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Huang et al.

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(45) **Date of Patent: Sep. 6, 2011**

(54) **COMBINED BULK THERMAL-ASSISTER AND BULK ERASER**

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(73) Assignee: **Hitachi Global Storage Technologies, Netherlands B.V.**, Amsterdam (NL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 224 days.

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(22) Filed: **Mar. 13, 2009**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
G11B 5/02 (2006.01)

(52) **U.S. Cl.** **360/59**; 360/57; 360/66

(58) **Field of Classification Search** .... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,742,404	A *	5/1988	Yunoki	360/66
4,970,711	A *	11/1990	Martin et al.	369/100
5,144,613	A *	9/1992	Johnson et al.	369/100
5,469,413	A *	11/1995	Kagawa	369/13.26
5,495,455	A *	2/1996	Kawashima et al.	369/13.11
6,714,398	B2 *	3/2004	Schultz	361/134
7,050,256	B1 *	5/2006	Oakley	360/66
7,193,933	B2 *	3/2007	Nakayama et al.	369/13.04
7,233,547	B2 *	6/2007	Teraoka et al.	369/13.06
7,626,800	B2 *	12/2009	Yoon	361/139
7,643,382	B2 *	1/2010	Nakayama et al.	369/13.03
7,701,656	B2 *	4/2010	Schultz et al.	360/66
7,885,032	B1 *	2/2011	Rahman et al.	360/66
2002/0196324	A1 *	12/2002	Abe et al.	347/179
2004/0051989	A1 *	3/2004	Hasegawa et al.	360/66
2006/0018075	A1 *	1/2006	Schultz	361/143

OTHER PUBLICATIONS

Wikipedia, "Magneto-Optical Drive", http://en.wikipedia.org/wiki/Magneto-optical_drive, 1-4.

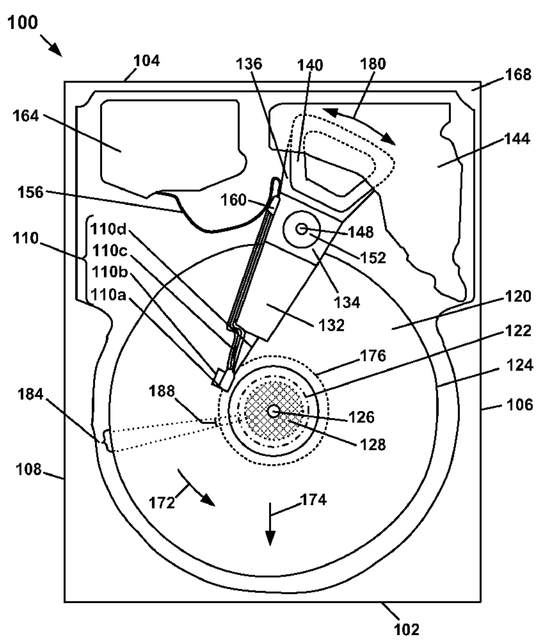
* cited by examiner

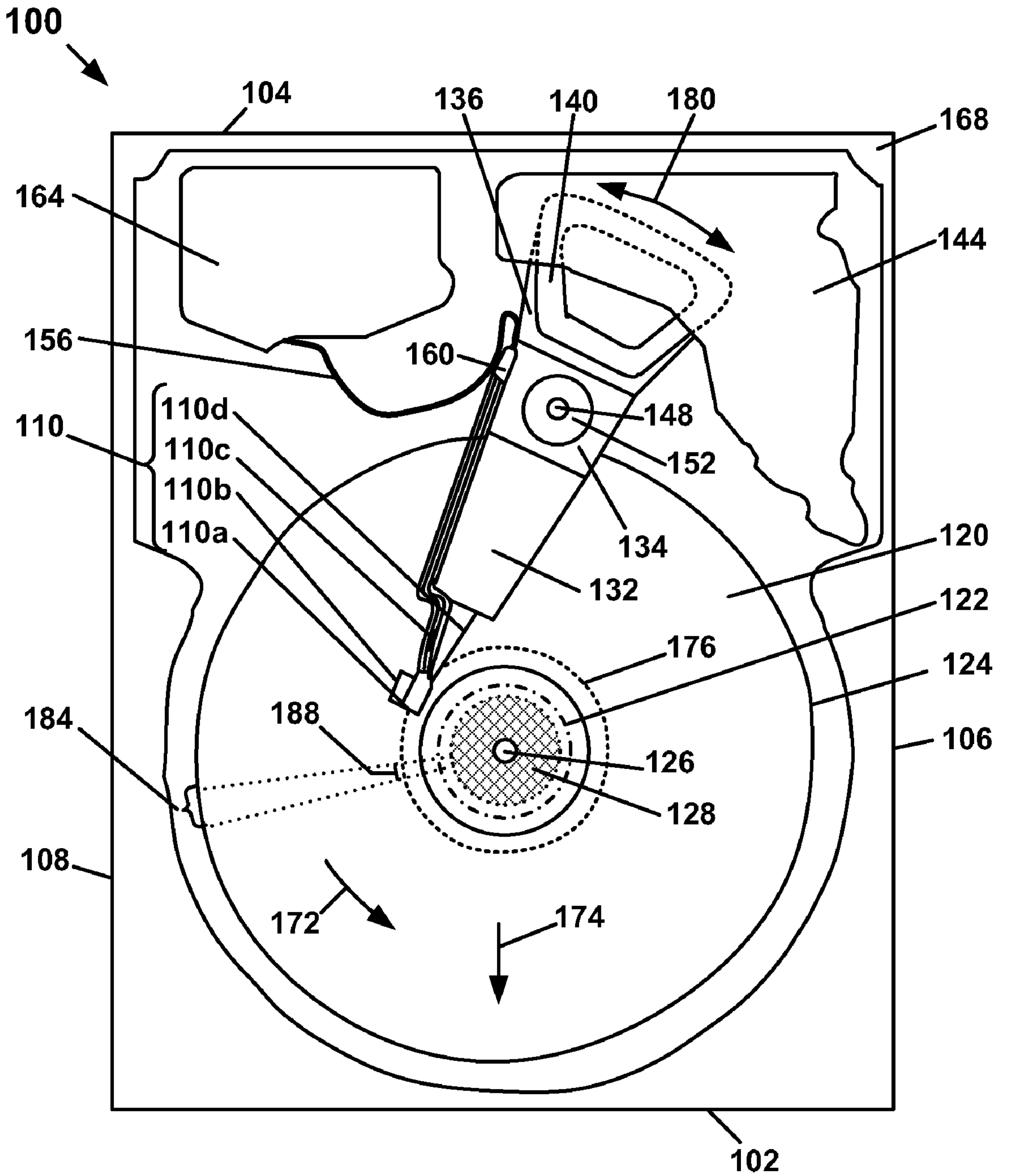
Primary Examiner — Dismery E Mercedes

(57) **ABSTRACT**

A combined bulk thermal-assister and bulk eraser. The bulk thermal-assister is configured to produce a temperature in a magnetic-recording disk in a hard-disk drive when the hard-disk drive is disposed in the bulk eraser. The temperature is about equal to a second temperature greater than a first temperature of the magnetic-recording disk. The bulk eraser is configured to erase recorded information from the magnetic-recording disk at the second temperature. The second temperature lowers a coercivity of the magnetic-recording disk so that, when recorded information is erased from the magnetic-recording disk at the second temperature, recorded information on the magnetic-recording disk is erased from a second magnetic-recording track in closer proximity to an inside diameter of the magnetic-recording disk than a first magnetic-recording track from which recorded information on the magnetic-recording disk may be erased, if recorded information were erased from the magnetic-recording disk at the first temperature.

20 Claims, 38 Drawing Sheets





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104
136
140
180
168
164
144
156
160
148
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110d
110c
110b
110a
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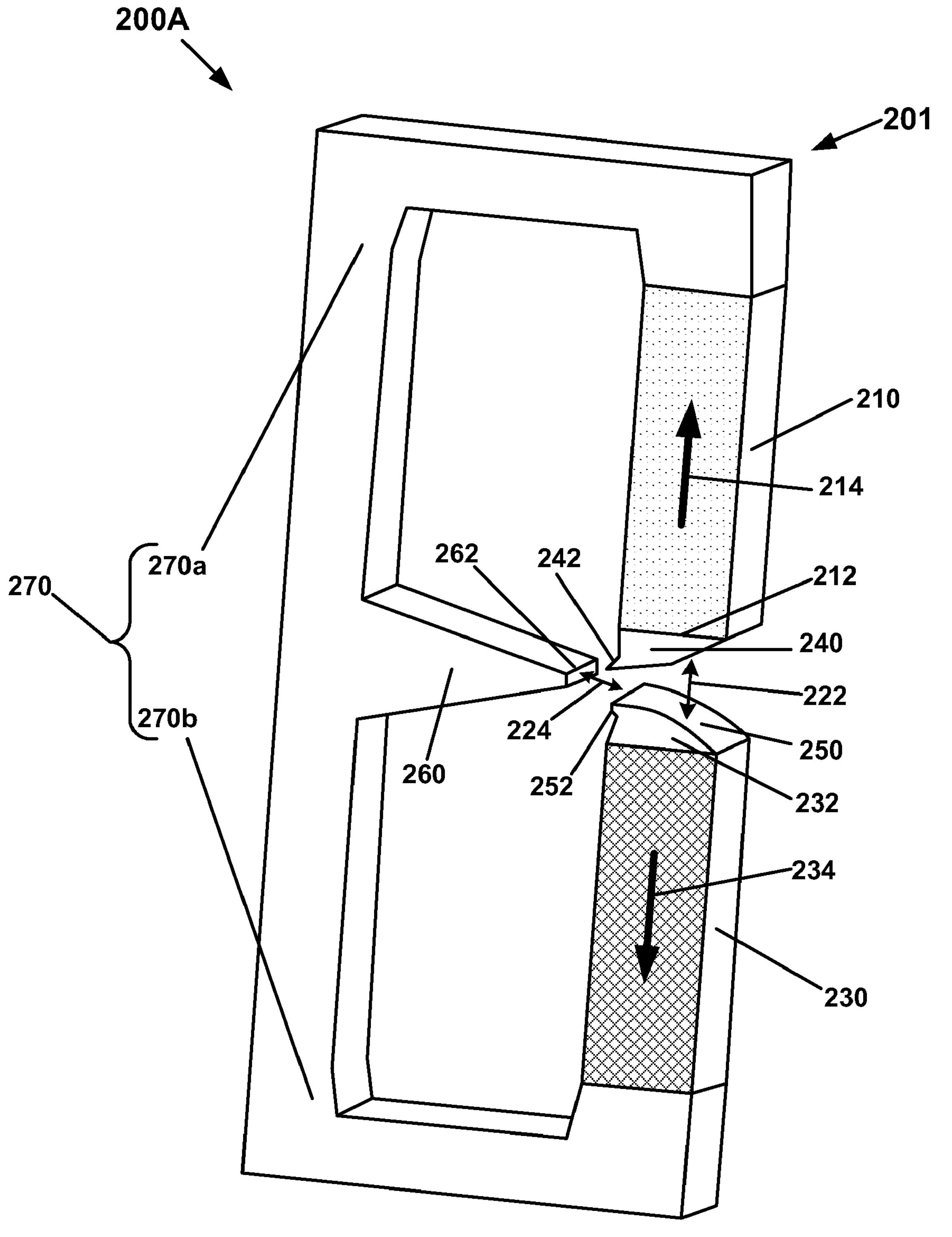
120
132
122
176
124
184
188
126
106
128
108
172
174
102

FIG. 1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270a
270b

FIG. 2A

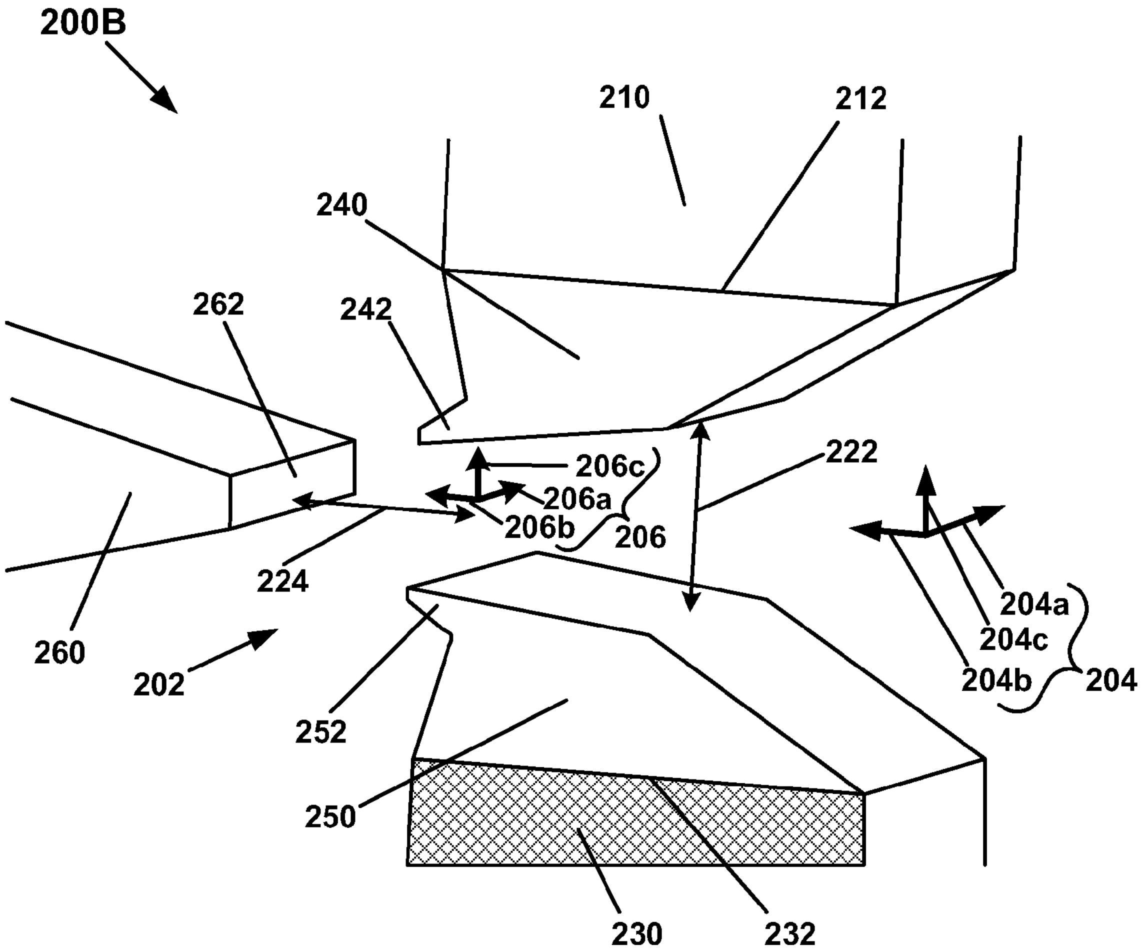
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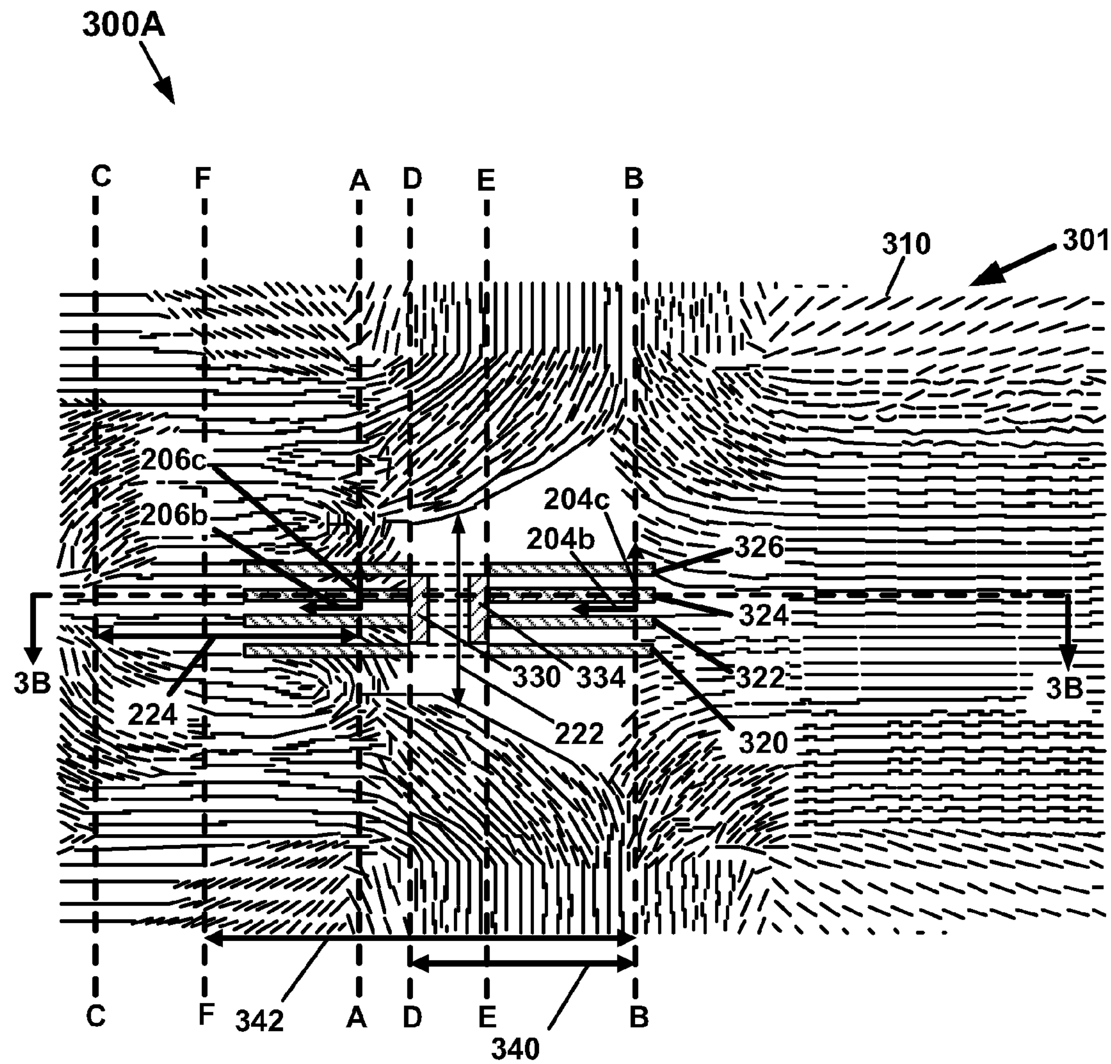
FIG. 2B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F
A
D
E
B
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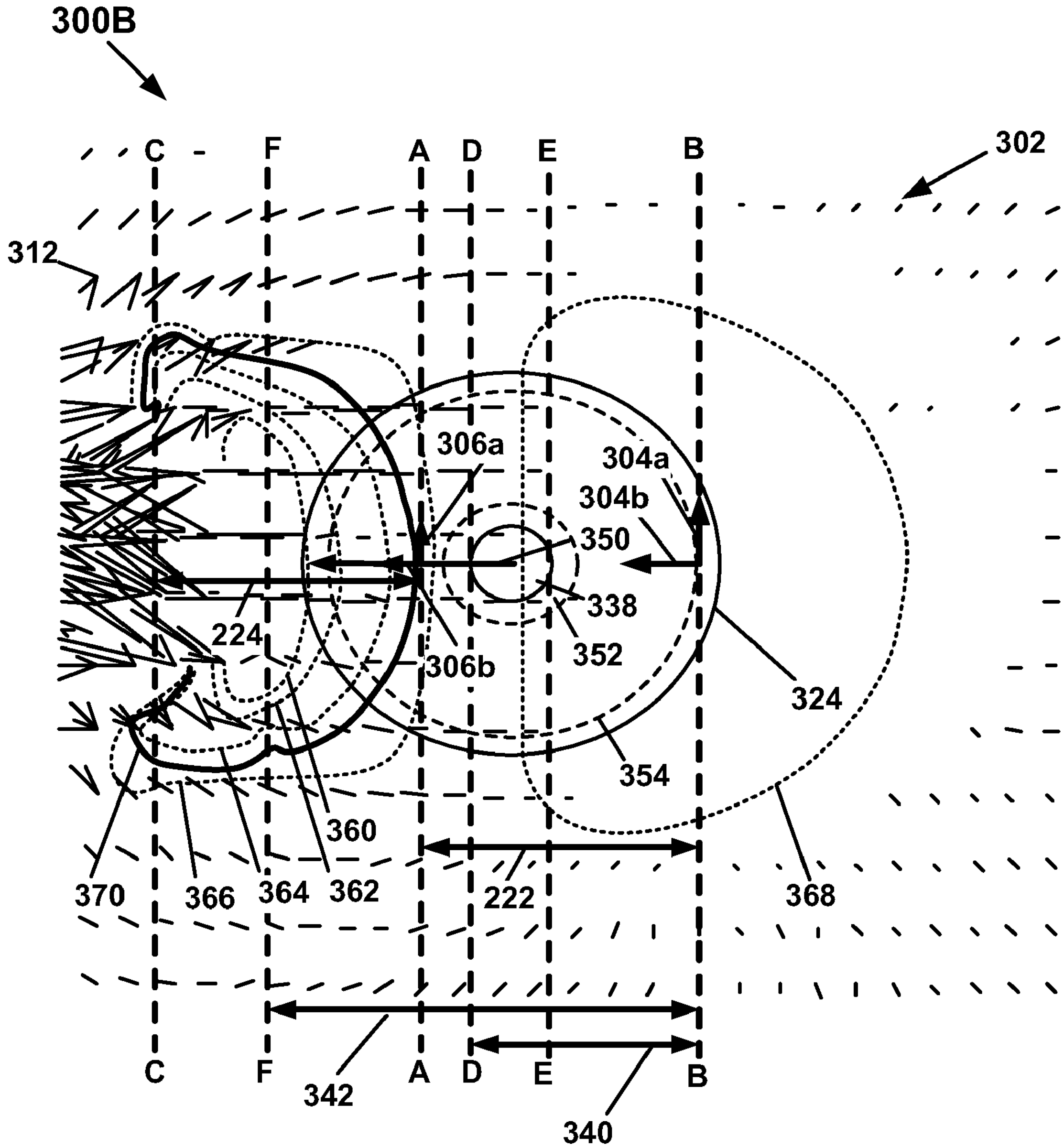
301
206c
206b
204c
204b
326
324
322
320
3B
3B
224
330
334
222
342
340
C
F
A
D
E
B

