip 27 and cause the write pattern to be developed, as shown in section 35, electrical current must be passing through the electrical coil as shown. In other words in the two upper legs 25a and 25b the current is passing into the figure while in the two segments 25c and 25d the current is passing out of the figure. In this way the flux will pass from the top of the figure through the write pole section and through the pole tip 27 as shown. As depicted in Figure 1 the relative strength of the magnetized areas is shown by the arrows. It will be noted that the arrow 37 is somewhat shorter than the rest of the arrows in section 29 indicating that there has been a slight weakening of that dipole identification because of the fringing flux 39 overlapping segment 29 before section 29 passes from under the fringing flux 39. The reduction of this adverse effect (downstream demagnetization) is one of the salient features of the

present invention. By way of comparison the arrow 42 is shown as being at a diminished even though it has not been under the pole tip at the point in time shown in Figure 1 but has been diminished because of the
5 conditions under which it was recorded at some previous time.

As can be seen further in Figure 1 there is a side shield 43 whose role is to intercept fringing flux that would pass over adjacent tracks, i.e. which are adjacent
10 to the track on the magnetic recording medium which is passing under the pole tip at the time depicted in Figure 1. The arrangement and the utility of the side shield 43 will be better understood by an examination of Figure 2.

In Figure 2 the various pieces of structure
15 described in Figure 1 are identified by the same numbers. As can be seen in Figure 2 the pole tip 27 provides fringing flux in the direction of the side tracks 45 and 47. That fringing flux is depicted in Figure 2 as the fringing flux 49 and fringing flux 51. The fringing flux
20 49 is intercepted by the side shield 43 while the fringing flux 51 is intercepted by the side shield 53. Accordingly the tracks 45 and 47 which lie adjacent to the track 55, that is the track that is being presently written upon in accordance with the arrangement depicted
25 in Figure 2, are not adversely affected by fringing flux. The gap between the pole tip 27 and the side shield 43 as well as the gap between the pole 27 and the side shield 53 can be larger than the downstream shield gap 30 so as to reduce the loss of flux to the shields.

30 Figure 3 depicts the underside of the device shown in Figure 2. The identification numbers of the structure in Figure 3 are the same as the identification numbers in Figures 1 and 2 and no further explanation thereof appears to be necessary. The arrangement of the device

shown in Figure 3 however does enable a clear understanding of the overall device particularly how the side shields are formed with respect to the downstream shield and with respect to the winged arrangements of the write pole section 19.

By arranging to have the shield extension of the write head located downstream of the write tip and by arranging to have the gap there between be relatively small, but not so small as to permit all of the flux to be intercepted by the shield, the present structure creates less of a diminishing effect on data information which has been previously written into the magnetic recording medium. In addition by having the write pole section formed into a partial loop, the amount of fringing flux which jumps the separation between the write pole section and the flux return section is minimized and the bay portion of the partial loop configuration provides a location for the magnetic flux generating coils. It is important to note that the gap dimension in the preferred embodiment is related to the distance between the bottom of the pole tip and the beginning of the soft layer or the layer having the low magnetic reluctance. If the air bearing, that is the distance between the pole tip and the upper surface of the hard layer 13, is decreased then the gap can be decreased because there will be a greater incentive for the flux to pass through the layer 13 as a result of the reduced air bearing. As can be readily seen in Figure 1 the vast majority of the flux passes through the layer 13 in a vertical direction and hence there is a vertical recording of the data in the layer 13. It should be further noted from the description and by examination of Figure 1 that the face of the downstream shield 21 is many times larger than the face of the pole tip. In

point of fact the pole tip 27 could have an even narrower face than shown in Figure 1. By providing a rather large downstream shield face, the flux is dispersed along that face and hence is relatively low in density. Because of the low density aspect of the flux passing on the return path into the downstream shield 21 there is very little effect on the magnetization condition in the layer 13 which lies under the shield. By not disturbing the magnetization pattern under the shield face one of the major objectives of the present system is accomplished.

Claim 1

1 An arrangement for effecting vertical magnetic
2 recording of information comprising in combination:
3 magnetizable recording means formed to have first and
4 second layers, said first layer comprised of magnetizable
5 material which is characterized by perpendicular uniaxial
6 anisotropy and said second layer comprised of material
7 characterized by low magnetic reluctance, said
8 magnetizable recording means arranged to be moved in a
9 downstream direction; magnetic recording head means
10 including magnetic flux generating means, formed to have
11 a write pole section and a downstream magnetic shield
12 section which is integrally connected to said write pole
13 section so that magnetic flux can readily pass, bi-
14 directionally, through said write pole section and said
15 downstream magnetic shield section; said downstream
16 magnetic shield section formed and disposed to have a
17 relatively large face lying in close proximity to said
18 first layer; said write pole section fashioned, while
19 extending in an upstream direction from said downstream
20 magnetic shield section, to form a partial loop
21 configuration ending in a pole tip which is disposed to
22 lie in close proximity to said first layer and in a
23 position such that a small gap is formed between said