FIG. 3A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302
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C
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D
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B
306a
304a
304b
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306b
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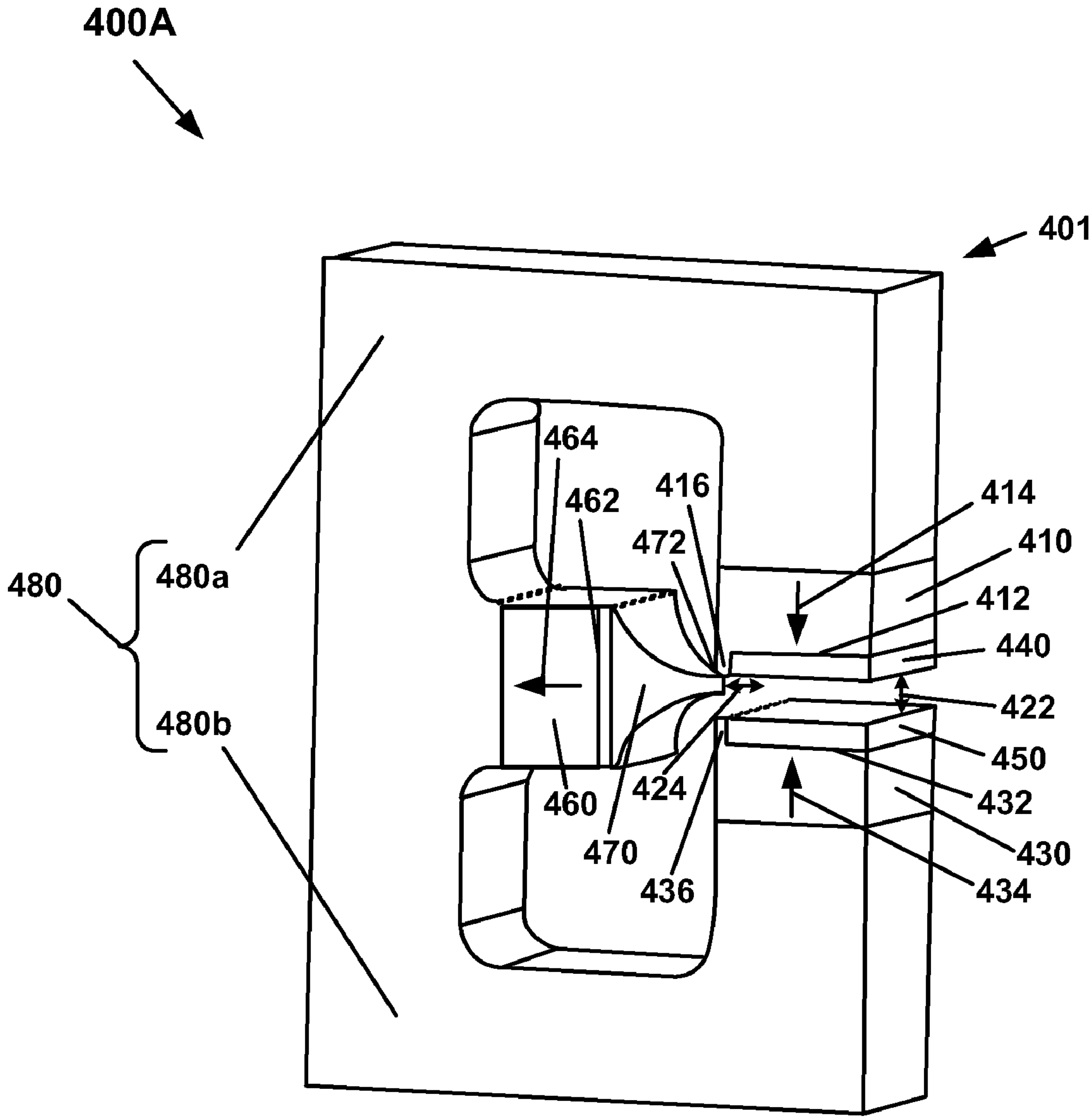
354
360
370
366
364
362
222
368
342
340

FIG. 3B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480a
480b
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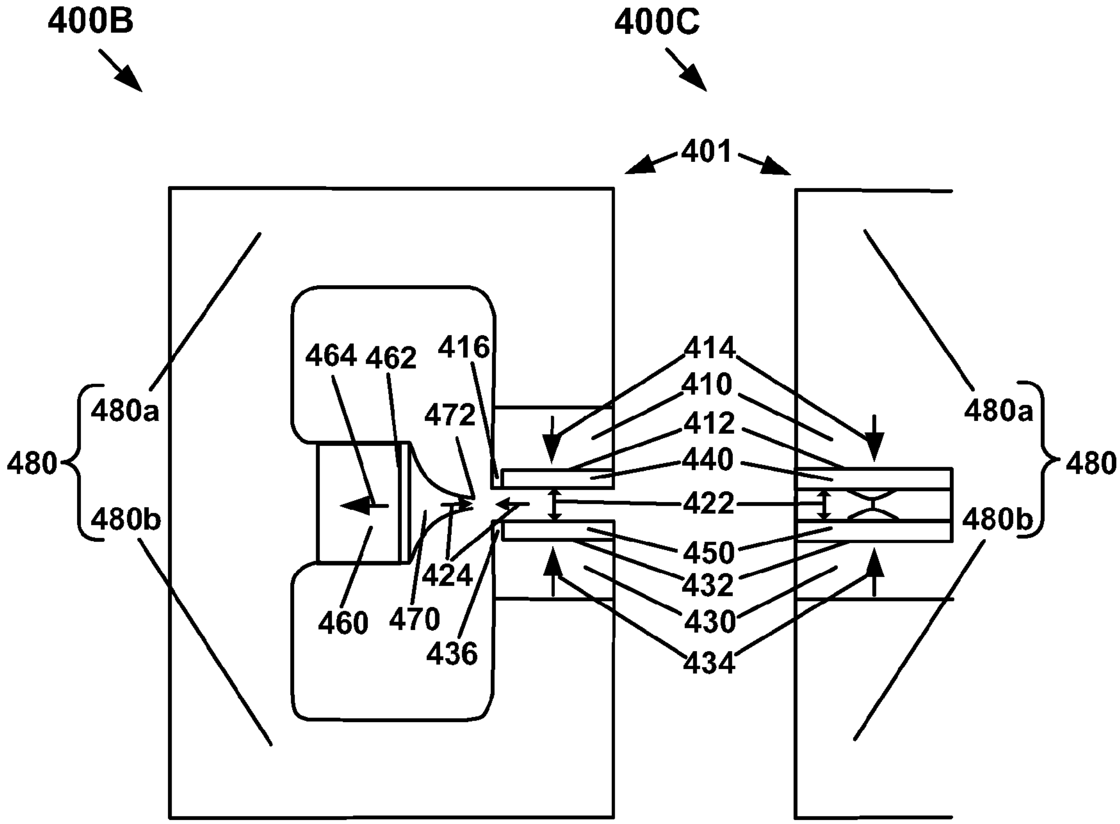
430
436
434

FIG. 4A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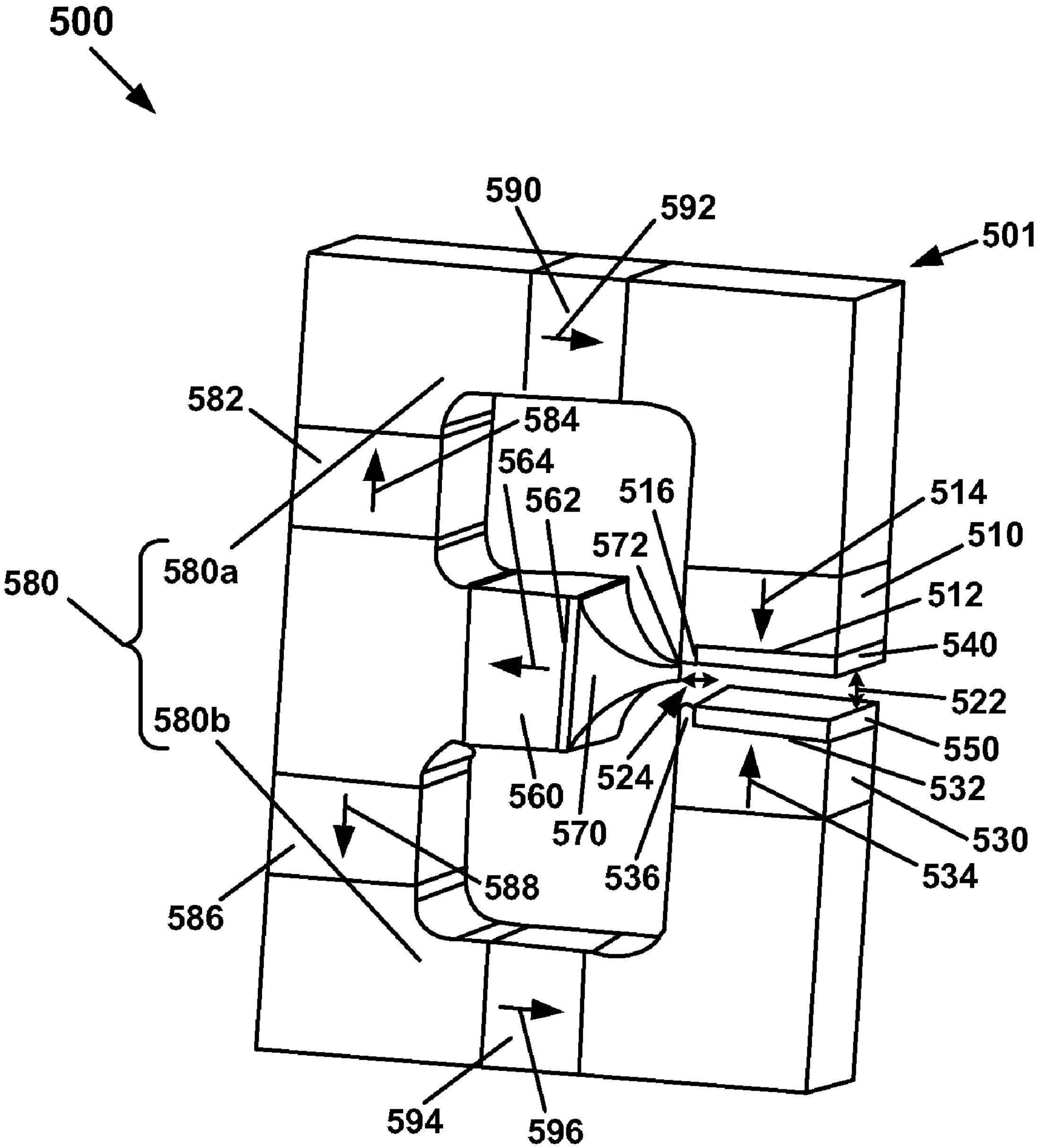
480
480a
480b
480a
480b
480

FIG. 4B, 4C



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584
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514
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572
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580b
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594
596

FIG. 5

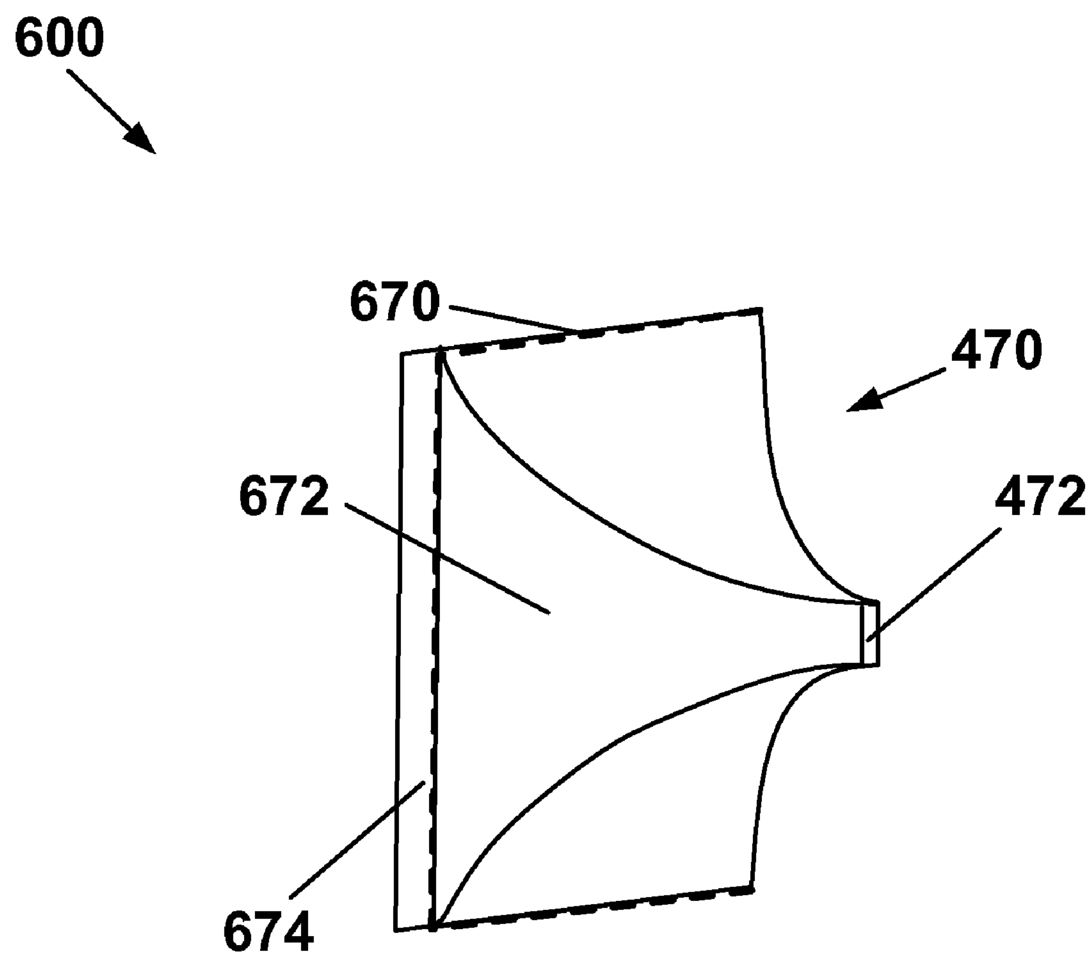


FIG. 6

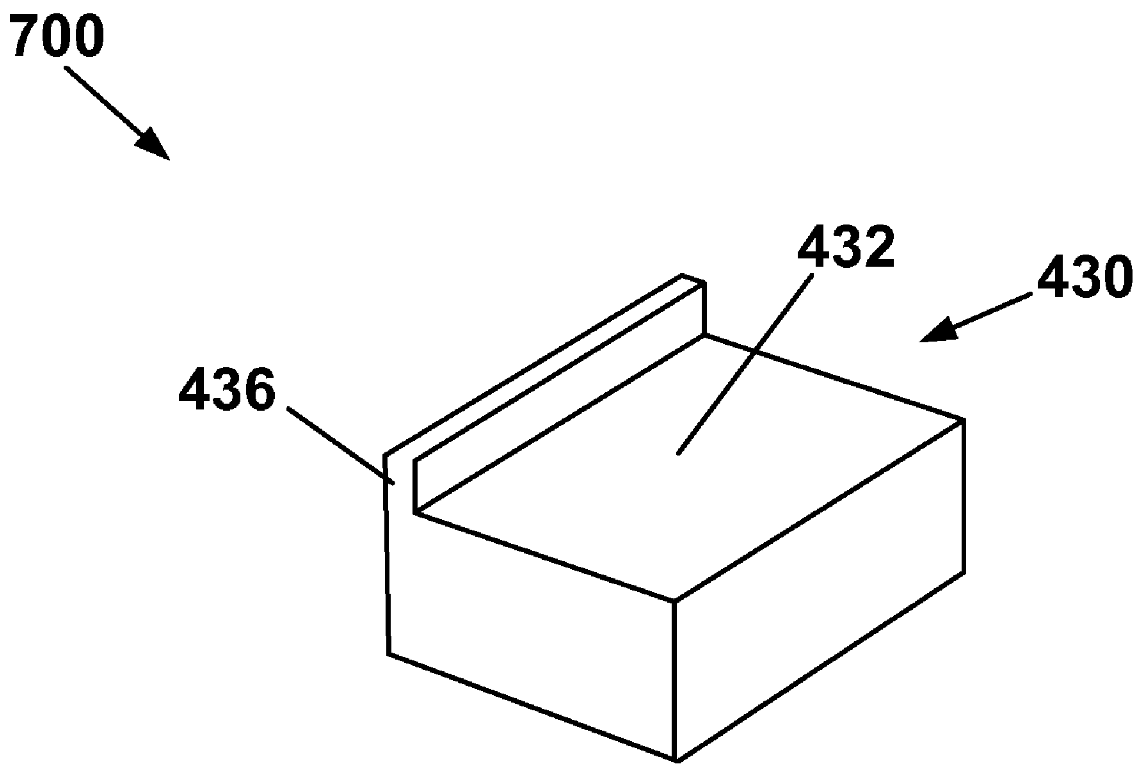
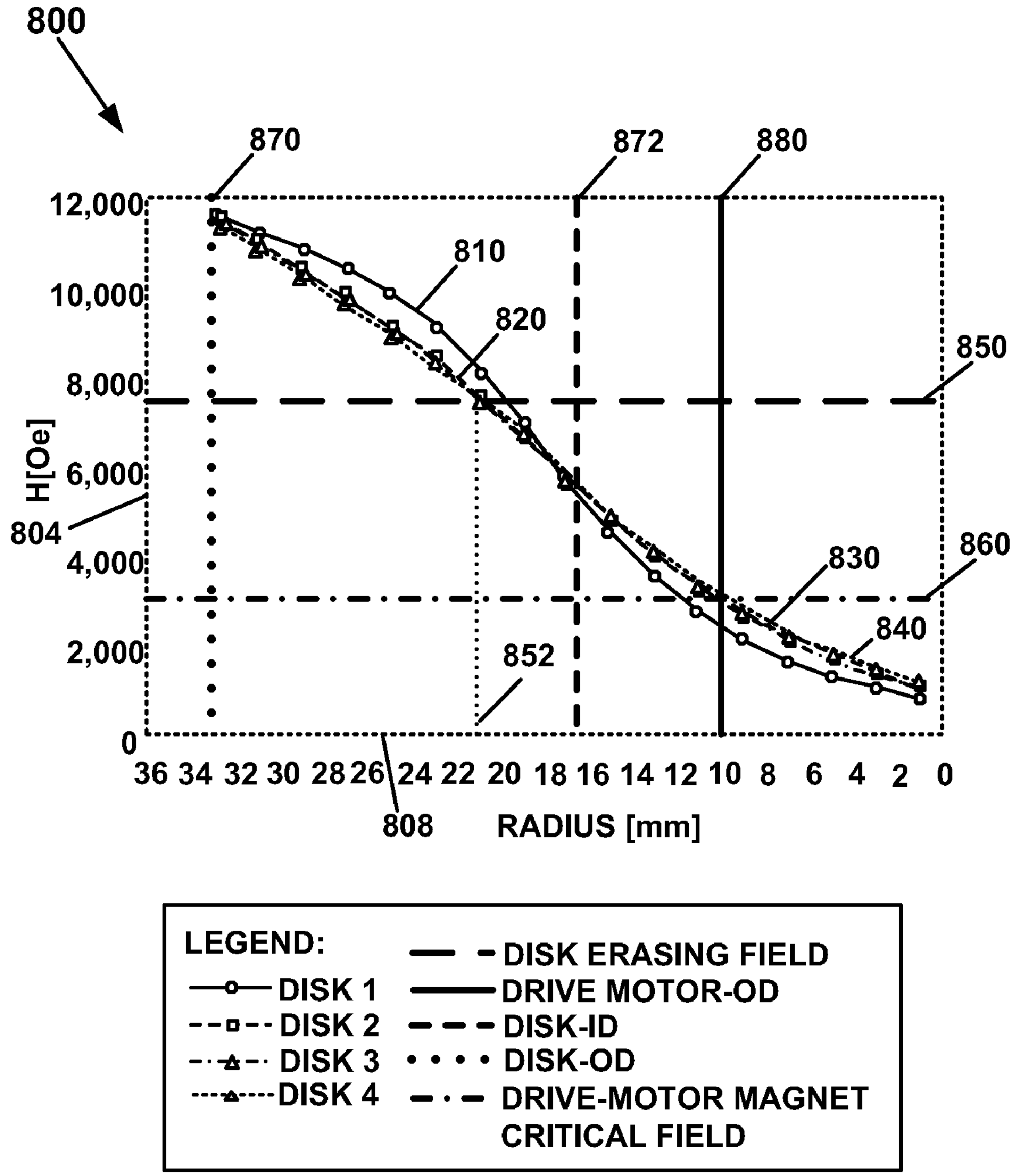


FIG. 7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870
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880
810
820
850
860
830
840
852
804
808
12,000
10,000
8,000
6,000
4,000
2,000
0
H[Oe]
36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0
RADIUS [mm]
LEGEND:
DISK 1
DISK 2
DISK 3
DISK 4
DISK ERASING FIELD
DRIVE MOTOR-OD
DISK-ID
DISK-OD
DRIVE-MOTOR MAGNET CRITICAL FIELD

FIG. 8

900

PROVIDE A BULK ERASER THAT PRODUCES MAGNETIC-FLUX DENSITY IN A SECOND PORTION OF A GAP SUFFICIENT TO ERASE RECORDED INFORMATION FROM A PORTION OF THE MAGNETIC-RECORDING DISK, A HARD-DISK DRIVE HAVING AN ENCLOSURE, A DISK-STACK HAVING AT LEAST ONE MAGNETIC-RECORDING DISK ROTATABLY MOUNTED ON A SPINDLE, AND A DRIVE MOTOR HAVING A ROTOR ATTACHED TO THE SPINDLE FOR ROTATING THE MAGNETIC-RECORDING DISK INSIDE THE ENCLOSURE
910

CONFIGURE A PLURALITY OF MAGNETS AND A STRUCTURE OF THE BULK ERASER SUCH THAT MAGNETIC-FLUX DENSITY IS ORIENTED SUBSTANTIALLY PARALLEL TO A CENTRAL PLANE IN THE SECOND PORTION OF THE GAP AND IN A SUBSTANTIALLY RADIAL DIRECTION OF THE PORTION OF THE MAGNETIC-RECORDING DISK WHEN THE HARD-DISK DRIVE IS INSERTED INTO THE SECOND PORTION OF THE GAP
920

ROTATE THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE
930

A

FIG. 9A

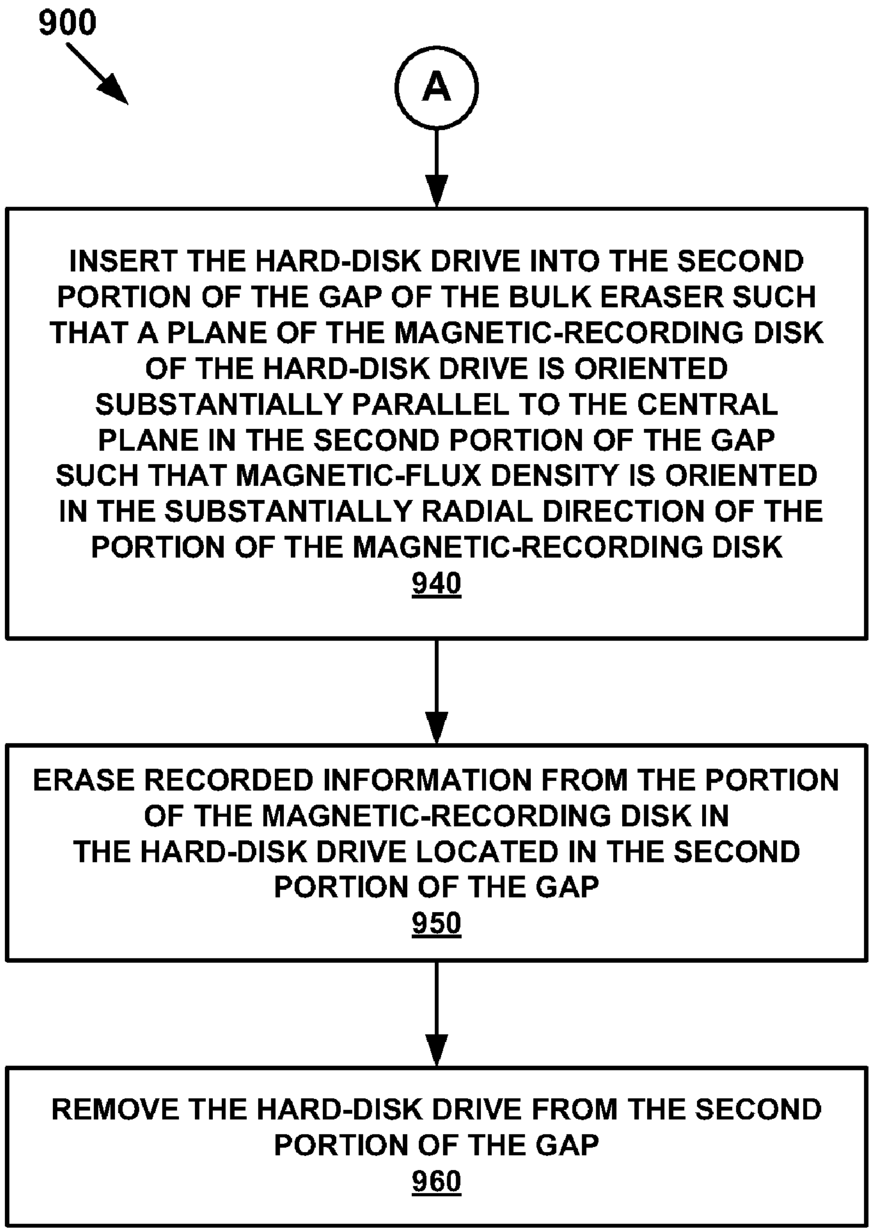

900
A
INSERT THE HARD-DISK DRIVE INTO THE SECOND PORTION OF THE GAP OF THE BULK ERASER SUCH THAT A PLANE OF THE MAGNETIC-RECORDING DISK OF THE HARD-DISK DRIVE IS ORIENTED SUBSTANTIALLY PARALLEL TO THE CENTRAL PLANE IN THE SECOND PORTION OF THE GAP SUCH THAT MAGNETIC-FLUX DENSITY IS ORIENTED IN THE SUBSTANTIALLY RADIAL DIRECTION OF THE PORTION OF THE MAGNETIC-RECORDING DISK
940
ERASE RECORDED INFORMATION FROM THE PORTION OF THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE LOCATED IN THE SECOND PORTION OF THE GAP
950
REMOVE THE HARD-DISK DRIVE FROM THE SECOND PORTION OF THE GAP
960

FIG. 9B

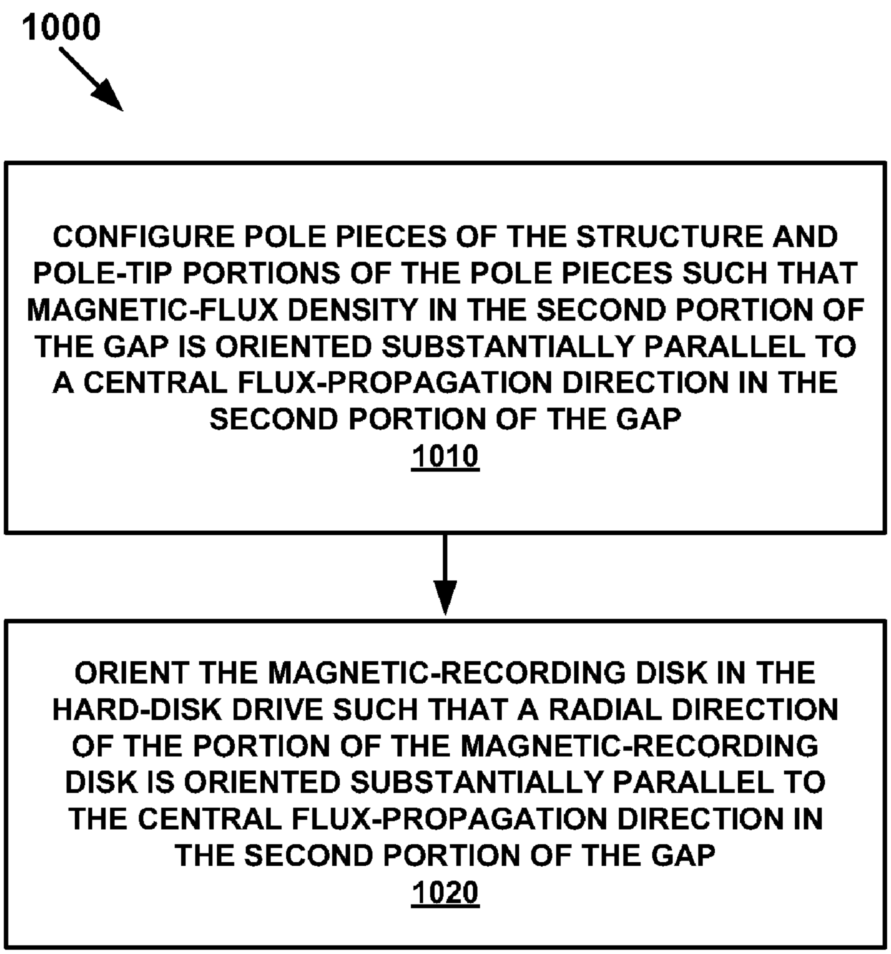

1000
CONFIGURE POLE PIECES OF THE STRUCTURE AND POLE-TIP PORTIONS OF THE POLE PIECES SUCH THAT MAGNETIC-FLUX DENSITY IN THE SECOND PORTION OF THE GAP IS ORIENTED SUBSTANTIALLY PARALLEL TO A CENTRAL FLUX-PROPAGATION DIRECTION IN THE SECOND PORTION OF THE GAP
1010
ORIENT THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE SUCH THAT A RADIAL DIRECTION OF THE PORTION OF THE MAGNETIC-RECORDING DISK IS ORIENTED SUBSTANTIALLY PARALLEL TO THE CENTRAL FLUX-PROPAGATION DIRECTION IN THE SECOND PORTION OF THE GAP
1020

FIG. 10

1100

INSERT THE HARD-DISK DRIVE INTO THE SECOND PORTION OF THE GAP WITH AN INSERTION SPEED THAT IS SUFFICIENT TO ASSURE COMPLETE ERASURE OF RECORDED INFORMATION FROM THE PORTION OF THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE
1110

WHEREIN AN INSERTION SPEED INTO THE GAP IS LESS THAN OR EQUAL TO 1 CENTIMETER PER SECOND
1120

FIG. 11

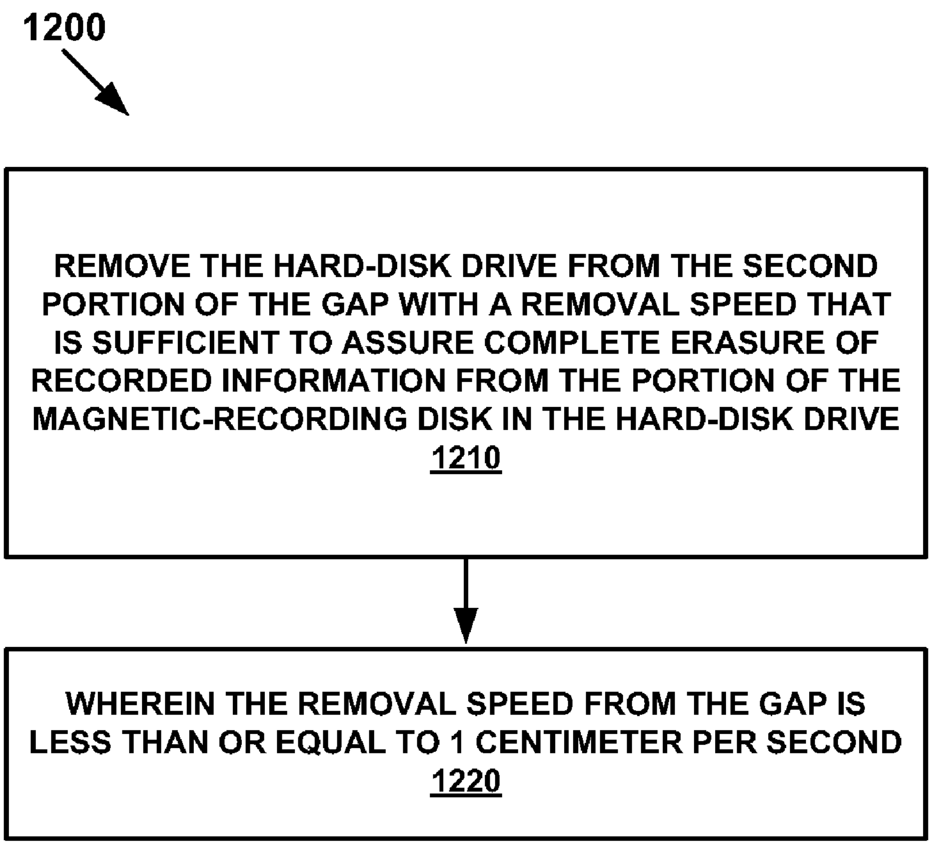

1200
REMOVE THE HARD-DISK DRIVE FROM THE SECOND PORTION OF THE GAP WITH A REMOVAL SPEED THAT IS SUFFICIENT TO ASSURE COMPLETE ERASURE OF RECORDED INFORMATION FROM THE PORTION OF THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE
1210
WHEREIN THE REMOVAL SPEED FROM THE GAP IS LESS THAN OR EQUAL TO 1 CENTIMETER PER SECOND
1220

FIG. 12

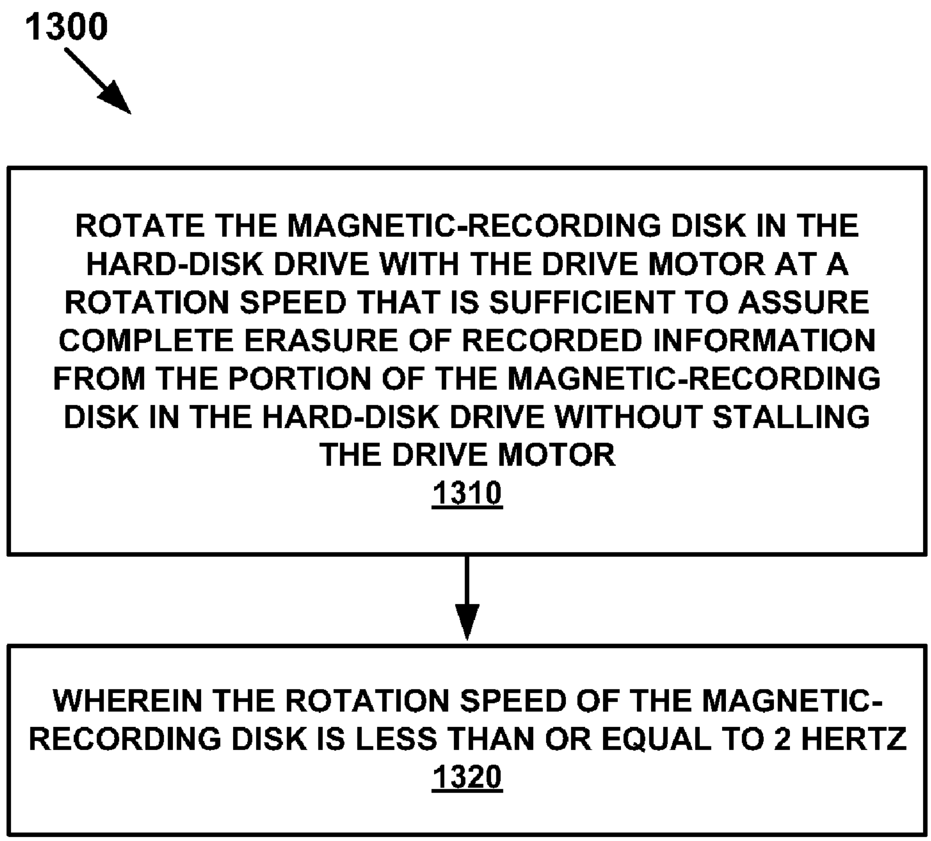

1300
ROTATE THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE WITH THE DRIVE MOTOR AT A ROTATION SPEED THAT IS SUFFICIENT TO ASSURE COMPLETE ERASURE OF RECORDED INFORMATION FROM THE PORTION OF THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE WITHOUT STALLING THE DRIVE MOTOR
1310
WHEREIN THE ROTATION SPEED OF THE MAGNETIC-RECORDING DISK IS LESS THAN OR EQUAL TO 2 HERTZ
1320

FIG. 13

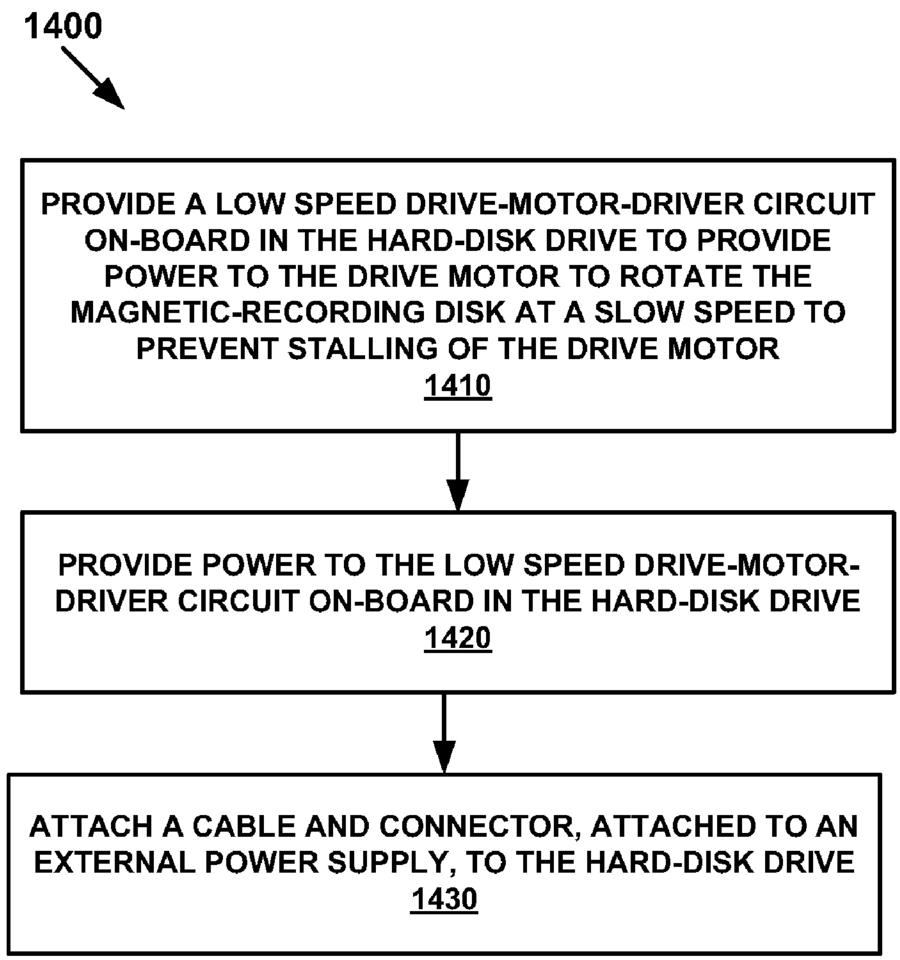

1400
PROVIDE A LOW SPEED DRIVE-MOTOR-DRIVER CIRCUIT ON-BOARD IN THE HARD-DISK DRIVE TO PROVIDE POWER TO THE DRIVE MOTOR TO ROTATE THE MAGNETIC-RECORDING DISK AT A SLOW SPEED TO PREVENT STALLING OF THE DRIVE MOTOR
1410
PROVIDE POWER TO THE LOW SPEED DRIVE-MOTOR-DRIVER CIRCUIT ON-BOARD IN THE HARD-DISK DRIVE
1420
ATTACH A CABLE AND CONNECTOR, ATTACHED TO AN EXTERNAL POWER SUPPLY, TO THE HARD-DISK DRIVE
1430

FIG. 14

1500

PROVIDE THE SECOND PORTION OF THE GAP WITH SUFFICIENT CLEARANCE TO ACCOMMODATE THE HARD-DISK DRIVE UPON INSERTING AND REMOVING THE HARD-DISK DRIVE FROM THE SECOND PORTION OF THE GAP
1510

WHEREIN THE CLEARANCE OF THE SECOND PORTION OF THE GAP MAY BE LESS THAN OR EQUAL TO ABOUT 2.6 CENTIMETERS
1520

FIG. 15

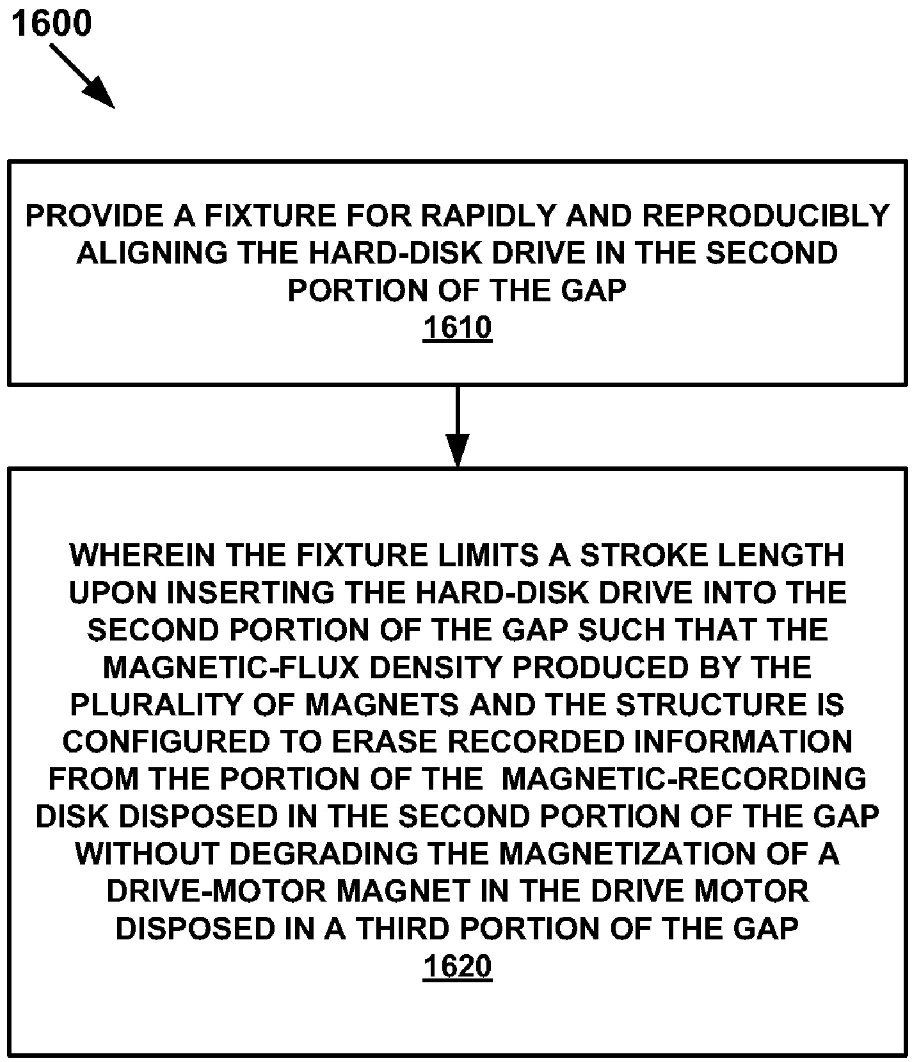

1600
PROVIDE A FIXTURE FOR RAPIDLY AND REPRODUCIBLY ALIGNING THE HARD-DISK DRIVE IN THE SECOND PORTION OF THE GAP
1610
WHEREIN THE FIXTURE LIMITS A STROKE LENGTH UPON INSERTING THE HARD-DISK DRIVE INTO THE SECOND PORTION OF THE GAP SUCH THAT THE MAGNETIC-FLUX DENSITY PRODUCED BY THE PLURALITY OF MAGNETS AND THE STRUCTURE IS CONFIGURED TO ERASE RECORDED INFORMATION FROM THE PORTION OF THE MAGNETIC-RECORDING DISK DISPOSED IN THE SECOND PORTION OF THE GAP WITHOUT DEGRADING THE MAGNETIZATION OF A DRIVE-MOTOR MAGNET IN THE DRIVE MOTOR DISPOSED IN A THIRD PORTION OF THE GAP
1620

FIG. 16

1700

DISPOSE TWO MAGNETS OF THE PLURALITY OF MAGNETS WITH OPPOSING POLARITY ACROSS A FIRST PORTION OF THE GAP
1710

ADJUST A SEPARARION BETWEEN THE TWO MAGNETS OF THE PLURALITY OF MAGNETS IN THE FIRST PORTION OF THE GAP SUCH THAT THE FIRST PORTION OF THE GAP HAS SUFFICIENT CLEARANCE TO ACCOMMODATE THE HARD-DISK DRIVE UPON INSERTING AND REMOVING THE HARD-DISK DRIVE FROM THE SECOND PORTION OF THE GAP AND THE MAGNETIC-FLUX DENSITY PRODUCED BY THE PLURALITY OF MAGNETS AND THE STRUCTURE IS SUFFICIENT TO ERASE RECORDED INFORMATION FROM A PLURALITY OF MAGNETIC-RECORDING DISKS OF THE DISK-STACK WHEN THE HARD-DISK DRIVE IS INSERTED INTO THE SECOND PORTION OF THE GAP
1720

FIG. 17

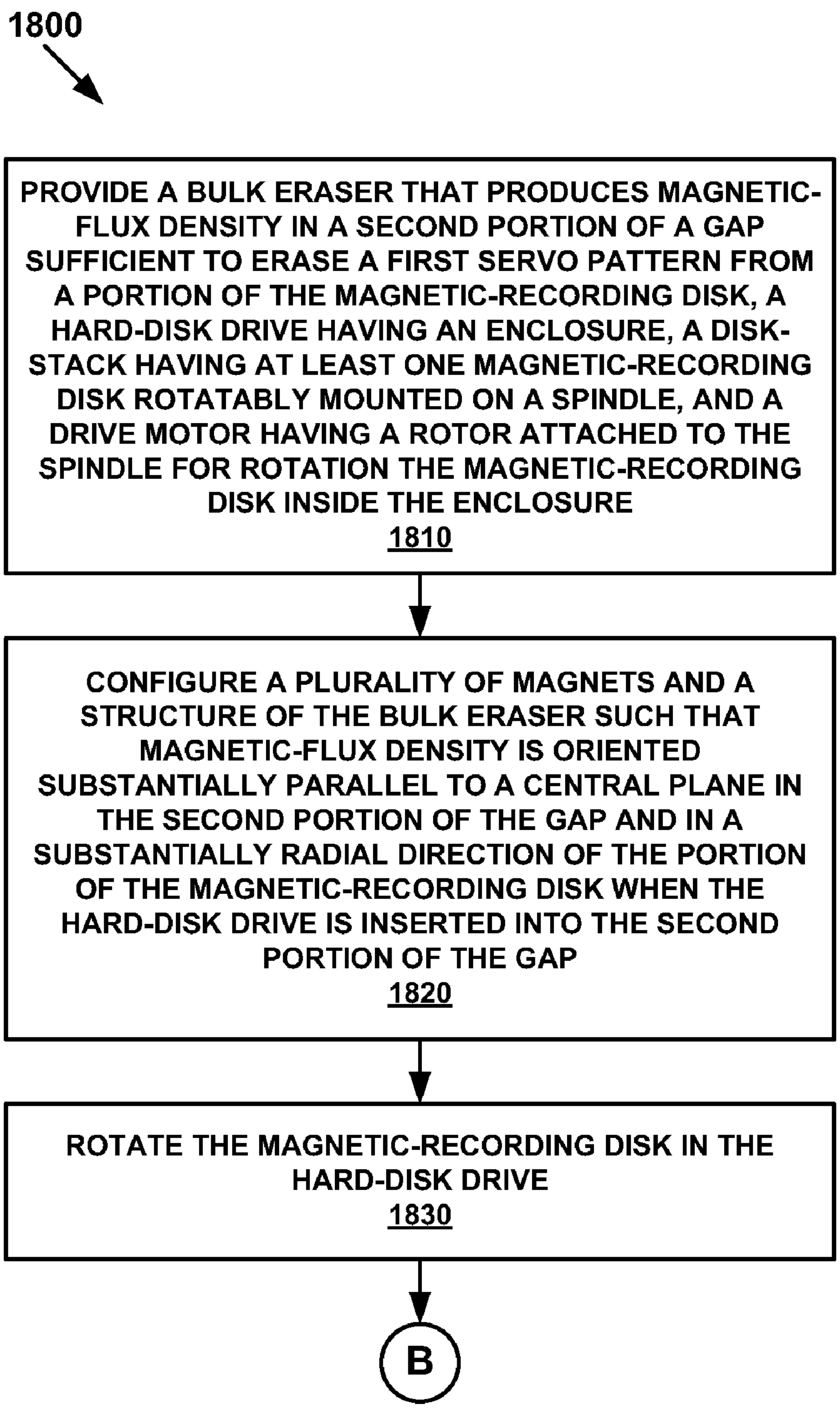

1800
PROVIDE A BULK ERASER THAT PRODUCES MAGNETIC-FLUX DENSITY IN A SECOND PORTION OF A GAP SUFFICIENT TO ERASE A FIRST SERVO PATTERN FROM A PORTION OF THE MAGNETIC-RECORDING DISK, A HARD-DISK DRIVE HAVING AN ENCLOSURE, A DISK-STACK HAVING AT LEAST ONE MAGNETIC-RECORDING DISK ROTATABLY MOUNTED ON A SPINDLE, AND A DRIVE MOTOR HAVING A ROTOR ATTACHED TO THE SPINDLE FOR ROTATION THE MAGNETIC-RECORDING DISK INSIDE THE ENCLOSURE
1810
CONFIGURE A PLURALITY OF MAGNETS AND A STRUCTURE OF THE BULK ERASER SUCH THAT MAGNETIC-FLUX DENSITY IS ORIENTED SUBSTANTIALLY PARALLEL TO A CENTRAL PLANE IN THE SECOND PORTION OF THE GAP AND IN A SUBSTANTIALLY RADIAL DIRECTION OF THE PORTION OF THE MAGNETIC-RECORDING DISK WHEN THE HARD-DISK DRIVE IS INSERTED INTO THE SECOND PORTION OF THE GAP
1820
ROTATE THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE
1830
B