24 pole tip and said downstream magnetic shield section
25 whereby, when said pole tip has magnetic flux passing
26 therethrough, fringing flux in a downstream direction
27 will substantially pass across said small gap into said
28 downstream magnetic shield face without passing through
29 said first layer, and whereby the remainder of said
30 magnetic flux passing through said pole tip passes
31 substantially vertically through said first layer into
32 said second layer, substantially parallel to and through
33 said second layer, and substantially vertically from said
34 second layer through said first layer into said
35 downstream magnetic shield face, thereby effecting
36 vertical magnetic recording of information in said first
37 layer.

Claim 2

1 An arrangement for effecting vertical magnetic
2 recording according to Claim 1 wherein the distance from
3 where said magnetic flux leaves said pole tip and enters
4 said second layer is G and wherein the width of said
5 small gap is between $G/2$ and $2G$.

Claim 3

1 An arrangement for effecting vertical magnetic
2 recording according to Claim 1 wherein said magnetic flux
3 generating means is a wire coil which in part passes
4 through the opening in said partial loop configuration of
5 said write pole section.

Claim 4

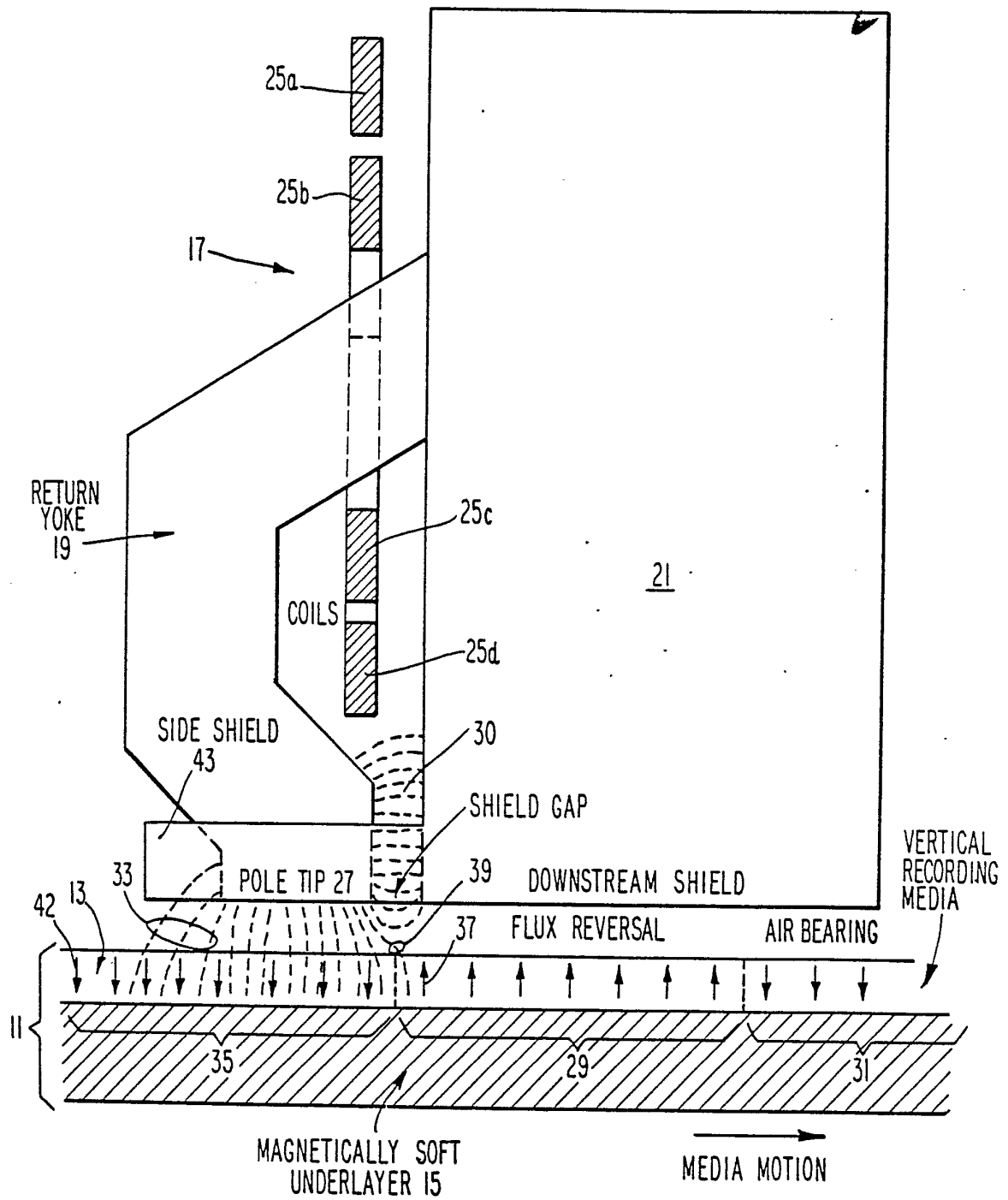
1 An arrangement for effecting vertical magnetic
2 recording according to Claim 1 wherein said write pole
3 tip defines a track on said magnetic recording means and
4 wherein there is further included side magnetic shield
5 means which are disposed to lie in close proximity to
6 said write pole section along at least one adjacent track
7 position to form at least one side gap there between to
8 enable said side shield means to intercept magnetic flux
9 which is fringing from said magnetic write pole tip in
10 the direction of tracks adjacent to said track defined by
11 the passage of said magnetic recording means relative to
12 said write pole tip.