FIG. 18A

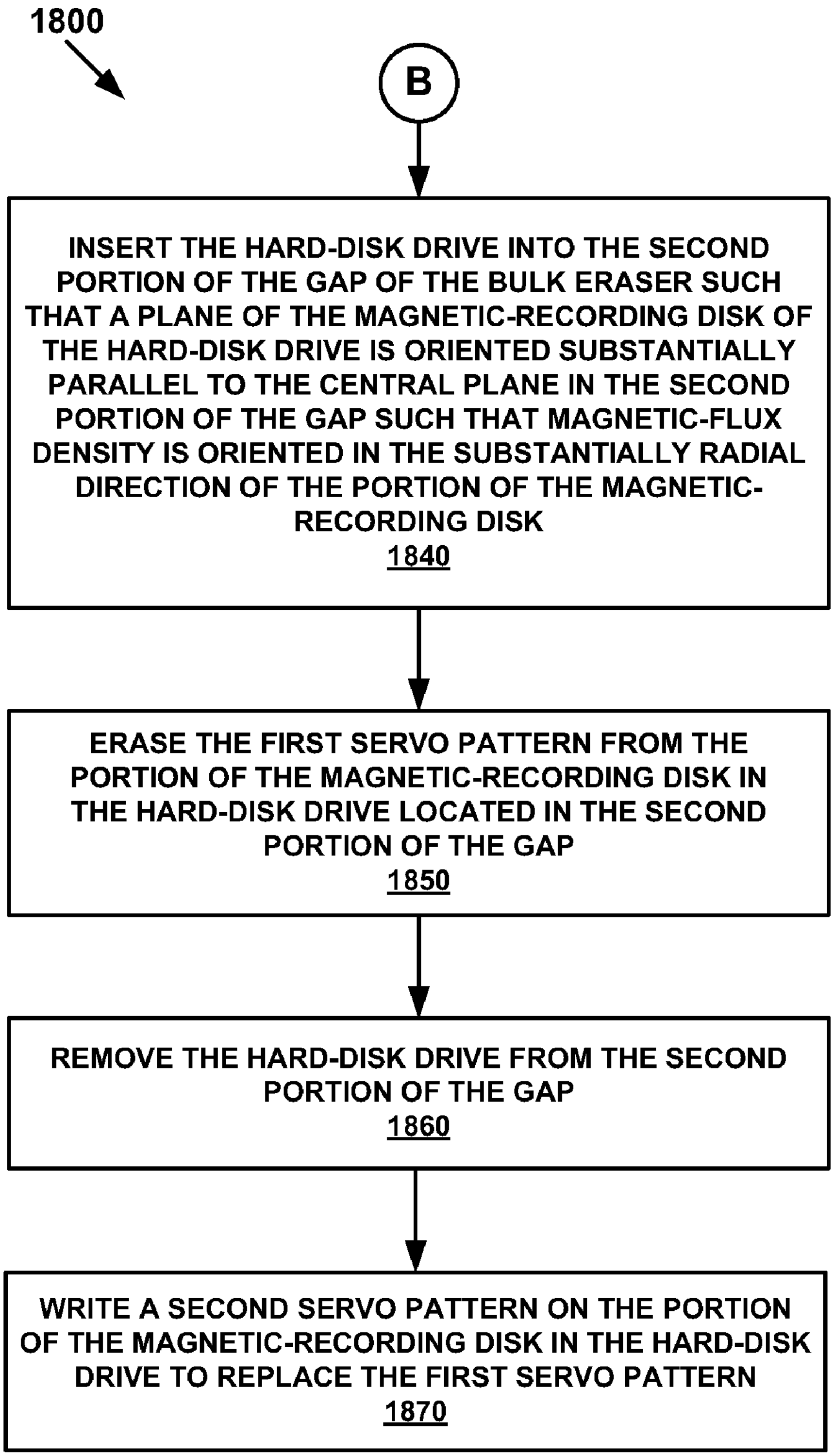

1800
B
INSERT THE HARD-DISK DRIVE INTO THE SECOND PORTION OF THE GAP OF THE BULK ERASER SUCH THAT A PLANE OF THE MAGNETIC-RECORDING DISK OF THE HARD-DISK DRIVE IS ORIENTED SUBSTANTIALLY PARALLEL TO THE CENTRAL PLANE IN THE SECOND PORTION OF THE GAP SUCH THAT MAGNETIC-FLUX DENSITY IS ORIENTED IN THE SUBSTANTIALLY RADIAL DIRECTION OF THE PORTION OF THE MAGNETIC-RECORDING DISK
1840
ERASE THE FIRST SERVO PATTERN FROM THE PORTION OF THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE LOCATED IN THE SECOND PORTION OF THE GAP
1850
REMOVE THE HARD-DISK DRIVE FROM THE SECOND PORTION OF THE GAP
1860
WRITE A SECOND SERVO PATTERN ON THE PORTION OF THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE TO REPLACE THE FIRST SERVO PATTERN
1870

FIG. 18B

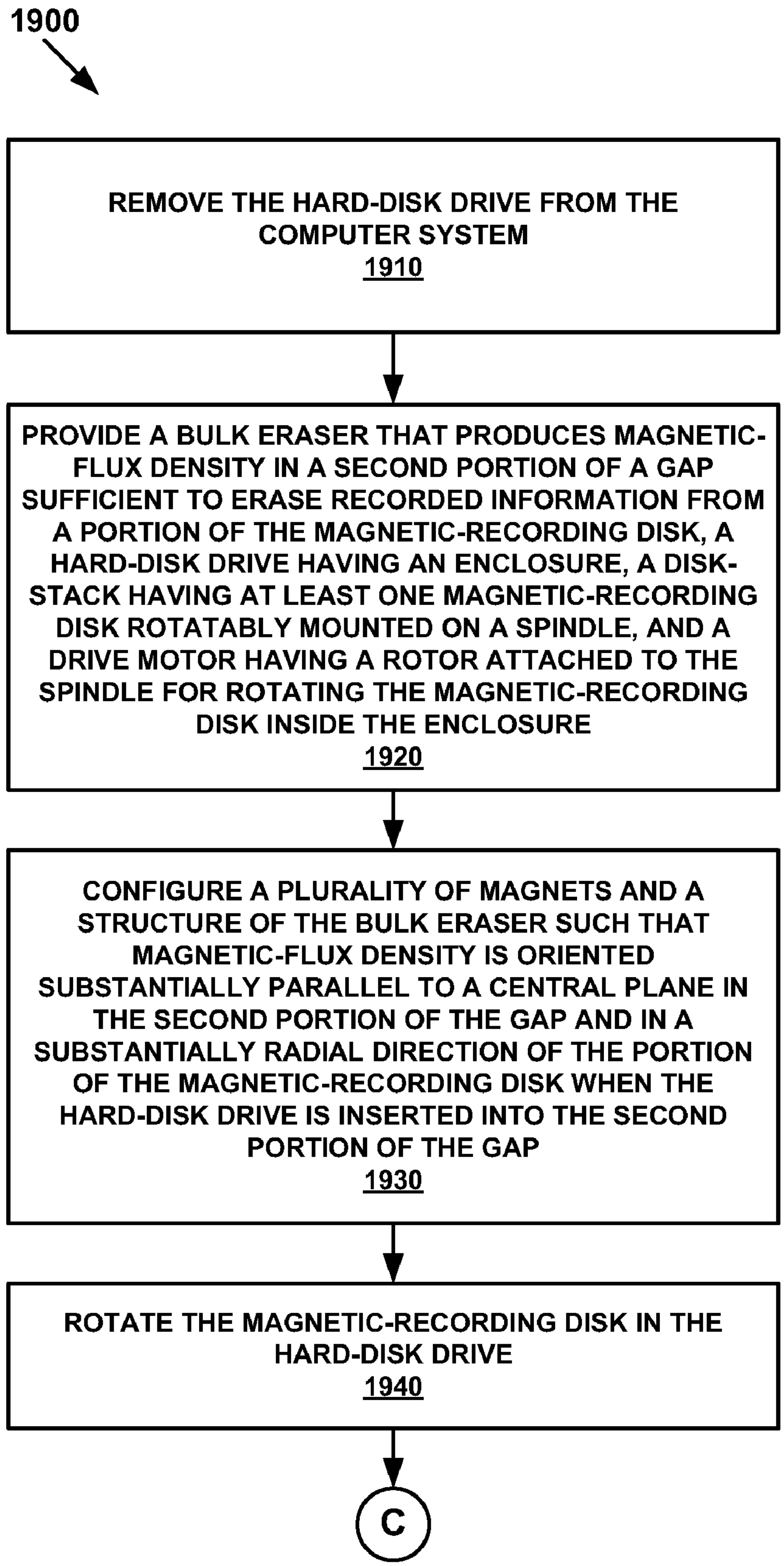

1900
REMOVE THE HARD-DISK DRIVE FROM THE COMPUTER SYSTEM
1910
PROVIDE A BULK ERASER THAT PRODUCES MAGNETIC-FLUX DENSITY IN A SECOND PORTION OF A GAP SUFFICIENT TO ERASE RECORDED INFORMATION FROM A PORTION OF THE MAGNETIC-RECORDING DISK, A HARD-DISK DRIVE HAVING AN ENCLOSURE, A DISK-STACK HAVING AT LEAST ONE MAGNETIC-RECORDING DISK ROTATABLY MOUNTED ON A SPINDLE, AND A DRIVE MOTOR HAVING A ROTOR ATTACHED TO THE SPINDLE FOR ROTATING THE MAGNETIC-RECORDING DISK INSIDE THE ENCLOSURE
1920
CONFIGURE A PLURALITY OF MAGNETS AND A STRUCTURE OF THE BULK ERASER SUCH THAT MAGNETIC-FLUX DENSITY IS ORIENTED SUBSTANTIALLY PARALLEL TO A CENTRAL PLANE IN THE SECOND PORTION OF THE GAP AND IN A SUBSTANTIALLY RADIAL DIRECTION OF THE PORTION OF THE MAGNETIC-RECORDING DISK WHEN THE HARD-DISK DRIVE IS INSERTED INTO THE SECOND PORTION OF THE GAP
1930
ROTATE THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE
1940
C

FIG. 19A

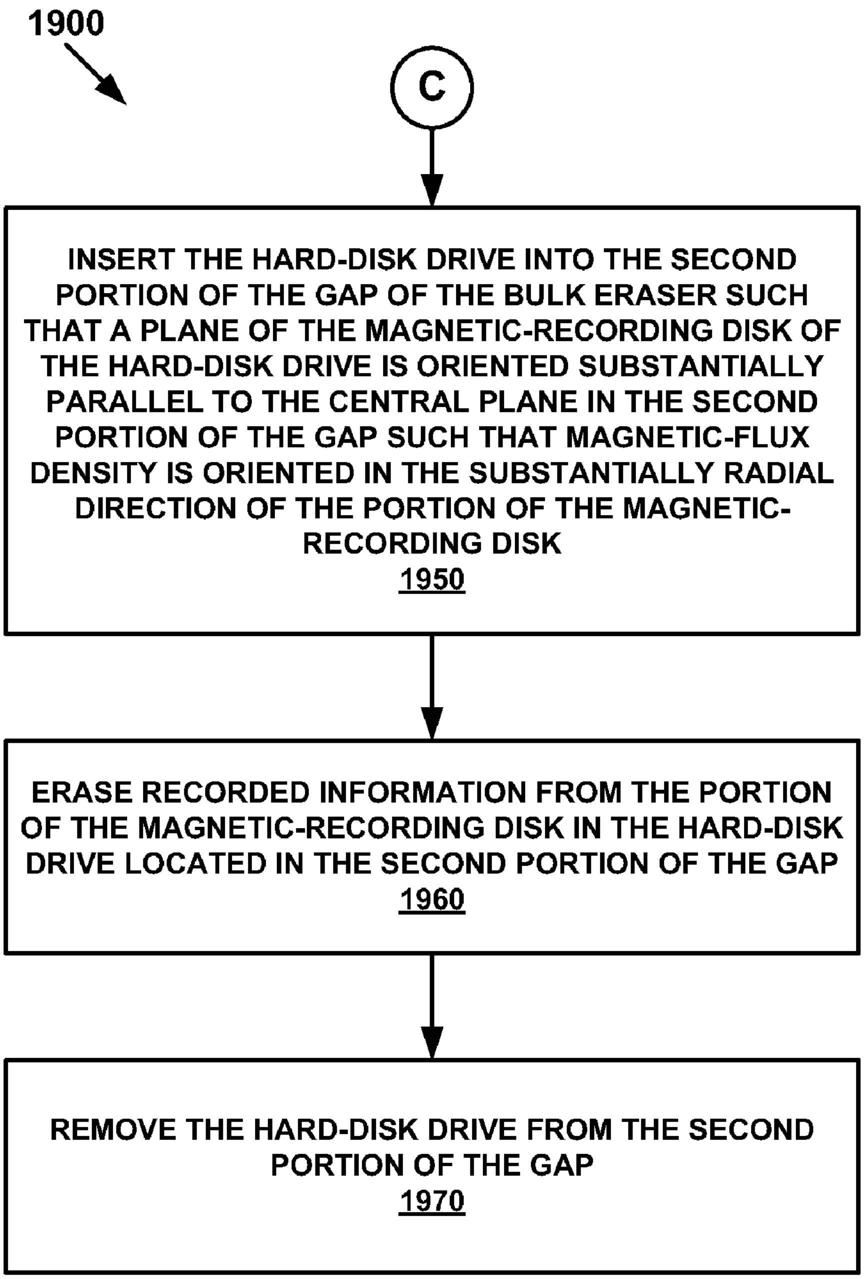
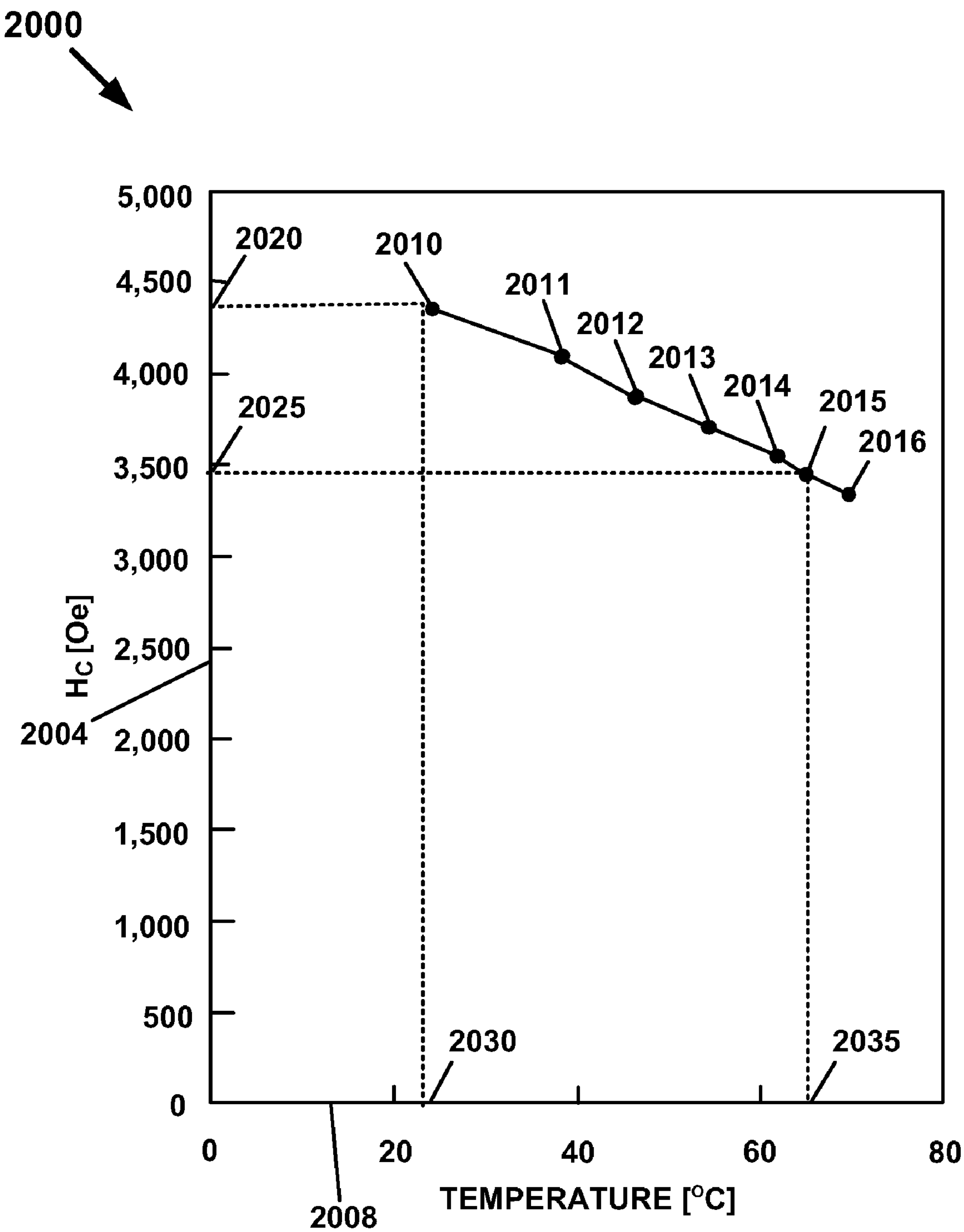

1900
C
INSERT THE HARD-DISK DRIVE INTO THE SECOND PORTION OF THE GAP OF THE BULK ERASER SUCH THAT A PLANE OF THE MAGNETIC-RECORDING DISK OF THE HARD-DISK DRIVE IS ORIENTED SUBSTANTIALLY PARALLEL TO THE CENTRAL PLANE IN THE SECOND PORTION OF THE GAP SUCH THAT MAGNETIC-FLUX DENSITY IS ORIENTED IN THE SUBSTANTIALLY RADIAL DIRECTION OF THE PORTION OF THE MAGNETIC-RECORDING DISK
1950
ERASE RECORDED INFORMATION FROM THE PORTION OF THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE LOCATED IN THE SECOND PORTION OF THE GAP
1960
REMOVE THE HARD-DISK DRIVE FROM THE SECOND PORTION OF THE GAP
1970

FIG. 19B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2012
2013
2014
2015
2016
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H_C [Oe]
2004
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2035
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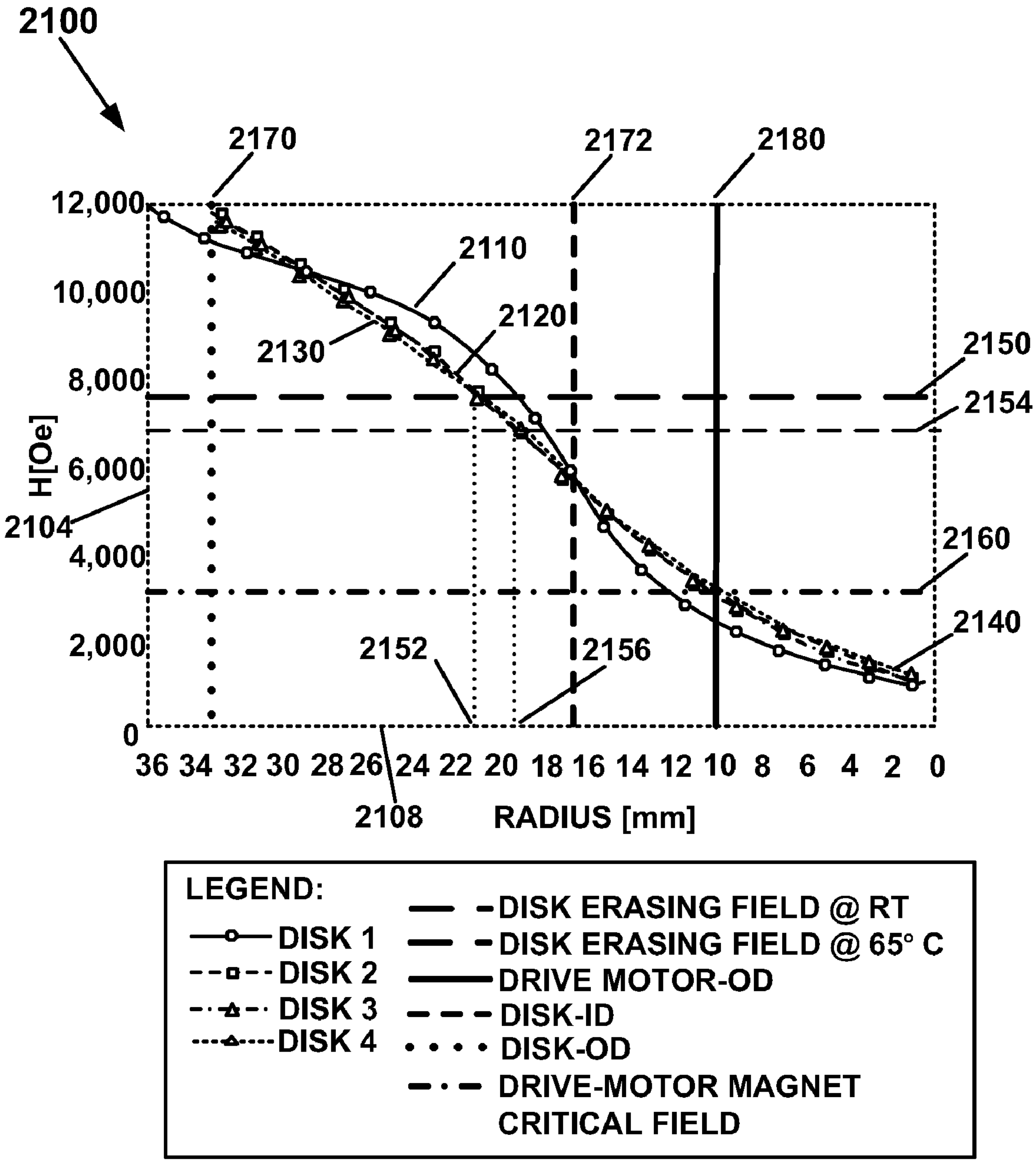
20
40
60
80
TEMPERATURE [°C]
2008

FIG. 20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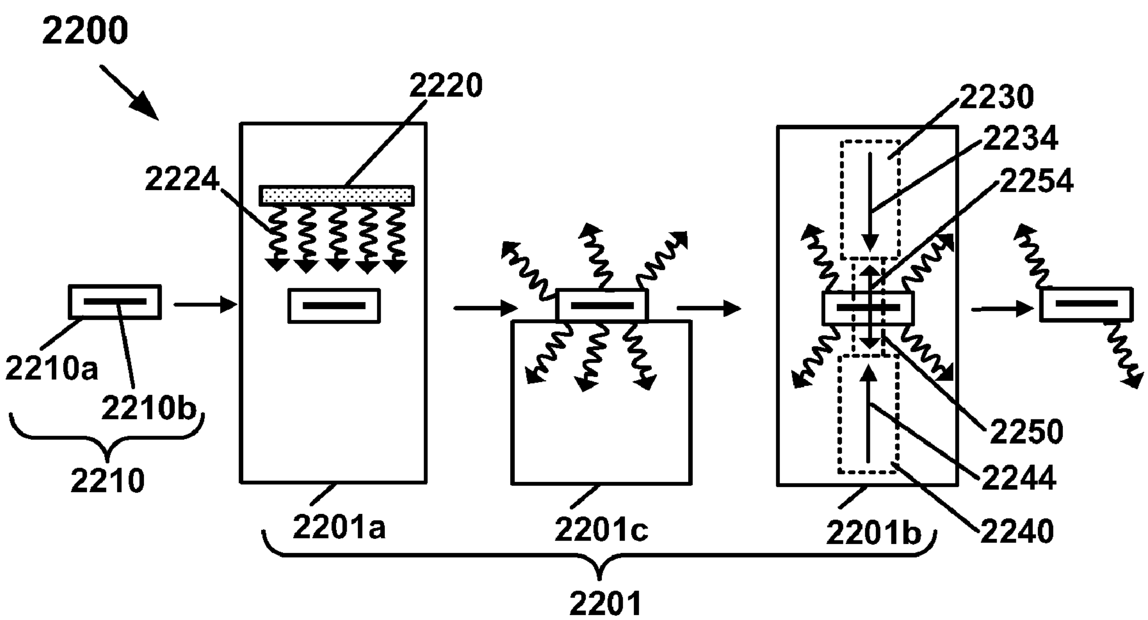
6,000
4,000
2,000
0
H[Oe]
2104
2110
2120
2130
2150
2154
2160
2140
2152
2156
36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0
2108
RADIUS [mm]
LEGEND:
DISK 1
DISK 2
DISK 3
DISK 4
DISK ERASING FIELD @ RT
DISK ERASING FIELD @ 65° C
DRIVE MOTOR-OD
DISK-ID
DISK-OD
DRIVE-MOTOR MAGNET CRITICAL FIELD

FIG. 21



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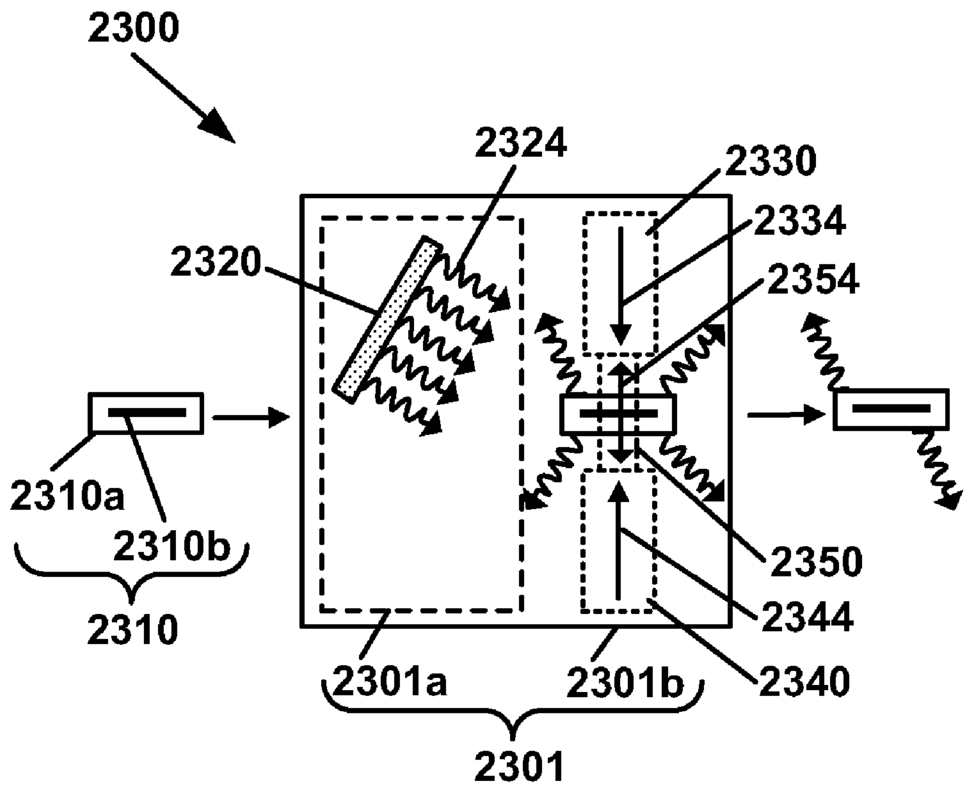
2201a
2201c
2201b
2201

FIG. 22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2310b
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2301b
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2301

FIG. 23

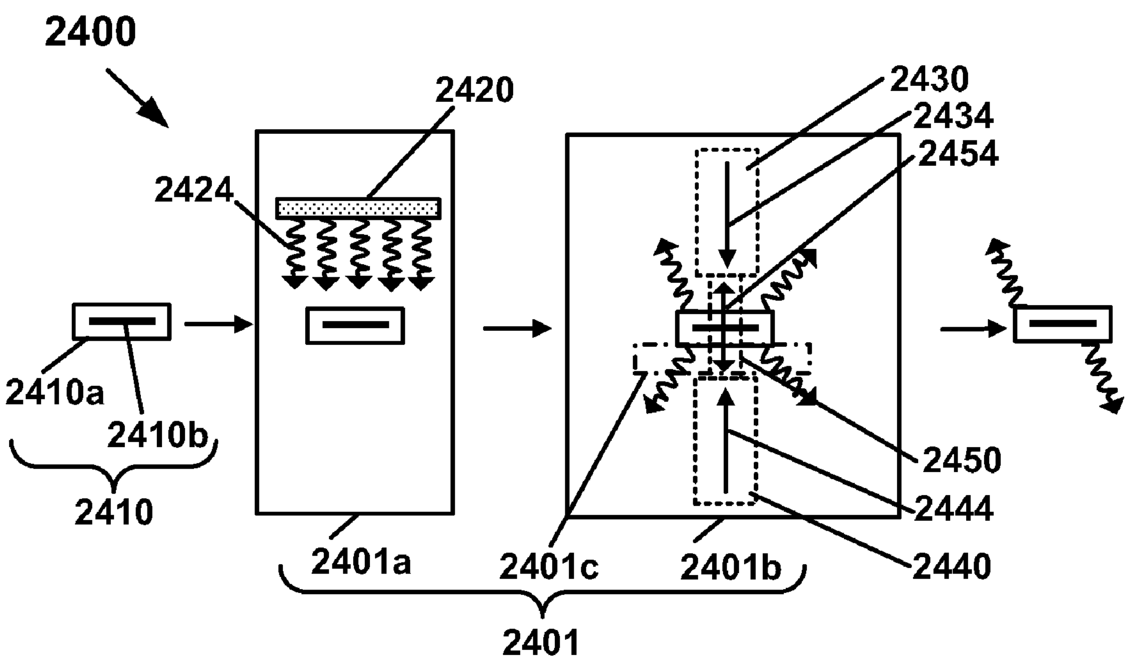
2400
2420
2424
2430
2434
2454
2410a
2410b
2410
2450
2444
2440
2401a
2401c
2401b
2401

FIG. 24

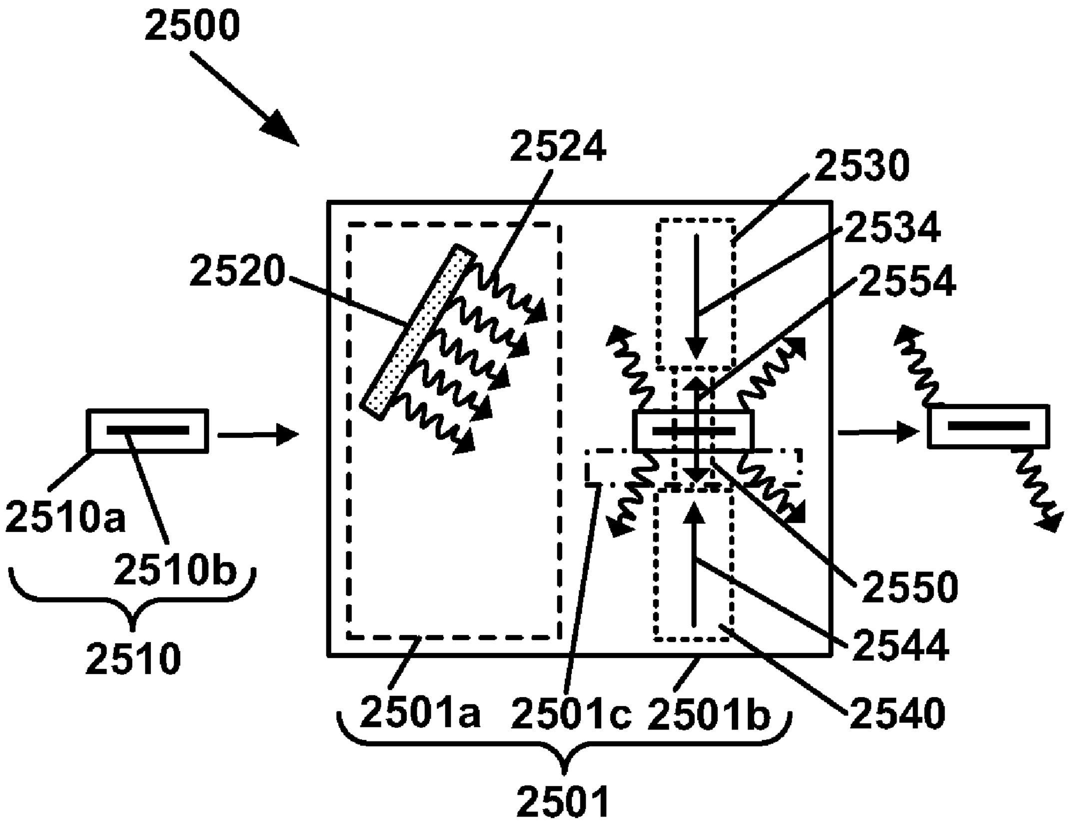
2500
2524
2530
2534
2520
2554
2510a
2510b
2510
2550
2544
2540
2501a
2501c
2501b
2501

FIG. 25

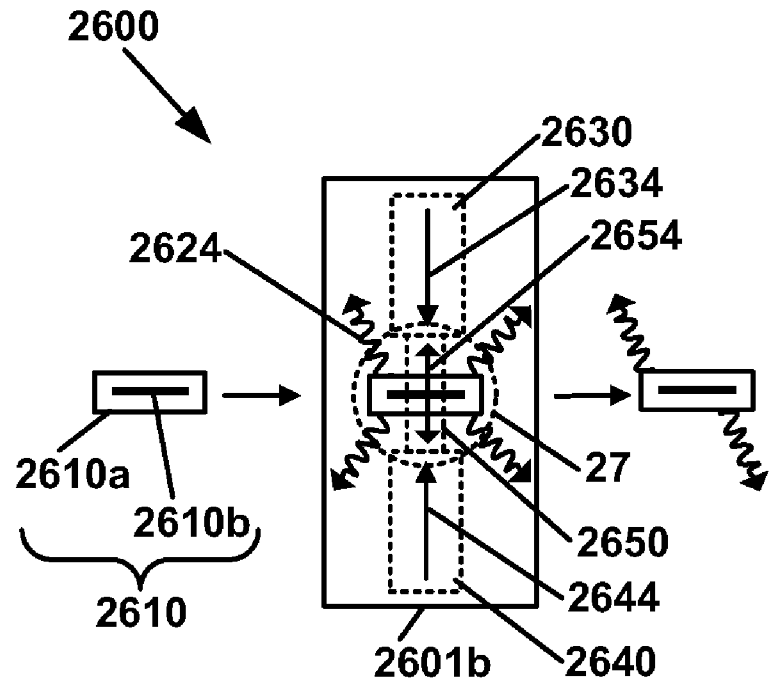
2600
2630
2634
2654
2624
27
2610a
2610b
2650
2644
2610
2601b
2640

FIG. 26

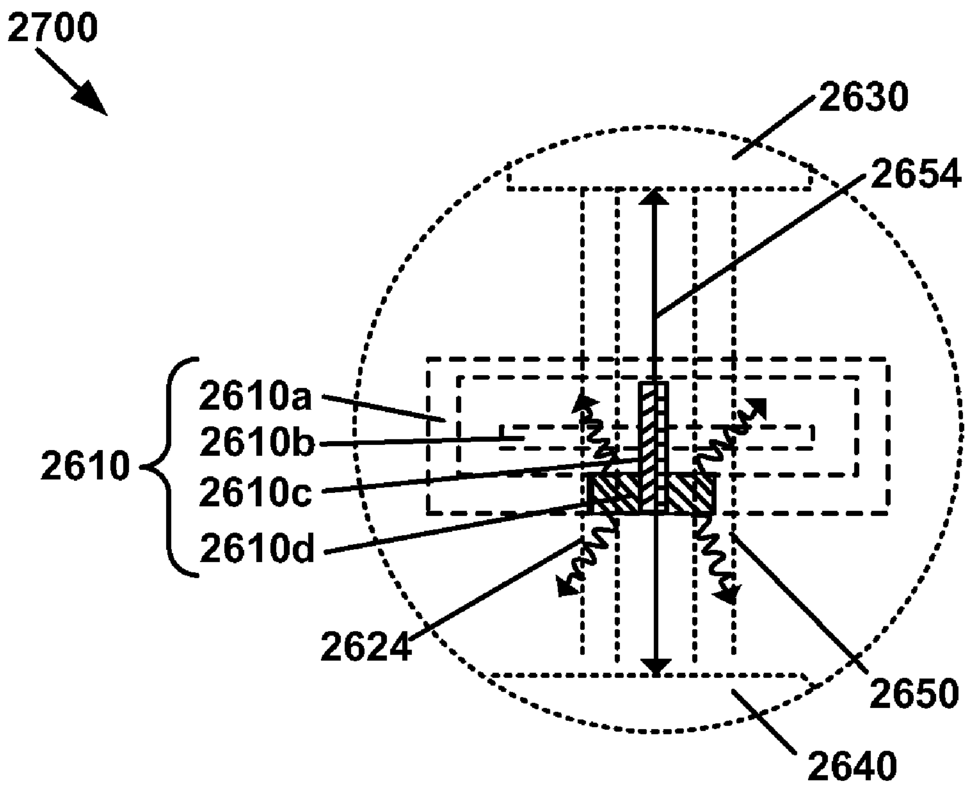

FIG. 27

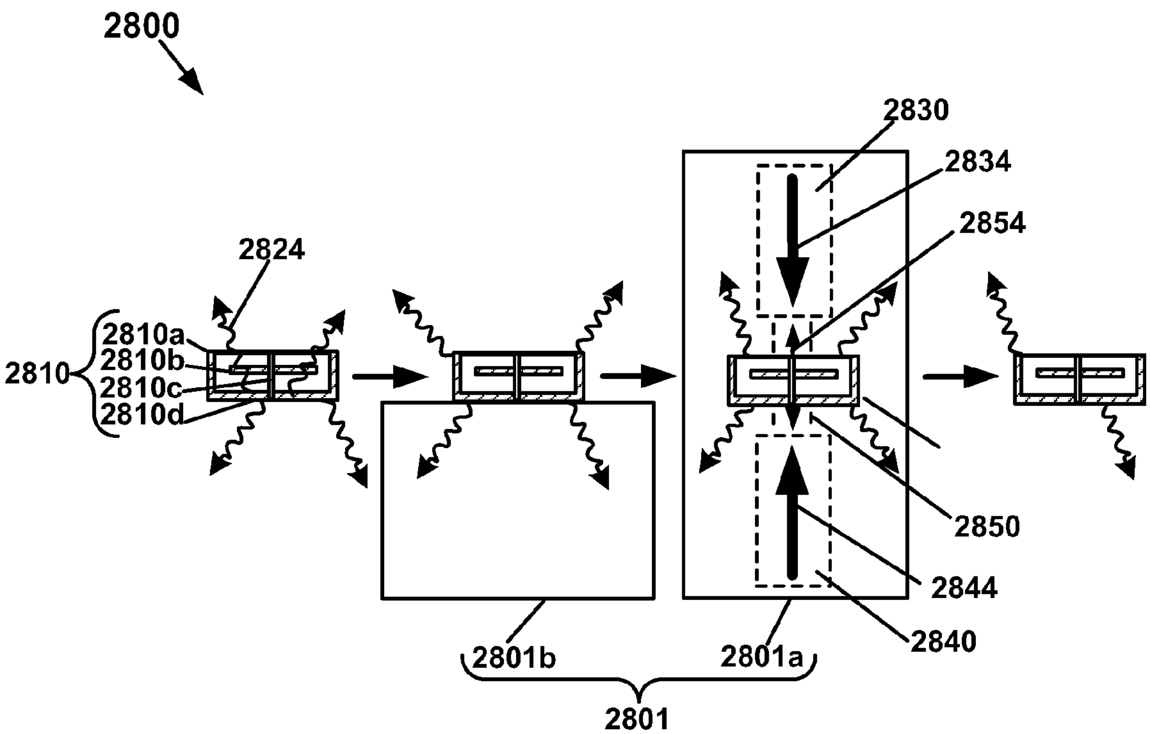
2800
2830
2834
2854
2824
2810a
2810b
2810
2810c
2810d
2850
2844
2840
2801b
2801a
2801

FIG. 28

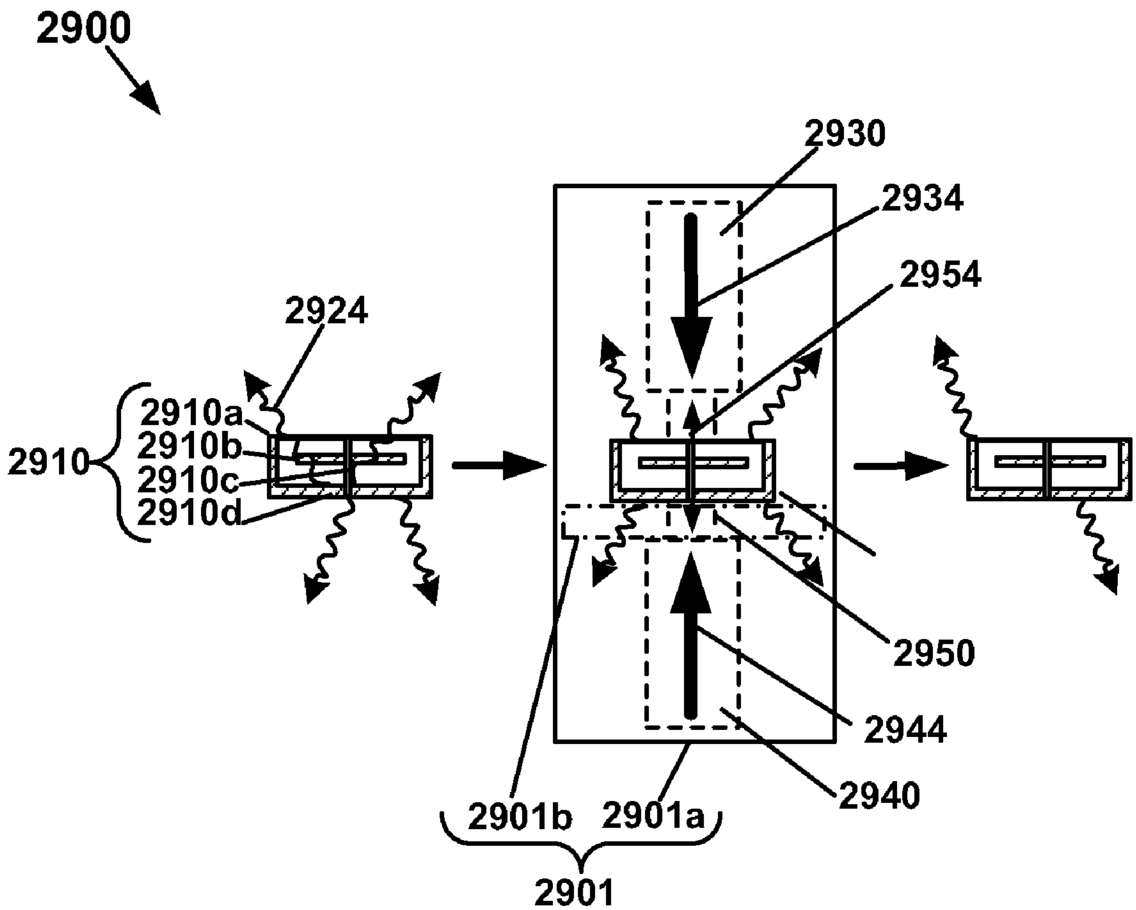
2900
2930
2934
2954
2924
2910a
2910b
2910
2910c
2910d
2950
2944
2940
2901b
2901a
2901

FIG. 29

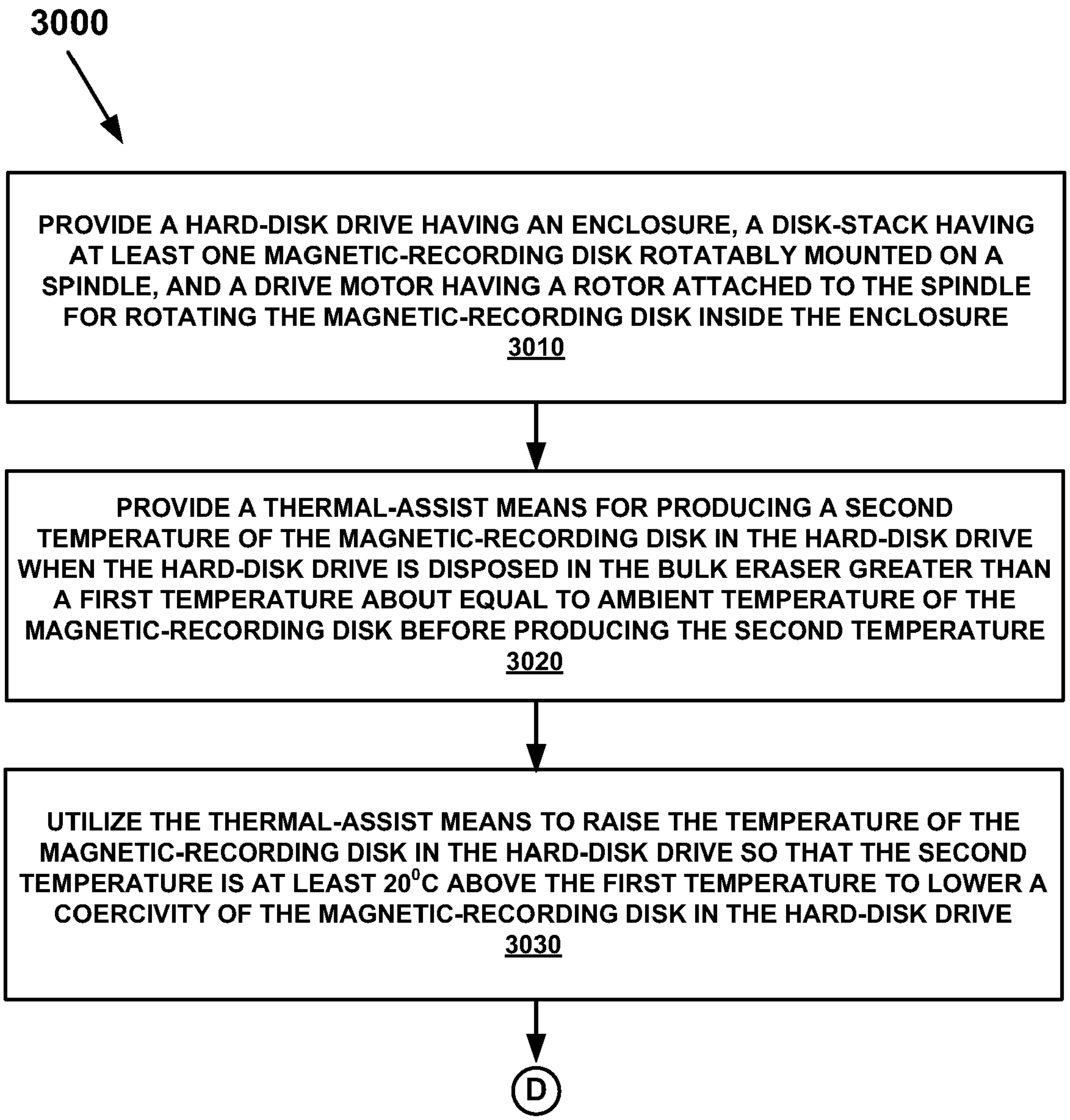
3000
PROVIDE A HARD-DISK DRIVE HAVING AN ENCLOSURE, A DISK-STACK HAVING AT LEAST ONE MAGNETIC-RECORDING DISK ROTATABLY MOUNTED ON A SPINDLE, AND A DRIVE MOTOR HAVING A ROTOR ATTACHED TO THE SPINDLE FOR ROTATING THE MAGNETIC-RECORDING DISK INSIDE THE ENCLOSURE
3010
PROVIDE A THERMAL-ASSIST MEANS FOR PRODUCING A SECOND TEMPERATURE OF THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE WHEN THE HARD-DISK DRIVE IS DISPOSED IN THE BULK ERASER GREATER THAN A FIRST TEMPERATURE ABOUT EQUAL TO AMBIENT TEMPERATURE OF THE MAGNETIC-RECORDING DISK BEFORE PRODUCING THE SECOND TEMPERATURE
3020
UTILIZE THE THERMAL-ASSIST MEANS TO RAISE THE TEMPERATURE OF THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE SO THAT THE SECOND TEMPERATURE IS AT LEAST 20^{0}C ABOVE THE FIRST TEMPERATURE TO LOWER A COERCIVITY OF THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE
3030
D