Claim 5

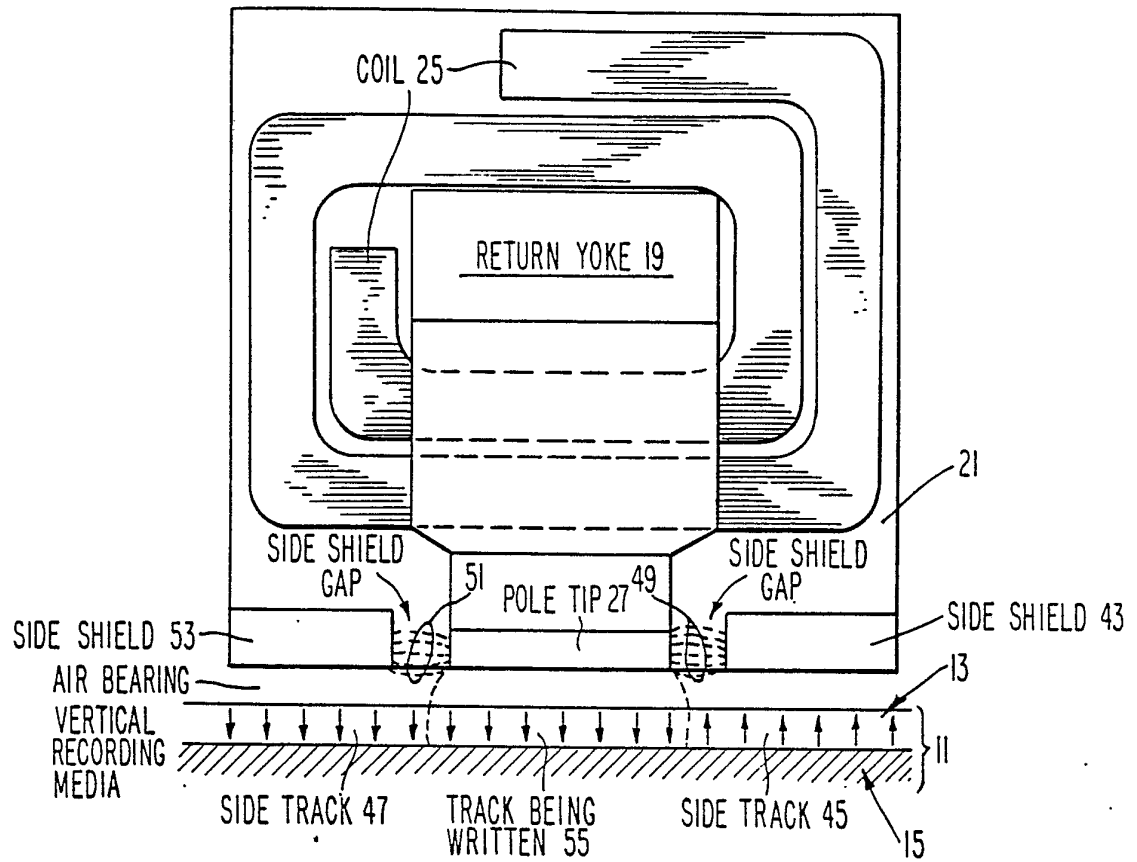
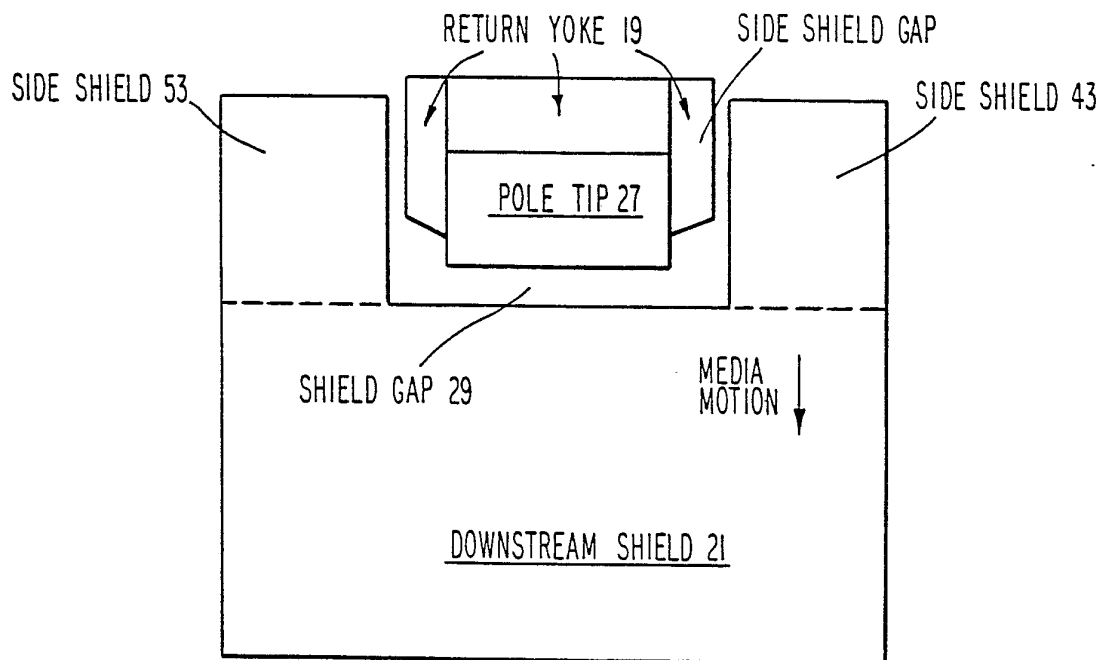
1 An arrangement for effecting magnetic recording
2 according to Claim 4 wherein said side magnetic shield
3 means includes first and second side magnetic shield
4 means each of which is disposed to lie on opposite sides
5 of, and in close proximity to, said write pole section to
6 respectively form first and second gaps between said
7 first and second side magnetic shield means and said
8 write pole section to enable said first and second side
9 shield means to intercept magnetic flux while is fringing
10 from said magnetic write pole tip in the direction of
11 tracks adjacent to said track defined by the extension of
12 said write pole tip onto said magnetic recording means.

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**Fig. 1****SUBSTITUTE SHEET**

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**Fig. 2****Fig. 3**

INTERNATIONAL SEARCH REPORT

International Application No **PCT/US86/00134**

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ³ According to International Patent Classification (IPC) or to both National Classification and IPC INT. CL. G. 11B 5/127 U.S. CL. 360/110											
II. FIELDS SEARCHED Minimum Documentation Searched ⁴ <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <th style="width: 20%;">Classification System</th> <th style="width: 80%;">Classification Symbols</th> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">U.S.</td> <td style="padding: 5px;">360/110, 113, 119, 121, 125</td> </tr> </table> Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵			Classification System	Classification Symbols	U.S.	360/110, 113, 119, 121, 125					
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U.S.	360/110, 113, 119, 121, 125										
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴ <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <th style="width: 10%;">Category *</th> <th style="width: 60%;">Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷</th> <th style="width: 30%;">Relevant to Claim No. ¹⁸</th> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">Y</td> <td style="padding: 5px;">US, A, 3156919 (Rutter) 10 November 1964</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-5</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;">JP, A, 58-88812 27 May 1983</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-3</td> </tr> </table>			Category *	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸	Y	US, A, 3156919 (Rutter) 10 November 1964	1-5	X	JP, A, 58-88812 27 May 1983	1-3
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* Special categories of cited documents: ¹⁵ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family											
IV. CERTIFICATION <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <td style="width: 50%; padding: 5px;"> Date of the Actual Completion of the International Search ¹ 24 February 1986 </td> <td style="width: 50%; padding: 5px;"> Date of Mailing of this International Search Report ² 18 MAR 1986 </td> </tr> <tr> <td style="width: 50%; padding: 5px;"> International Searching Authority ¹ ISA/US </td> <td style="width: 50%; padding: 5px;"> Signature of Authorized Officer ²⁰ A. J. Heinz </td> </tr> </table>			Date of the Actual Completion of the International Search ¹ 24 February 1986	Date of Mailing of this International Search Report ² 18 MAR 1986	International Searching Authority ¹ ISA/US	Signature of Authorized Officer ²⁰ A. J. Heinz					
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