FIG. 30A

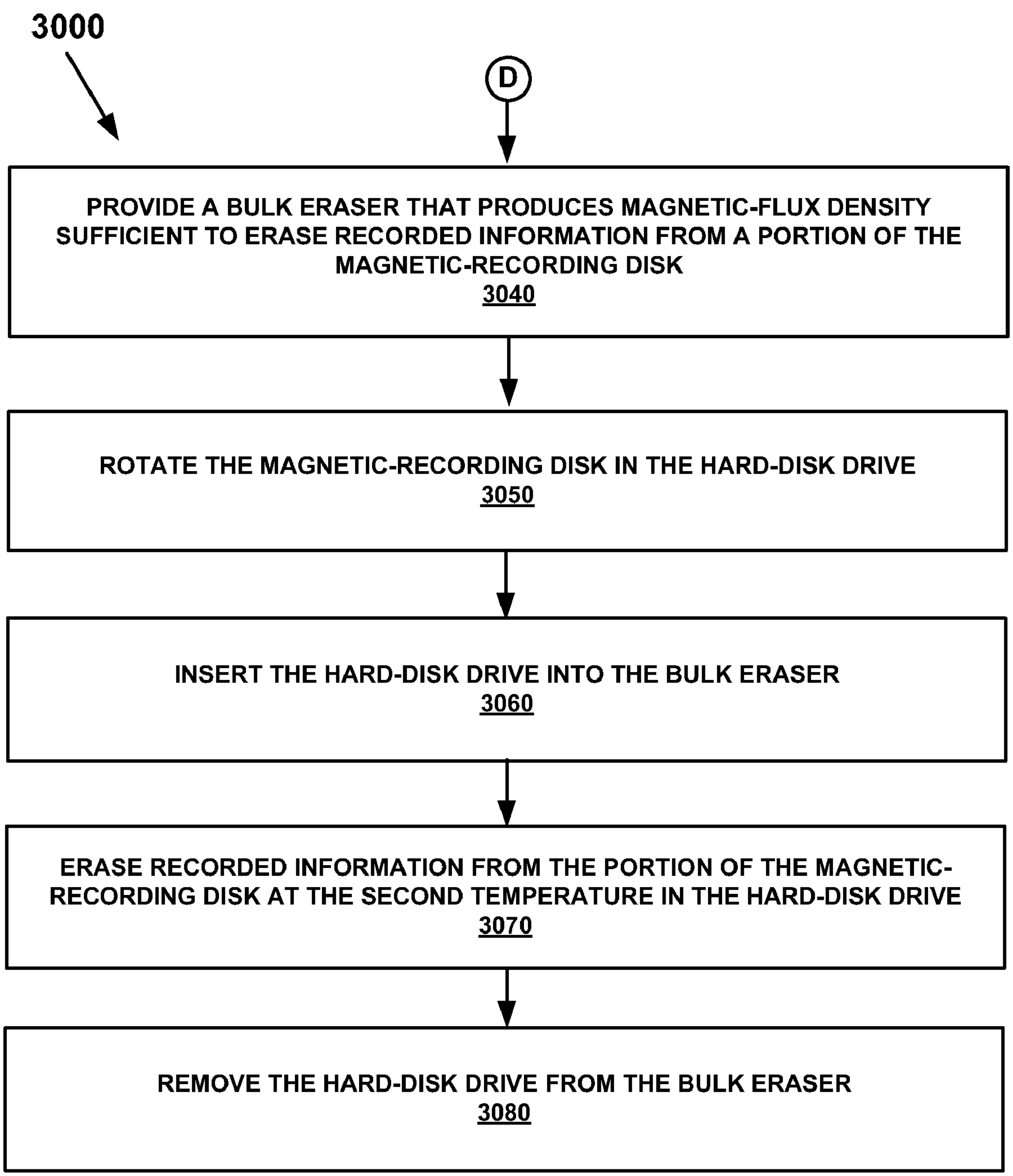
3000
D
PROVIDE A BULK ERASER THAT PRODUCES MAGNETIC-FLUX DENSITY SUFFICIENT TO ERASE RECORDED INFORMATION FROM A PORTION OF THE MAGNETIC-RECORDING DISK
3040
ROTATE THE MAGNETIC-RECORDING DISK IN THE HARD-DISK DRIVE
3050
INSERT THE HARD-DISK DRIVE INTO THE BULK ERASER
3060
ERASE RECORDED INFORMATION FROM THE PORTION OF THE MAGNETIC-RECORDING DISK AT THE SECOND TEMPERATURE IN THE HARD-DISK DRIVE
3070
REMOVE THE HARD-DISK DRIVE FROM THE BULK ERASER
3080

FIG. 30B

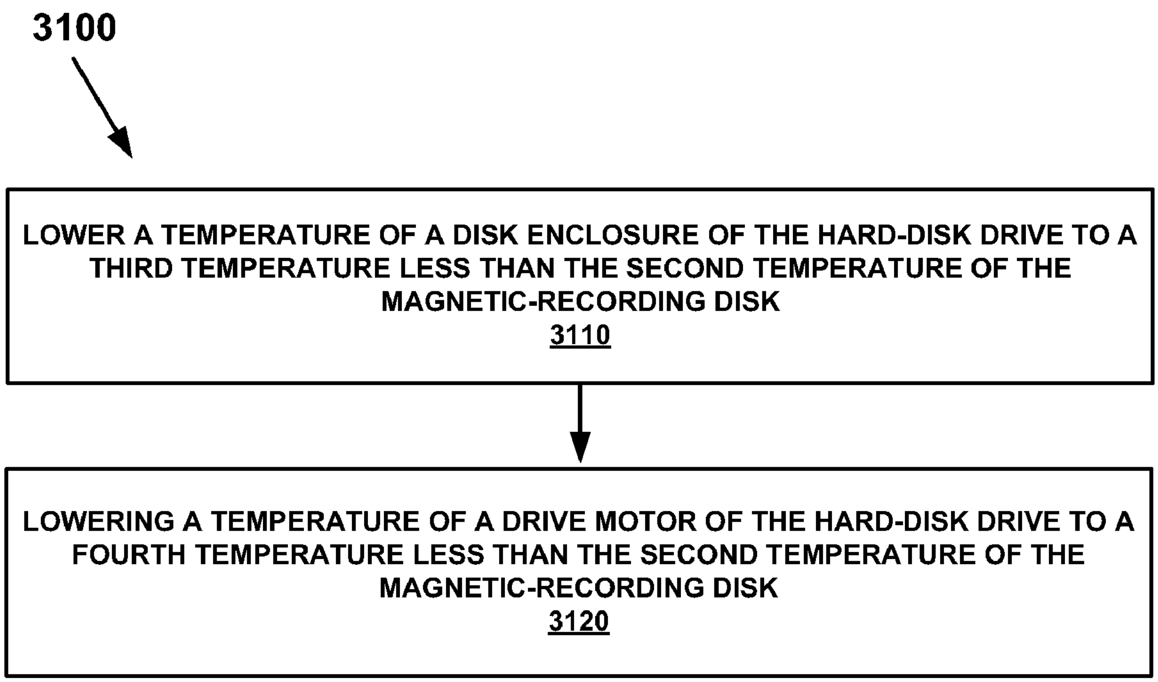
3100
LOWER A TEMPERATURE OF A DISK ENCLOSURE OF THE HARD-DISK DRIVE TO A THIRD TEMPERATURE LESS THAN THE SECOND TEMPERATURE OF THE MAGNETIC-RECORDING DISK
3110
LOWERING A TEMPERATURE OF A DRIVE MOTOR OF THE HARD-DISK DRIVE TO A FOURTH TEMPERATURE LESS THAN THE SECOND TEMPERATURE OF THE MAGNETIC-RECORDING DISK
3120

FIG. 31

COMBINED BULK THERMAL-ASSISTER AND BULK ERASER

TECHNICAL FIELD

Embodiments of the present invention relate generally to the field of magnetic-recording, hard-disk drives and methods for manufacturing magnetic-recording, hard-disk drives.

BACKGROUND

The magnetic-recording, hard-disk-drive (HDD) industry is extremely competitive. The demands of the market for ever increasing storage capacity, storage speed, and other enhancement features compounded with the desire for low cost creates tremendous pressure for improved HDDs. Therefore, scientists at the frontiers of magnetic-recording-technology research are driven to improve methods for reducing the cost of manufacturing and are constantly striving to develop new manufacturing tools to effect such cost reductions.

A critical factor affecting the cost of manufacturing is time expended in rework during the manufacturing process. Engineers and scientists engaged in manufacturing research are highly motivated to reduce the time expended in the rework of HDDs, because it goes directly to the profit margin for the product, which can make the difference between success and failure in the marketplace. The challenges of new technologies such as perpendicular-magnetic recording add further complexity to the daunting task of cost reductions. Therefore, the development of methods and tooling by scientists engaged in HDD research that can meet these challenges are crucial to success.

SUMMARY

Embodiments of the present invention include a combined bulk thermal-assister and bulk eraser for erasing recorded information on a magnetic-recording disk. The combined bulk thermal-assister and bulk eraser includes a bulk thermal-assister and a bulk eraser. The bulk thermal-assister is configured to produce a temperature in a magnetic-recording disk in a hard-disk drive when the hard-disk drive is disposed in the bulk eraser. The temperature is about equal to a second temperature greater than a first temperature of the magnetic-recording disk in the hard-disk drive. The bulk eraser is configured to erase recorded information from the magnetic-recording disk at the second temperature in the hard-disk drive. The second temperature lowers a coercivity of the magnetic-recording disk in the hard-disk drive so that, when recorded information is erased from the magnetic-recording disk in the hard-disk drive at the second temperature, recorded information on the magnetic-recording disk is erased from a second magnetic-recording track in closer proximity to an inside diameter of the magnetic-recording disk than a first magnetic-recording track from which recorded information on the magnetic-recording disk may be erased, if recorded information were erased from the magnetic-recording disk in the hard-disk drive at the first temperature.

DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the embodiments of the invention:

FIG. **1** is plan view of a hard-disk drive (HDD) drive that is manufactured using the bulk eraser for erasing recorded information on a magnetic-recording disk in the HDD, in an embodiment of the present invention.

FIG. **2**A is a perspective view of a bulk eraser for erasing recorded information on a magnetic-recording disk in a HDD, in an embodiment of the present invention.

FIG. **2**B is a detailed perspective view of a gap of the bulk eraser of FIG. **2**A illustrating the configuration of the pole-tip portions at the gap, in an embodiment of the present invention.

FIG. **3**A is a plot of the distribution of magnetic-flux density at the gap of the bulk eraser of FIGS. **2**A and **2**B showing the distribution of magnetic-flux density with respect to a disk-stack in the HDD, in an embodiment of the present invention.

FIG. **3**B is a plot of the distribution of magnetic-flux density and contours of constant magnitude of magnetic-flux density in the plane **3**B-**3**B of one magnetic-recording disk of the disk-stack of FIG. **3**A showing a portion of the disk wherein the magnetic-flux density is sufficient to erase recorded information, in an embodiment of the present invention.

FIG. **4**A is a perspective view of an alternative embodiment of a bulk eraser showing three magnets and a structure magnetically coupled with the three magnets to produce magnetic-flux density in a gap sufficient to erase recorded information from a portion of the magnetic-recording disk in a disk-stack of the HDD, in an embodiment of the present invention.

FIG. **4**B is an elevation view of a left side of the bulk eraser of FIG. **4**A, in an embodiment of the present invention.

FIG. **4**C is an elevation view of a front side of the bulk eraser of FIG. **4**A, in an embodiment of the present invention.

FIG. **5** is a perspective view of an alternative embodiment of a bulk eraser that includes seven magnets and a structure magnetically coupled with the seven magnets to produce magnetic-flux density in a gap sufficient to erase recorded information from a portion of the magnetic-recording disk in a disk-stack of the HDD, in an embodiment of the present invention.

FIG. **6** is a perspective view of the pole piece of the bulk erasers of FIGS. **4**A-**4**C and **5** disposed on a third end pole of a third magnet disposed in proximity to a second portion of the gap for concentrating the magnetic-flux density to erase recorded information from the portion of the magnetic-recording disk in the HDD inserted into the second portion of the gap, in an embodiment of the present invention.

FIG. **7** is a perspective view of the second magnet of the bulk eraser of FIGS. **4**A-**4**C and **5** disposed in proximity to a first portion of the gap and a second pole-tip portion of the second magnet disposed proximate a second portion of the gap for concentrating the magnetic-flux density to erase recorded information from the portion of the magnetic-recording disk in the HDD inserted into the second portion of the gap, in an embodiment of the present invention.

FIG. **8** is a plot of the intensities of the magnetic field intensity (magnetic-flux density) as a function of radial distance from center of a disk in the plane of each of four magnetic-recording disks in a disk-stack of a HDD inserted into the second portion of the gap of a bulk eraser configured with five magnets to erase recorded information from the magnetic-recording disk in a disk-stack of an HDD in the second portion of the gap, in an embodiment of the present invention.

FIG. **9**A is a flow chart illustrating a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **9**B is a continuation of the flow chart of FIG. **9**A illustrating a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **10** is a flow chart illustrating further embodiments of the present invention for a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **11** is a flow chart illustrating further embodiments of the present invention for a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **12** is a flow chart illustrating further embodiments of the present invention for a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **13** is a flow chart illustrating further embodiments of the present invention for a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **14** is a flow chart illustrating further embodiments of the present invention for a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **15** is a flow chart illustrating further embodiments of the present invention for a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **16** is a flow chart illustrating further embodiments of the present invention for a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **17** is a flow chart illustrating further embodiments of the present invention for a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **18**A is a flow chart illustrating a method of reworking a hard-disk drive in manufacturing the hard-disk drive using a bulk eraser for erasing a servo pattern on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **18**B is a continuation of the flow chart of FIG. **20**A illustrating a method of reworking a hard-disk drive in manufacturing the hard-disk drive using a bulk eraser for erasing a servo pattern on a magnetic-recording disk, in an embodiment of the present invention.

FIG. **19**A is a flow chart illustrating a method of preserving security of recorded information in a hard-disk drive in a computer system using a bulk eraser, in an embodiment of the present invention.

FIG. **19**B is a continuation of the flow chart of FIG. **21**A illustrating a method of manufacturing of preserving security of recorded information in a hard-disk drive in a computer system using a bulk eraser, in an embodiment of the present invention.

FIG. **20** is a plot of the coercivity, H_C, of the magnetic-recording medium of a magnetic-recording disk measured along the easy axis of magnetization perpendicular to the recording surface of the magnetic-recording disk as a function of temperature that illustrates the decrease from a first value of the coercivity as measured at a first temperature to a second value of the coercivity as measured at a second temperature at which recorded information may be erased from the magnetic-recording disk in the hard-disk drive, in an embodiment of the present invention.

FIG. **21** is a plot of the intensities of the magnetic field intensity (magnetic-flux density) as a function of radial distance from center of a disk in the plane of each of four magnetic-recording disks in a disk-stack of a HDD inserted into a bulk eraser of the combined bulk thermal-assister and bulk eraser that illustrates the expected improvement in the erasure of the magnetic-recording disk upon heating the magnetic-recording disk with the bulk thermal-assister in comparison with the erasure of the magnetic-recording disk without heating the magnetic-recording disk, in an embodiment of the present invention.

FIG. **22** is a block diagram of a first example embodiment of the present invention, a combined bulk thermal-assister and bulk eraser with an optional chiller, that illustrates the work-flow of a magnetic-recording disk in a hard-disk drive initially at a first temperature, which upon passing through the bulk thermal-assister is heated by a thermal-assist means, is optionally passed through the chiller which is configured to lower a temperature of the drive-motor magnet of the hard-disk drive to a fourth temperature less than a second temperature of the magnetic-recording disk, and is subsequently passed through the bulk eraser at the second temperature at which recorded information is erased from the magnetic-recording disk.

FIG. **23** is a block diagram of a second example embodiment of the present invention, a combined bulk thermal-assister and bulk eraser wherein the bulk thermal-assister is integrated with the bulk eraser, that illustrates the work-flow of a magnetic-recording disk in a hard-disk drive initially at a first temperature, which upon passing into the integrated combined bulk thermal-assister and bulk eraser is heated by a thermal-assist means and is erased at a second temperature.

FIG. **24** is a block diagram of a third example embodiment of the present invention, a combined bulk thermal-assister and bulk eraser having a chiller integrated with the bulk eraser, that illustrates the work-flow of a magnetic-recording disk in a hard-disk drive initially at a first temperature which upon passing through the bulk thermal-assister is heated by a thermal-assist means, subsequently passes into the bulk eraser and is chilled by the bulk eraser integrated with the chiller so that the drive-motor magnet is at a fourth temperature less than the second temperature at which recorded information is erased from the magnetic-recording disk.

FIG. **25** is a block diagram of a fourth example embodiment of the present invention, a combined bulk thermal-assister and bulk eraser having a chiller, wherein the bulk thermal-assister and the chiller are both integrated with the bulk eraser that illustrates the work-flow of a magnetic-recording disk in a hard-disk drive initially at a first temperature, which upon passing into the integrated combined bulk thermal-assister and bulk eraser is heated by a thermal-assist means and is erased at a second temperature, and is chilled by the bulk eraser with integrated the chiller so that the drive-motor magnet is at a fourth temperature less than the second temperature.

FIG. **26** is a block diagram of a fifth example embodiment of the present invention, a bulk eraser with a thermal-assist means, that illustrates the work-flow of a magnetic-recording disk in a hard-disk drive initially at a first temperature which upon passing into the bulk eraser with the thermal-assist means is heated by the thermal-assist means and is erased at a second temperature at least 20° C. above the first temperature.

FIG. **27** is an enlarged view of the hard-disk drive shown in the block diagram of FIG. **26** that details the thermal-assist means, for example, the drive motor of the hard-disk drive operated to produce the second temperature of the magnetic-recording disk at least 20° C. above the first temperature of the magnetic-recording disk in the hard-disk drive, in an embodiment of the present invention.

FIG. **28** is a block diagram of a sixth example embodiment of the present invention, a bulk eraser with a thermal-assist means having a chiller, that illustrates the work-flow of a magnetic-recording disk in a hard-disk drive initially at a first temperature which before passing into the bulk eraser is heated by the thermal-assist means, is passed through the chiller which is configured to lower a temperature of a drive-motor magnet of a drive motor of the hard-disk drive to a fourth temperature less than a second temperature of the magnetic-recording disk, and is subsequently erased in the bulk eraser at the second temperature at least 20° C. above the first temperature.

FIG. **29** is a block diagram of a seventh example embodiment of the present invention, a bulk eraser with a thermal-assist means having a chiller integrated with the bulk eraser, that illustrates the work-flow of a magnetic-recording disk in a hard-disk drive initially at a first temperature which before passing into the bulk eraser is heated by the thermal-assist means, is erased at a second temperature at least 20° C. above the first temperature, and is chilled by the bulk eraser integrated with the chiller so that the drive-motor magnet is at a fourth temperature less than the second temperature.

FIG. **30**A is a flow chart illustrating a method of erasing recorded information on a magnetic-recording disk in a hard-disk drive using a bulk eraser with thermal-assist means, in an embodiment of the present invention.

FIG. **30**B is a continuation of the flow chart of FIG. **30**A illustrating a method of erasing recorded information on a magnetic-recording disk in a hard-disk drive using a bulk eraser with thermal-assist means, in an embodiment of the present invention.

FIG. **31** is a flow chart illustrating further embodiments of the present invention for a method of erasing recorded information on a magnetic-recording disk in a hard-disk drive using a bulk eraser with thermal-assist means, in an embodiment of the present invention.

The drawings referred to in this description should not be understood as being drawn to scale except if specifically noted.

DESCRIPTION OF EMBODIMENTS

Reference will now be made in detail to the alternative embodiments of the present invention. While the invention will be described in conjunction with the alternative embodiments, it will be understood that they are not intended to limit the invention to these embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the invention as defined by the appended claims.

Furthermore, in the following description of embodiments of the present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it should be noted that embodiments of the present invention may be practiced without these specific details. In other instances, well known methods, procedures, and components have not been described in detail as not to unnecessarily obscure embodiments of the present invention.

Overview

Section I describes in detail various embodiments of the present invention for a bulk eraser (Sub-Section A), a bulk eraser including at least three magnets configured for erasing recorded information (Sub-Section B), as well as a method of manufacturing of a hard-disk drive using a bulk eraser for erasing recorded information on a magnetic-recording disk (Sub-Section C). Various embodiments of the present invention described in Section I Sub-Sections A and B may be incorporated as elements of a combined bulk thermal-assister and bulk eraser, in accordance with embodiments of the present invention. Various embodiments of the present invention described in Section I Sub-Section C may be incorporated as elements of a method of erasing recorded information on a magnetic-recording disk in a hard-disk drive using a bulk eraser with thermal-assist means, in accordance with embodiments of the present invention. The embodiments of the present invention described in Section I are illustrated in FIGS. **1**-**19**B.

Section II provides a detailed description of various embodiments of the present invention for a combined bulk thermal-assister and bulk eraser (Sub-Section A) and a method of erasing recorded information on a magnetic-recording disk in a hard-disk drive using a bulk eraser with thermal-assist means (Sub-Section B). FIGS. **20**-**29** illustrate detailed arrangements of element combinations for the combined bulk thermal-assister and bulk eraser, in accordance with embodiments of the present invention. FIGS. **30**A-**31** illustrate specific embodiments of the present invention for a method of erasing recorded information on a magnetic-recording disk in a hard-disk drive using a bulk eraser with thermal-assist means, in accordance with embodiments of the present invention.

Section I:

Sub-Section A: Physical Description of Embodiments of the Present Invention for a Bulk Eraser

With reference to FIG. **1**, in accordance with an embodiment of the present invention, a plan view of a hard-disk drive (HDD) **100** manufactured with a tool, for example, a bulk eraser, for erasing recorded information from a hard-disk drive is shown. FIG. **1** illustrates the functional arrangement of component parts in HDD **100**. The HDD **100** includes at least one HGA **110** including a magnetic-recording head **110*a***, for example, a perpendicular magnetic recording (PMR) head, a lead suspension **110*c*** attached to the magnetic-recording head **110*a***, and a load beam **110*d*** attached to a slider **110*b***, which includes the magnetic-recording head **110*a*** at a distal end of the slider **110*b***; the slider **110*b*** is attached at the distal end of the load beam **110*d*** to a gimbal portion of the load beam **110*d***. The HDD **100** also includes at least one magnetic-recording disk **120**, for example, a PMR disk, rotatably mounted on a spindle **126** and a drive motor (not shown, but whose location is indicated by the crosshatching at the center of the magnetic-recording disk **120**) attached to the spindle **126** for rotating the magnetic-recording disk **120**. The magnetic-recording disk includes at least one magnetic layer, which may include a structure including many thin-film layers including a thin-film layer of high coercivity magnetic material; the magnetic layer is deposited on a substrate, but need not be in contact with the substrate, as other layers may be interposed between the substrate and the magnetic layer to provide the magnetic layer with suitable magnetic properties, such as magnetic anisotropy. The substrate may be composed of aluminum, an alloy of aluminum, a ceramic, or glass. The drive motor includes a drive-motor stator and a rotor; the rotor may include one or more drive-motor magnets which cause the rotor to rotate in response to a magnetic field generated by a drive-motor stator including motor windings; alternatively, the drive-motor stator may include one or more drive-motor magnets which cause the rotor to rotate in response to a magnetic field generated by motor windings wound on the rotor. The magnetic-recording head **110***a* includes a write element, a so-called writer, a read element, a so-called reader, for respectively writing and reading information stored on the magnetic-recording disk **120** of the HDD **100**, and a thermal-fly-height-control (TFC) element. The TFC element is configured to position the read element of the magnetic-recording head **110***a* in communication with the magnetic-recording disk **120** for reading recorded data from the magnetic-recording disk **120**. The magnetic-recording disk **120** or a plurality (not shown) of magnetic-recording disks may be affixed to the spindle **126** with a disk clamp **128**. If a plurality of magnetic-recording disks is provided, the plurality of magnetic-recording disks along with interposed spacers between the magnetic-recording disks is referred to by the term of art, "disk-stack"; however, as used herein, to simplify the discussion, the term disk-stack will be also used to refer to a single magnetic-recording disk. The magnetic-recording disk **120** also has an outside diameter (OD) **124** and an inside diameter (ID) **122**. A radial direction **174** of the magnetic-recording disk **120** is also shown in FIG. **1** that is utilized in aligning the HDD in the bulk eraser for erasing recorded information from the magnetic-recording disk **120**. The HDD **100** further includes an arm **132** attached to the HGA **110**, a voice-coil motor (VCM) that includes an armature **136** including a voice-coil **140** attached to the arm **132**; and a VCM stator **144** including a voice-coil magnet (not shown); the armature **136** of the VCM, which is mounted on a pivot **148** with an interposed pivot bearing **152**, is attached to the arm **132** and is configured to move the arm **132** and the HGA **110** to access portions of the magnetic-recording disk **120**.

With further reference to FIG. **1**, in accordance with an embodiment of the present invention, electrical signals, for example, current to the voice-coil **140** of the VCM, write signal to and read-back signal from the magnetic-recording head **110***a*, are provided by a flexible cable **156**. Interconnection between the flexible cable **156** and the magnetic-recording head **110***a* may be provided by an arm-electronics (AE) module **160**, which may have an on-board pre-amplifier for the read-back signal, as well as other read-element-channel and write-element-channel electronic components. The flexible cable **156** is coupled to an electrical-connector block **164**, which provides electrical communication through electrical feedthroughs (not shown) provided by an HDD housing **168**. The HDD housing **168**, also referred to as a casting, in conjunction with an HDD cover (not shown, as FIG. **1** shows the HDD **100** with the cover removed) provides an enclosure, which is sealed and protects the information storage components of the HDD **100**. The enclosure of the HDD also has: a front side **102**, a backside **104**, a right side **106** and a left side **108**. As shown in FIG. **1**, the view shown is onto the topside of the HDD with the cover removed. The bottom side of the HDD is not shown in FIG. **1**, but a printed circuit board is mounted on the bottom side which includes electronic components used to control the access to the magnetic-recording disk **120** for writing recorded information to the magnetic-recording disk **120** or reading recorded information from the magnetic-recording disk **120**.

With further reference to FIG. **1**, in accordance with an embodiment of the present invention, other electronic components (not shown), including as a disk controller and servo-control electronics including a digital-signal processor (DSP), provide electrical signals to the drive motor, the voice-coil **140** of the VCM and the magnetic-recording head **110***a* of the HGA **110**. The electrical signal provided to the drive motor enables the drive motor to spin providing a torque to the spindle **126** which is in turn transmitted to the magnetic-recording disk **120** that is affixed to the spindle **126** by the disk clamp **128**; as a result, the magnetic-recording disk **120** spins in a direction **172**. The spinning magnetic-recording disk **120** creates a cushion of air that acts as an air bearing on which the air-bearing surface (ABS) of the slider **110***b* rides so that the slider **110***b* flies above the surface of the magnetic-recording disk **120** without making contact with a thin magnetic-recording medium of the magnetic-recording disk **120** in which information is recorded. The electrical signal provided to the voice-coil **140** of the VCM enables the magnetic-recording head **110***a* of the HGA **110** to access a data track **176** on which information is recorded. Thus, the armature **136** of the VCM swings through an arc **180**, which enables the HGA **110** attached to the armature **136** by the arm **132** to access various data tracks on the magnetic-recording disk **120**. Information is stored on the magnetic-recording disk **120** in a plurality of concentric data tracks (not shown) arranged in sectors on the magnetic-recording-head-facing side of the magnetic-recording disk **120**, for example, sector **184**. Correspondingly, each data track is composed of a plurality of sectored data track portions, for example, sectored data track portion **188**. Each sectored data track portion **188** is composed of recorded data and a header containing a servo-burst-signal pattern, for example, an ABCD-servo-burst-signal pattern, information that identifies the data track **176**, and error correction code information. In accessing the data track **176**, the read element of the magnetic-recording head **110***a* of the HGA **110** reads the servo-burst-signal pattern which provides information to the servo-control electronics, which controls the electrical signal provided to the voice-coil **140** of the VCM, enabling the magnetic-recording head **110***a* to follow the data track **176**. Upon finding the data track **176** and identifying a particular sectored data track portion **188**, the magnetic-recording head **110***a* either reads data back from the data track **176** or writes data to the data track **176** depending on instructions received by the disk controller from an external agent, for example, a microprocessor of a computer system.

With further reference to FIG. **1**, in accordance with an embodiment of the present invention, a plan view of a head-arm-assembly (HAA) is shown. FIG. **1** illustrates the functional arrangement of the HAA with respect to VCM and HGA **110**. The HAA includes the HGA **110** and the arm **132**. The HAA is attached at the arm **132** to a carriage **134**. In the case of an HDD having multiple disks, or platters as disks are sometimes referred to in the art, the carriage **134** is called an "E-block," or comb, because the carriage **134** is arranged to carry a ganged array of arms that gives it the appearance of a comb. As shown in FIG. **1**, the armature **136** of the VCM is attached to the carriage **134** and the voice-coil **140** is attached to the armature **136**. The AE module **160** may be attached to the carriage **134** as shown. The carriage **134** is mounted on the pivot **148** with the interposed pivot bearing **152**, as previously described.

With reference now to FIG. **2**A, in accordance with an embodiment of the present invention, a perspective view **200**A of a bulk eraser **201** for erasing recorded information on a magnetic-recording disk, for example, magnetic-recording disk **120**, in a HDD, for example, HDD **100**, is shown. The bulk eraser **201** includes a plurality of magnets, for example, a first magnet **210** and a second magnet **230**, without limitation thereto, as embodiments of the present invention may include more than two magnets or two sources of magnetic flux. The bulk eraser **201** includes a structure magnetically coupled with the plurality of magnets to produce magnetic-flux density in a gap, wherein the gap has a first portion **222**, a second portion **224** and a third portion (not shown, but see description of FIG. **3**A-**3**B). As used herein, it should be recognized that the Gaussian system of units are used, so that a magnetic-flux density, known in the art as a magnetic induction field, or B-field, given in units of Gauss, is equal to a magnetic field intensity, known in the art as a H-field, given in units of Oersteds, if the magnetization, known in the art as a M-field, is negligible. Therefore, it should be understood that when referring to a magnetic-flux density, B-field, in a gap, the magnetic-flux density, B-field, in the gap is equivalent to an associated magnetic field intensity, H-field, in the gap, which is a well-known convention in the art when using Gaussian units. In an embodiment of the present invention, as shown in FIG. **2**A, the structure may include: a yoke **270** including a first yoke portion **270***a* and a second yoke portion **270***b*, a first pole piece **240**, a second pole piece **250** in the third pole piece **260**. Two magnets, first magnet **210** and second magnet **230**, are disposed with opposing polarity across the first portion **222** of the gap. The direction **214** of the B-field, the magnetic-flux density, as well as the magnetization field, in the first magnet **210** is shown by the black arrow. The black arrow indicates that a first end pole **212** proximate the first portion **222** of the gap has the polarity of a south pole, and the end pole of the first magnet **210** opposite the south pole has the polarity of a north pole. The black arrow also indicates the direction of magnetic flux propagation through the first magnet **210**. Similarly, the direction **234** of the B-field, the magnetic-flux density, as well as the magnetization field, in the second magnet **230** is shown by the white arrow. The white arrow indicates that a second end pole **232** proximate first portion **222** of the gap has the polarity of a south pole, and the end pole of the second magnet **230** opposite the south pole has the polarity of a north pole. The white arrow also indicates the direction of magnetic flux propagation through the second magnet **230**. At least one of the plurality of magnets, for example, magnets **210** and **230**, may be a high-field-strength, permanent magnet, which may be composed of a material such as neodymium iron boron, NdFeB. The grade of the NdFeB material used for at least one magnet of the plurality of magnets may be a grade between about grade 48 and about grade 54; however, a grade of about grade 50 provides a very stable magnet. The plurality of magnets **210** and **230** and the structure are configured to produce a magnetic-flux density in the second portion **224** of the gap sufficient to erase recorded information from a portion of at least one magnetic-recording disk, for example, magnetic-recording disk **120**, in a disk-stack of the HDD when the HDD is inserted into the second portion **224** of the gap. The plurality of magnets **210** and **230** and the structure are configured to direct the magnetic-flux density in a substantially radial direction, for example, radial direction **174**, of the portion of the magnetic-recording disk in the HDD in the second portion **224** of the gap. For example, the first pole piece **240** has a first pole-tip portion **242**, the second pole piece **250** has a second pole-tip portion **252** and the third pole piece **260** has a third pole-tip portion **262** configured to provide magnetic-flux density in the second portion **224** of the gap with the characteristics described above.

With further reference to FIG. **2**A, in accordance with an embodiment of the present invention, the plurality of magnets, for example, magnets **210** and **230**, and the structure are configured to produce a magnetic-flux density sufficient to erase recorded information from portions of a plurality of magnetic-recording disks in a disk-stack of the HDD, for example, HDD **100**. One type of recorded information that is frequently required to be erased in manufacturing is servo pattern information on the magnetic-recording disk. Occasionally, it is found in the manufacturing process that the servo pattern is corrupted and it becomes necessary to erase the corrupted servo pattern and to write a new servo pattern to replace it. However, erasing the corrupted servo pattern by using the magnetic recording heads can take a substantially long time, tens of minutes. The bulk eraser, for example, bulk eraser **201**, can substantially reduce the erase time to tens of seconds. To accomplish this, the HDD with the corrupted servo pattern is inserted into the erase field of the bulk eraser in a type of batch processing procedure, which erases several portions of the magnetic-recording disk simultaneously, which gives rise to the term of art "bulk eraser" to describe the tool for erasing recorded information on a magnetic-recording disk of an HDD. Therefore, the plurality of magnets are configured to produce a magnetic-flux density sufficient to erase recorded information from a portion of at least one magnetic-recording disk containing servo information in a disk-stack of the HDD. Moreover, the bulk eraser can be used outside the scope of manufacturing, for example, to erase recorded information, for example, data recorded by a user, from an HDD used in an in-service environment. Therefore, the plurality of magnets are configured to produce a magnetic-flux density sufficient to erase recorded data from a portion of at least one magnetic-recording disk containing recorded data in a disk-stack of the HDD to preserve security of the recorded data.

With further reference to FIG. **2**A, in accordance with an embodiment of the present invention, another particularly useful application of the bulk eraser is for erasing magnetic-recording disks having high coercivity, such as PMR disks. Thus, the plurality of magnets, for example, magnets **210** and **230**, and the structure may also be configured to erase recorded information from a magnetic-recording disk that is a PMR disk. Moreover, the plurality of magnets and the structure are configured to produce magnetic-flux density such that magnetic-flux density is applied to a localized portion of the magnetic-recording disk to suppress eddy currents in the magnetic-recording disk of the HDD. This allows for the magnetic-recording disk to be erased more quickly, because eddy currents can stall the drive motor preventing rotation of the magnetic-recording disk during the erasure process.

With further reference to FIG. **2**A, in accordance with an embodiment of the present invention, another issue attending the use of the bulk eraser in the manufacturing process is that the erase fields used to erase recorded information on the magnetic-recording disk are fairly high to overcome the coercivity of magnetic recording materials used in the magnetic layer of the magnetic-recording disk. The magnetic moment in the drive-motor magnets can potentially be degraded when using the bulk eraser to erase recorded information on the magnetic-recording disk. Consequently, the magnetic-flux density produced by the plurality of magnets and the structure is configured to erase recorded information from the magnetic-recording disk disposed in the second portion of the gap without degrading the magnetization of a drive-motor magnet in the drive motor disposed in the third portion of the gap. To assure that a large portion of the magnetic-recording disk is erased without degrading the magnetization of the drive-motor magnets, the intensity of a field component of the magnetic-flux density directed along the radial direction in the plane of the magnetic-recording disk produced by the plurality of magnets and the structure has a gradient as a function of distance along the radial direction at a transition region between the second portion of the gap and the third portion of the gap such that the gradient allows erasing recorded information from the magnetic-recording disk in close proximity to the drive-motor magnet in the drive motor without degrading the magnetization of the drive-motor magnet in the drive motor. The high field gradient is also desirable, because it reduces the amount of time to erase portions of the magnetic-recording disk that cannot be reached by the erase field, for which it is necessary to erase with a magnetic recording head; in other words, the more of the magnetic-recording disk that can be erased with the bulk eraser, the less of the magnetic-recording disk will have to be erased by a magnetic recording head, which is a time-consuming process. Consequently, every additional millimeter along the radius of the magnetic-recording disk that can be erased by the erase field can significantly reduce the amount of time expended by erasing the remaining portions of the magnetic-recording disk with the magnetic recording head, which reduces the cost of manufacturing. Therefore, it is desirable to provide a bulk eraser with a strong erase field, magnetic-flux density, over the magnetic-recording disk and a steep gradient in the magnetic-flux density in the proximity to the drive-motor magnet.

With reference now to FIG. **2**B, in accordance with an embodiment of the present invention, a detailed perspective view **200**B of a gap **202** of the bulk eraser **201** of FIG. **2**A illustrating the configuration of the pole-tip portions **242**, **252** and **262** at the gap **202** is shown. The bulk eraser **201** includes a first source of magnetic flux, for example, first magnet **210**, disposed opposite a second source of magnetic flux, for example, second magnet **230**, across a first portion **222** of the gap **202**. At least one of the first source of magnetic flux and the second source of magnetic flux produces sufficient magnetic-flux density in the second portion **224** of the gap **202** to erase the magnetic-recording disk in the HDD. At least one of the first source of magnetic flux and the second source of magnetic flux may be an electromagnet. Alternatively, at least one of the first source of magnetic flux and the second source of magnetic flux may be a high-field-strength, permanent magnet. The first source of magnetic flux may be a first magnet, for example, first magnet **210**, composed of the material NdFeB and the second source of magnetic flux may be a second magnet, for example, second magnet **230**, composed of the material NdFeB. The NdFeB material may have a grade between about grade 48 and about grade 54; the NdFeB material may also have a grade of about grade 50.

With further reference to FIG. **2**B, in accordance with an embodiment of the present invention, the first source has first end pole **212** disposed proximate the first portion **222** of the gap **202**, and the second source has a second end pole **232** disposed proximate the first portion **222** of the gap **202**; the first and second end poles have **212** and **232** the same polarity, for example, both are north poles, or alternatively, both are south poles. The bulk eraser **201** also includes: a first pole piece **240**, which has a first pole-tip portion **242** and is disposed on the first end pole **212** in proximity to the first portion **222** of the gap **202**; a second pole piece **250**, which has a second pole-tip portion **252** and is disposed on the second end pole **232** in proximity to the second portion **224** of the gap **202**; and, a third pole piece **260**, which has third pole-tip portion **262** and is disposed proximate to the second portion **224** of the gap **202**. The first pole-tip portion **242**, the second pole-tip portion **252**, and the third pole-tip portion **262** define the second portion **224** of the gap **202** that is located between the first pole-tip portion **242**, the second pole-tip portion **252**, and the third pole-tip portion **262** and are configured such that magnetic-flux density in the second portion **224** of the gap **202** lies substantially parallel to a plane of the magnetic-recording disk, for example, magnetic-recording disk **120**, to erase recorded information from a portion of the magnetic-recording disk when the HDD, for example, HDD **100**, is inserted into the second portion **224** of the gap **202**. As used herein, the term "lies substantially parallel to a plane of the magnetic-recording disk" means that the plane of the magnetic-recording disk is aligned parallel to the plane of the magnetic-flux density within the manufacturing tolerances for inserting the HDD **100** into the bulk eraser **201** and for providing magnetic-flux density within the bulk eraser that is about oriented within a plane in the second portion **224** of the gap **202**.

With further reference to FIG. **2**B, in accordance with an embodiment of the present invention, two trihedrals **204** and **206** are shown. Trihedral **204** is located at the center of the front of the first portion **222** of the gap **202**. Trihedral **204** includes three vectors **204***a*, **204***b* and **240***c* orthogonally disposed with respect to one another in a right-handed configuration. Vectors **204***a* and **204***b* lie in a plane disposed in the center of the gap **202** halfway between the first end pole **212** and the second end pole **232** and separates the top of the gap **202** from the bottom of the gap **202**; the plane defined by the vectors **204***a* and **204***b* lies substantially parallel to a plane of the magnetic-recording disk of the HDD when inserted into the gap to erase recorded information on the magnetic-recording disk. As used herein, the phrase "lies substantially parallel to a plane of the magnetic-recording disk" means about parallel with the plane of the magnetic recording disk within the manufacturing tolerances for insertion of the HDD into the bulk eraser **201**, and for fabricating a bulk eraser. Vectors **204***b* and **204***c* lie in a median plane that bisects the gap **202** into two symmetrical halves, a left half and a right half, when viewed from the front of the gap **202**. Thus, vector **204***b* lies on a line down the center of the gap **202**, which lies in a substantially radial direction, for example, radial direction **174**, of the portion of the magnetic-recording disk in the HDD when inserted into the gap to erase recorded information on the magnetic-recording disk. As used herein, the phrase "lies in a substantially radial direction" means about coincidently with the radial direction within the manufacturing tolerances for insertion of the HDD into the bulk eraser **201**, and for fabricating a bulk eraser. Vector **204***c* lies substantially perpendicular to the plane of the magnetic-recording disk of the HDD when inserted into the gap to erase recorded information on the magnetic-recording disk and is about parallel to the direction of the axis of the spindle on which the disk-stack is mounted. As used herein, the phrase "lies substantially perpendicular to the plane of the magnetic-recording disk" means about perpendicularly to the plane of the magnetic-recording disk within the manufacturing tolerances for insertion of the HDD into the bulk eraser **201**, and for fabricating a bulk eraser. Vector **204***a* lies perpendicular to the median plane defined by vectors **204***b* and **204***c*; vector **204***a* and vector **204***c* lie in a plane at the front of the gap **202**, which is parallel to the front side, for example, front side **102**, of the HDD when inserted into the gap to erase recorded information on the magnetic-recording disk. The distance that separates the front plane of the gap **202** defined by the vectors **204***a* and **204***c* from the front side of the HDD is referred to by the term of art "stroke length," which is a measure of the distance that the HDD is inserted into the gap **202** of the bulk eraser, for example, bulk eraser **201**.

With further reference to FIG. **2**B, in accordance with an embodiment of the present invention, trihedral **206** is similarly located at the center of the front of the second portion

224 of the gap 202. Trihedral 206 includes three vectors 206*a*, 206*b* and 240*c* orthogonally disposed with respect to one another in a right-handed configuration. Vectors 206*a* and 206*b* lie in the same plane as vectors 204*a* and 204*b* that is disposed in the center of the gap 202 halfway between the first end pole 212 and the second end pole 232 and separates the top of the gap 202 from the bottom of the gap 202. Thus, the plane defined by the vectors 206*a* and 206*b* also lies substantially parallel to a plane of the magnetic-recording disk of the HDD when inserted into the gap to erase recorded information on the magnetic-recording disk. Vectors 206*b* and 206*c* lie in the same plane as vectors 204*a* and 204*b* that is the median plane that bisects the gap 202 into two symmetrical halves, a left half and a right half, when viewed from the front of the gap 202. Thus, vector 206*b* also lies on a line down the center of the gap 202, which lies in a substantially radial direction, for example, radial direction 174, of the portion of the magnetic-recording disk in the HDD when inserted into the gap to erase recorded information on the magnetic-recording disk. Similar to vector 204*c*, vector 206*c* lies substantially perpendicular to the plane of the magnetic-recording disk of the HDD when inserted into the gap to erase recorded information on the magnetic-recording disk and is about parallel to the direction of the axis of the spindle on which the disk-stack is mounted. Vector 206*a* lies perpendicular to the median plane defined by vectors 206*b* and 206*c*; vector 206*a* and vector 206*c* lie in a plane at the front of the second portion 224 of the gap 202 and in the back of the first portion 222 of the gap 202, which is located about where the magnetic-flux density becomes sufficient to erase recorded information from the magnetic-recording disk.

With further reference to FIG. 2B, in accordance with an embodiment of the present invention, the first pole-tip portion 242, the second pole-tip portion 252, and the third pole-tip portion 262 are configured such that the magnetic-flux density in the second portion 224 of the gap 202 lies in a substantially radial direction, for example, radial direction 174, of the portion of the magnetic-recording disk in the HDD from which recorded information is erased. The first pole-tip portion 242, the second pole-tip portion 252, and the third pole-tip portion 262 are configured to suppress magnetic-flux density in a third portion of the gap 202 such that the magnetization of the drive-motor magnet of the drive motor in the HDD is not degraded when located within the third portion. The first pole-tip portion 242, the second pole-tip portion 252, and the third pole-tip portion 262 are configured to confine the magnetic-flux density in the second portion 224 of the gap 202 to a region of the magnetic-recording disk sufficiently localized such that strength of eddy currents in the magnetic-recording disk are suppressed when rotating the magnetic-recording disk to erase recorded information on the magnetic-recording disk.

With further reference to FIG. 2B, in accordance with an embodiment of the present invention, the first pole-tip portion 242 may be configured to direct magnetic flux emanating from the first pole-tip portion 242 to the third pole-tip portion 262 and to concentrate magnetic-flux density in the second portion 224 of the gap 202 substantially parallel to a plane of the magnetic-recording disk in the HDD in the second portion 224 of the gap 202. For example, the first pole-tip portion 242 may be tapered to concentrate magnetic-flux density in the second portion 224 of the gap 202 substantially parallel to a plane of the magnetic-recording disk in the HDD in the second portion 224 of the gap 202. The second pole-tip portion 252 may be configured to direct magnetic flux emanating from the second pole-tip portion 252 to the third pole-tip portion 262 and to concentrate magnetic-flux density in the second portion 224 of the gap 202 substantially parallel to a plane of the magnetic-recording disk in the HDD in the second portion of the gap. For example, the second pole-tip portion 252 may also be tapered to concentrate magnetic-flux density in the second portion 224 of the gap 202 substantially parallel to a plane of the magnetic-recording disk in the HDD in the second portion 224 of the gap 202. The third pole-tip portion 262 may be configured to receive the magnetic flux emanating from the first pole-tip portion 242 and the magnetic flux emanating from the second pole-tip portion 252 and to concentrate magnetic-flux density in the second portion 224 of the gap 202 substantially parallel to a plane of the magnetic-recording disk in the HDD in the second portion 224 of the gap 202.

With further reference to FIG. 2B, in accordance with an embodiment of the present invention, alternatively, the third pole-tip portion 262 maybe configured to direct a second portion of magnetic flux emanating from the third pole-tip portion 262 to the first pole-tip portion 242 and to direct a second portion of magnetic flux emanating from the third pole-tip portion 262 to the second pole-tip portion 252 and to concentrate magnetic-flux density in the second portion 224 of the gap 202 substantially parallel to a plane of the magnetic-recording disk in the HDD in the second portion 224 of the gap 202. The first pole-tip portion 242 may be configured to receive the second portion of magnetic flux emanating from the third pole-tip portion 262 and to concentrate magnetic-flux density in the second portion 224 of the gap 202 substantially parallel to a plane of the magnetic-recording disk in the HDD in the second portion 224 of the gap 202. For example, the first pole-tip portion 242 may be tapered to concentrate magnetic-flux density in the second portion 224 of the gap 202 substantially parallel to a plane of the magnetic-recording disk in the HDD in the second portion 224 of the gap 202. The second pole-tip portion 252 may be configured to receive the second portion of magnetic flux emanating from the third pole-tip portion 262 and to concentrate magnetic-flux density in the second portion 224 of the gap 202 substantially parallel to a plane of the magnetic-recording disk in the HDD in the second portion 224 of the gap 202. For example, the second pole-tip portion 252 may also be tapered to concentrate magnetic-flux density in the second portion 224 of the gap 202 substantially parallel to a plane of the magnetic-recording disk in the HDD in the second portion 224 of the gap 202.

With further reference to FIG. 2A, in accordance with an embodiment of the present invention, the bulk eraser 201 further includes yoke 270 having first yoke portion 270*a* and second yoke portion 270*b*. The first yoke portion 270*a* is magnetically coupled with the first source of magnetic flux, for example, first magnet 210, and the third pole piece 260. The second yoke portion 270*b* is magnetically coupled with the second source of magnetic flux, for example, second magnet 230, and the third pole piece 260. The yoke 270 is configured to suppress stray magnetic flux and to increase magnetic-flux density in the second portion 224 of the gap 202.

With further reference to FIGS. 1 and 2A-2B, in accordance with an embodiment of the present invention, the bulk eraser 201 may be used in manufacturing of the HDD 100 to erase recorded information on the magnetic-recording disk 120. In manufacturing of the HDD 100, the bulk eraser 201 is provided that produces magnetic-flux density in a second portion 224 of the gap 202 that is sufficient to erase recorded information on the magnetic-recording disk, for example, magnetic-recording disk 120. Also, a HDD, for example, HDD 100, is provided; the HDD has an enclosure, a disk-stack having at least one magnetic-recording disk **120** rotatably mounted on a spindle **126** and a drive motor; the drive motor has a rotor such that the rotor is attached to the spindle for rotating the magnetic-recording disk **120** inside the enclosure. The plurality of magnets, for example, magnets **210** and **230**, and a structure of the bulk eraser **201** are configured such that magnetic-flux density is oriented substantially parallel to a central plane, defined by vectors **206***a* and **206***b*, in the second portion **224** of the gap **202** and in a substantially radial direction, for example, radial direction **174**, which is aligned with the vector **206***b*, of a portion of the magnetic-recording disk **120** when the HDD **100** is inserted into the second portion **224** of the gap **202**. The magnetic-recording disk **120** is rotated in the HDD **100**. The HDD **100** is inserted into the second portion **224** of the gap **202** of the bulk eraser **201** such that a plane of the magnetic-recording disk of the HDD is oriented substantially parallel to the central plane, defined by vectors **206***a* and **206***b*, in second portion **224** of the gap **202** such that magnetic-flux density is oriented in the substantially radial direction, for example, radial direction **174**, which is aligned with the vector **206***b*, of the portion of the magnetic-recording disk. Consequently, the recorded information is erased from the portion of the magnetic-recording disk **120** in the HDD **100** located in the second portion **224** of the gap **202**. The HDD **100** may then be removed from the second portion **224** of the gap **202**.

With further reference to FIGS. **1** and **2**A-**2**B, in accordance with an embodiment of the present invention, in using the bulk eraser **201** to manufacture the HDD **100**, the pole pieces **240**, **250** and **260** of the structure of the bulk eraser **201** and pole-tip portions **242**, **252** in **262** of the pole pieces **240**, **250** and **260** are configured such that magnetic-flux density in the second portion **224** of the gap **202** is oriented substantially parallel to a central flux-propagation direction in the second portion **224** of the gap **202**. When the HDD is inserted into the second portion **224** of the gap **202** of the bulk eraser **201**, the magnetic-recording disk **120** is oriented in the HDD **100** such that a radial direction **174** of a portion of the magnetic-recording disk **120** is oriented substantially parallel to the central flux-propagation direction, for example, the direction of the vector **206***b*, in the second portion **224** of the gap **202**. Also, upon inserting the HDD **100** into the second portion of the gap, the HDD **100** is inserted with an insertion speed that is sufficient to assure complete erasure of recorded information on the magnetic-recording disk in the HDD **100**. A sufficient insertion speed into the gap **202** is less than or equal to 1 centimeter per second (cm/sec). When the HDD is removed from the second portion **224** of the gap **202** of the bulk eraser **201**, the HDD **100** is removed from the second portion **224** of the gap **202** with a removal speed that is sufficient to assure complete erasure of recorded information on the magnetic-recording disk **120** in the HDD **100**. A sufficient removal speed from the gap is less than or equal to 1 cm/sec.

With further reference to FIGS. **1** and **2**A-**2**B, in accordance with an embodiment of the present invention, when the magnetic-recording disk **120** is rotated in the HDD **100**, the magnetic-recording disk **120** is rotated in the HDD with the drive motor at a rotation speed that is sufficient to assure complete erasure of recorded information on the magnetic-recording disk **120** in the HDD **100** without stalling the drive motor. A sufficient rotation speed of the magnetic-recording disk **120** is less than or equal to 2 Hertz (Hz). When rotating the magnetic-recording disk **120** in the HDD **100** with the drive motor, the drive motor is driven by a low speed drive-motor-driver circuit on-board in the HDD **100** to provide power to the drive motor to rotate the magnetic-recording disk **120** at a slow speed to prevent stalling of the drive motor. When rotating the magnetic-recording disk in the HDD **100** with the drive motor, power is provided to the low speed drive-motor-driver circuit on-board in the HDD **100**. This power may be provided to the low speed drive-motor-driver circuit on-board in the HDD **100** by attaching a cable and connector, attached to an external power supply, to the HDD **100**.

With further reference to FIGS. **1** and **2**A-**2**B, in accordance with an embodiment of the present invention, in using the bulk eraser **201** to manufacture the HDD **100**, the second portion **224** of the gap **202** is provided with sufficient clearance to accommodate the HDD **100** upon inserting and removing the HDD **100** from the second portion **224** of the gap **202**. A sufficient clearance of the second portion **224** of the gap **202** may be less than or equal to about 2.6 centimeters (cm). Moreover, a fixture may be provided for rapidly and reproducibly aligning the HDD **100** in the second portion **224** of the gap **202**. The fixture limits a stroke length upon inserting the HDD **100** into the second portion **224** of the gap **202** such that the magnetic-flux density produced by the plurality of magnets, for example, magnets **210** in **230**, and the structure is configured to erase recorded information from the portion of the magnetic-recording disk **120** disposed in the second portion **224** of the gap **202** without degrading the magnetization of a drive-motor magnet in the drive motor disposed in a third portion of the gap **202**. In addition, two magnets, for example, magnets **210** in **230**, of the plurality of magnets are disposed with opposing polarity across the first portion **222** of the gap **202**; a separation between the two magnets of the plurality of magnets may be adjusted in the first portion **222** of the gap **202** such that the first portion **222** of the gap **202** has sufficient clearance to accommodate the HDD **100** upon inserting and removing the HDD **100** from the second portion **224** of the gap **202** and the magnetic-flux density produced by the plurality of magnets and the structure is sufficient to erase recorded information from a plurality of magnetic-recording disks of the disk-stack when the HDD **100** is inserted into the second portion **224** of the gap **202**.

Consequently, a HDD **100** manufactured using a bulk eraser **201** for erasing recorded information on a magnetic-recording disk **120** in a HDD **100** lies within the spirit and scope of embodiments of the present invention. In accordance with embodiments of the present invention, the HDD **100** includes at least one magnetic-recording disk **120** in a disk-stack of the HDD **100** from which recorded information has been erased by the bulk eraser **201**. For example, in a re-work procedure of the manufacturing process the recorded information may be a first servo pattern erased by the bulk eraser to prepare the magnetic-recording disk to write a second servo pattern to replace the first servo pattern. Moreover, the recorded information may be recorded data on the magnetic-recording disk **120** in the HDD **100**, which is erased to preserve the security of the recorded data.

With reference now to FIG. **3**A, in accordance with an embodiment of the present invention, a plot **300**A of the distribution **301** of magnetic-flux density at the gap **202** of the bulk eraser **201** of FIGS. **2**A and **2**B is shown. FIG. **3**A shows the distribution **301** of magnetic-flux density with respect to a disk-stack, including magnetic-recording disks **320**, **322**, **324** and **326**, in a HDD, for example, HDD **100**. The magnetic-recording disk **326** at the top of the disk-stack may be identified with the magnetic-recording disk **120** of FIG. **1**. The magnetic-flux density in the distribution **301** is indicated by the magnitude and direction of the arrows shown in FIG. **3**A, for example, the magnetic-flux-density vector **310**. The plane of FIG. **3**A coincides with the median plane defined by vectors **206***b* and **206***c* and defined by vectors **204***b* and **204***c* of

FIG. 2A. The traces of several planes are indicated, which serve to show the various portions of the gap **202**. The trace of the plane **3**B-**3**B corresponds to a plane parallel to the plane of the magnetic-recording disk **324**; the plane **3**B-**3**B also corresponds to the plane of the FIG. **3**B, subsequently described. The trace of plane A-A indicated by a dashed line coincides with the plane at the front of the second portion **224** of the gap **202** and in the back of the first portion **222** of the gap **202**, in which vector **206***a* and vector **206***c* lie as shown in FIG. **2**A. The trace of plane B-B indicated by a dashed line coincides with the plane at the front of the first portion **222** of the gap **202**, in which vector **204***a* and vector **204***c* lie as shown in FIG. **2**A. Thus, the first portion **222** of the gap **202** lies between the plane A-A and the plane B-B; the first portion **222** of the gap **202** lies between the outer surfaces of the first pole piece **240** in the second pole piece **250**; these outer surfaces are indicated by the arrow-heads of the vertical arrow indicating the location of the first portion **222** of the gap **202**, which coincide with the boundaries of a relatively feel free area shown at the center of FIG. **3**A. The trace of plane C-C indicated by a dashed line coincides with the plane in the back of the second portion **224** of the gap **202**, which lies at the face of the third pole-tip portion **262**. Thus, the second portion **224** of the gap **202**, indicated by the double headed arrow, lies between the plane A-A and the plane C-C. As shown in FIG. **3**A, the distribution **301** of magnetic-flux density in the second portion **224** of the gap **202** is intense as indicated by the magnitude and crowding of the arrows associated with the magnetic-flux-density vectors. As shown in FIG. **3**A, magnetic-flux density in the second portion **224** of the gap **202** defined by first pole-tip portion **242**, the second pole-tip portion **252**, and the third pole-tip portion **262** and located between the first pole-tip portion **242**, the second pole-tip portion **252**, and the third pole-tip portion **262** lies substantially parallel to a plane of the magnetic-recording disk, for example, to plane **3**B-**3**B of the magnetic-recording disks **324**, as well as to each of the planes of the remaining magnetic-recording disks **320**, **324** and **326** of the disk-stack, to erase recorded information from a portion of the magnetic-recording disk when the HDD, for example, HDD **100**, is inserted into the second portion **224** of the gap **202**.

With further reference to FIG. **3**A and as shown therein, in accordance with an embodiment of the present invention, the end poles **212** and **232** of the first magnet **210** and the second magnet **230** are south poles so that the magnetic-flux-density vectors are directed towards the first pole-tip portion **242** and the second pole-tip portion **252** from the third pole-tip portion **262**. Thus, the third pole-tip portion **262** is configured to direct a first portion of magnetic flux emanating from the third pole-tip portion **262** to the first pole-tip portion **242** and to direct a second portion of magnetic flux emanating from the third pole-tip portion **262** to the second pole-tip portion **252** and to concentrate magnetic-flux density in the second portion **222** of the gap **202** substantially parallel to a plane of the magnetic-recording disk, for example, to plane **3**B-**3**B of the magnetic-recording disks **324**, in the HDD in the second portion **222** of the gap **202**. The first pole-tip portion **242** is configured to receive the first portion of magnetic flux emanating from the third pole-tip portion **262** and to concentrate magnetic-flux density in the second portion **224** of the gap **202** substantially parallel to a plane of the magnetic-recording disk, for example, each of the magnetic-recording disks **320**, **322**, **324** and **326** of the disk-stack, in the HDD **100** in the second portion **224** of the gap **202**. The second pole-tip portion **252** is configured to receive the second portion of magnetic flux emanating from the third pole-tip portion **262** and to concentrate magnetic-flux density in the second portion **224** of the gap **202** substantially parallel to a plane of the magnetic-recording disk, for example, to plane **3**B-**3**B of the magnetic-recording disks **324**, in the HDD **100** in the second portion **224** of the gap **202**.

Alternatively, the end poles **212** and **232** of the first magnet **210** and the second magnet **230** may be north poles so that the magnetic-flux-density vectors are directed towards the third pole-tip portion **262** from the first pole-tip portion **242** and the second pole-tip portion **252**. Thus, the first pole-tip portion **242** may be configured to direct magnetic flux emanating from the first pole-tip portion **242** to the third pole-tip portion **262** and to concentrate magnetic-flux density in the second portion **224** of the gap **202** substantially parallel to a plane of the magnetic-recording disk, for example, to plane **3**B-**3**B of the magnetic-recording disks **324**, in the HDD **100** in the second portion **224** of the gap **202**. The second pole-tip portion **252** may be configured to direct magnetic flux emanating from the second pole-tip portion **252** to the third pole-tip portion **262** and to concentrate magnetic-flux density in the second portion **224** of the gap **202** substantially parallel to a plane of the magnetic-recording disk, for example, each of the magnetic-recording disks **320**, **322**, **324** and **326** of the disk-stack, in the HDD **100** in the second portion **224** of the gap **202**. The third pole-tip portion **262** may be configured to receive the magnetic flux emanating from the first pole-tip portion **242** and the magnetic flux emanating from the second pole-tip portion **252** and to concentrate magnetic-flux density in the second portion **224** of the gap **202** substantially parallel to a plane of the magnetic-recording disk, for example, to plane **3**B-**3**B of the magnetic-recording disks **324**, in the HDD **100** in the second portion **224** of the gap **202**.

With further reference to FIG. **3**A, in accordance with an embodiment of the present invention, the trace of plane D-D indicated by a dashed line coincides with a plane tangent to the surface of a drive-motor magnet **330** proximate to the second portion **224** of the gap **202**. The trace of plane E-E indicated by a dashed line coincides with a plane tangent to the surface of a drive-motor magnet **334** proximate to the front of the first portion **222** of the gap **202**. The space in the first portion **222** of the gap **202** between the front of the first portion **222** of the gap **202**, plane B-B, and plane D-D defines the third portion **340** of the gap **202**. The magnetic-flux density produced by the plurality of magnets and the structure is configured to erase recorded information from the magnetic-recording disk disposed in the second portion **224** of the gap **202** without degrading the magnetization of a drive-motor magnet, for example, drive-motor magnet **330** and drive-motor magnet **334**, in the drive motor disposed in the third portion **340** of the gap **202**. Moreover, the first pole-tip portion **242**, the second pole-tip portion **252**, and the third pole-tip portion **262** are configured to suppress magnetic-flux density in a third portion **340** of the gap **202** such that the magnetization of the drive-motor magnet, for example, drive-motor magnet **330** and drive-motor magnet **334**, of the drive motor in the HDD is not degraded when located within the third portion **340**. The trace of plane F-F indicated by a dashed line coincides with the front side **102** of the HDD **100**. The stroke length **342** is the distance between the plane F-F and the plane B-B indicated by the double headed arrow labeled **342** and determines the maximum safe distance that the HDD **100** can be inserted into the gap **202** without erasing the drive-motor magnets, for example, drive-motor magnet **330** and drive-motor magnet **334**.

With reference now to FIG. **3**B, in accordance with an embodiment of the present invention, a plot **300**B of the distribution **302** of magnetic-flux density and contours **360**, **362**, **364**, **368** and **370** of constant magnitude of magnetic-flux density in the plane 3B-3B of one magnetic-recording disk **324** of the disk-stack of FIG. **3**A is shown. In contrast with FIG. **3**A, the magnetic-flux-density vectors are directed towards the third pole-tip portion **262**, as for the case when the first end pole **212** and the second end pole **232** are north poles instead of the south poles as for FIGS. **2**A, **2**B and **3**A; this change of polarity is of little consequence for the description, as the bulk eraser **201** can work with end poles of either polarity are previously described, as long as the end poles **212** and **232** have the same polarity. FIG. **3**B shows a portion of the disk wherein the magnetic-flux density is sufficient to erase recorded information. The magnetic-flux density in the distribution **302** is indicated by the magnitude and direction of the arrows shown in FIG. **3**A, for example, the magnetic-flux-density vector **312**. The plane of FIG. **3**A coincides with the plane 3B-3B of the magnetic-recording disk **324** of FIG. **3**A. Several contours **360**, **362**, **364**, **368** and **370** of constant magnitude of magnetic-flux density are indicated. The traces of several planes, for example, planes A-A, B-B, C-C, D-D, E-E and F-F, are indicated, which serve to identify the various portions of the gap **202** as previously described for FIG. **3**B. The magnetic-recording disk **324** has a radial direction **350**, an OD track **354** and an ID track **352**. The outside diameter **338** of the drive motor is shown as the drive motor is disposed in the gap **202** of the bulk eraser **201**. Contours closer to the trace of plane C-C, which lies at the face of the third pole-tip portion **262**, correspond to magnetic-flux-density vectors that have greater magnitude. For example, contour **360** has the greatest magnitude and contour **368** has the least magnitude; this is also indicated by the density of magnetic-flux-density vectors located within the contour; for example, contour **368** shows virtually no magnetic-flux density vectors of measurable magnitude. The contour **370** corresponds to a magnetic-flux density sufficient to erase a portion of the magnetic-recording disk **324**; the portion of the magnetic-recording disk **324** that lies between contour **370** and the outside perimeter of the magnetic-recording disk **324** defines the portion of the magnetic-recording disk **324** where the magnetic-flux density is sufficient to erase recorded information on the magnetic-recording disk **324** in the disk-stack of the HDD **100**.

With further reference to FIG. **3**B, in accordance with an embodiment of the present invention, the magnetic-flux-density vectors in the portion of the magnetic-recording disk where the magnetic-flux density is sufficient to erase recorded information are such that the magnetic-flux density in the second portion **224** of the gap **202** lies in the substantially radial direction **350** of the portion of the magnetic-recording disk **324** in the HDD **100**. As used herein, the phrase "lies in the substantially radial direction" means that the directions of the magnetic-flux-density vectors are aligned as a whole as parallel as to the radial direction as can be obtained within manufacturing tolerances. Because an individual magnetic-flux-density vector may deviate from the radial direction **350** and the magnetic-flux-density vectors are symmetrically disposed about the radial direction **350**, on the average, the deviations of all the magnetic-flux-density vectors in the second portion **224** of the gap **202** from the radial direction **350** is about zero, when the magnetic-flux density in the second portion **224** of the gap **202** lies in the substantially radial direction **350** of the portion of the magnetic-recording disk **324**. The stroke length **342** is also shown indicating the relative disposition of the HDD **100** in the distribution **302** of the magnetic-flux density in the gap **202** of the bulk eraser **201**. As the plane **3**B-**3**B does not coincide with plane disposed in the center of the gap **202** halfway between the first end pole **212** and the second end pole **232**, which separates the top of the gap **202** from the bottom of the gap **202**, defined by the vectors **204***a* and **204***b* and vectors **206***a* and **20***b* of FIG. **2**B, the corresponding projection vectors of these vectors onto the plane **3**B-**3**B are shown: vectors **304***a* and **304***b* and vectors **306***a* and **306***b*, respectively. Therefore, vectors **304***a* and **306***a* lie in the same median plane as vectors **204***a* and **206***a* that bisects the gap **202** into two symmetrical halves, a left half and a right half, when viewed from the front of the gap **202**. As the median plane of the bulk eraser is located at a central portion of the gap it contains a central flux-propagation direction for each disk in the disk-stack; a radial direction **350** of a portion of the magnetic-recording disk **324** is oriented substantially parallel to the central flux-propagation direction, for example, the direction of the vector **306***b*, in the second portion **224** of the gap **202**. Even though the magnetic-recording disk has a plurality of radial directions, a radial direction of a portion of the magnetic-recording disk, as used herein, refers to a radial direction substantially aligned within the median plane of the bulk eraser as shown in FIG. **3**B. Therefore, such a radial direction, as used herein, may provide a maximum stroke length that precludes erasure of a drive-motor magnet, yet allows the greatest portion of a magnetic-recording disk to be disposed within a portion of the distribution of magnetic-flux density sufficient to erase the portion of the magnetic-recording disk.

With further reference to FIG. **3**B, in accordance with an embodiment of the present invention, the plurality of magnets, for example, magnets **210** in **230**, and the structure are configured to direct the magnetic-flux density in a substantially radial direction, for example, radial direction **350**, of the portion of the magnetic-recording disk, for example, magnetic-recording disk **324**, in the HDD **100** in the second portion **224** of the gap **202**. The intensity of a field component of the magnetic-flux density directed along the radial direction, for example, radial direction **350**, in the plane of the magnetic-recording disk, for example, magnetic-recording disk **324**, produced by the plurality of magnets and the structure has a gradient as a function of distance along the radial direction, for example, radial direction **350**, at a transition region between the second portion **224** of the gap **202** and the third portion **340** of the gap **202** such that the gradient allows erasing recorded information from the magnetic-recording disk in close proximity to the drive-motor magnet in the drive motor, for example, indicated by the outside diameter **338** of the drive motor, without degrading the magnetization of the drive-motor magnet, for example, drive-motor magnets **330** in **334**, in the drive motor. As shown in FIG. **3**B, the transition region lies substantially within the first portion **222** of the gap **202** between plane A-A and plane D-D; however, as shown in FIG. **3**B the transition region may extend from plane A-A somewhat into the second portion **224** of the gap **202** to the contour **370** corresponding to magnetic-flux density sufficient to erase a portion of the magnetic-recording disk, for example, magnetic-recording disk **324**. Moreover, the first pole-tip portion **242**, the second pole-tip portion **252**, and the third pole-tip portion **262** are configured such that the magnetic-flux density in the second portion **224** of the gap **202** lies in a substantially radial direction, for example, radial direction **350**, of the portion of the magnetic-recording disk, for example, magnetic-recording disk **324**, in the HDD **100**, which is indicated by the numerous magnetic-flux-density vectors lying parallel to the radial direction **350** in FIG. **3**B. Moreover, the plurality of magnets, for example, magnets **210** in **230**, and the structure are configured to produce the magnetic-flux density such that the magnetic-flux density is applied to a localized portion of the magnetic-recording disk, for example, the portion, without limitation thereto, of the magnetic-recording disk **324** that lies between contour **370** and the outside perimeter of the magnetic-recording disk **324**, to suppress eddy currents in the magnetic-recording disk, for example, magnetic-recording disk **324**, of the HDD **100**.

Sub-Section B: Physical Description of Embodiments of the Present Invention for a Bulk Eraser Including at Least Three Magnets Configured for Erasing Recorded Information

With reference now to FIG. **4**A, in accordance with an embodiment of the present invention, a perspective view **400**A of an alternative embodiment of a bulk eraser **401** is shown. FIG. **4**A shows at least three magnets **410**, **430** and **460** and a structure magnetically coupled with the at least three magnets **410**, **430** and **460** to produce magnetic-flux density in a gap sufficient to erase recorded information from a portion of the magnetic-recording disk, for example, magnetic-recording disk **120**, in a disk-stack of the HDD, for example, HDD **100**. The bulk eraser **401** includes at least three magnets **410**, **430** and **460** and a structure magnetically coupled with the at least three magnets **410**, **430** and **460** to produce magnetic-flux density in a gap. In one embodiment of the present invention, as shown in FIG. **4**A, the structure may include a yoke **480** including a first yoke portion **470***a* and a second yoke portion **470***b*, a first shield **440**, a second shield **450** and a pole piece **470** having a third pole-tip portion **472**. The first magnet **410** has a first pole-tip portion **416**; the second magnet **430** has a second pole-tip portion **436**; and the pole piece **470** has a third pole-tip portion **472**, all of which serve to produce magnetic-flux density in a gap. The gap, similar to gap **202** of FIGS. **2**A and **2**B, has a first portion **422**, a second portion **424** and a third portion, similar to third portion **340** of FIGS. **3**A and **3**B. The first magnet **410** and a second magnet **430** are disposed with opposing end poles **412** and **432**, respectively, of the same polarity across the first portion **422** of the gap. The direction **414** of the B-field, the magnetic-flux density, as well as the magnetization field, in the first magnet **410** is shown by the upper arrow. The upper arrow indicates that a first end pole **412** proximate the first portion **422** of the gap has the polarity of a north pole, and the end pole of the first magnet **410** opposite the north pole has the polarity of a south pole. The arrow also indicates the direction of magnetic flux propagation through the first magnet **410**. Similarly, the direction **434** of the B-field, the magnetic-flux density, as well as the magnetization field, in the second magnet **430** is shown by the lower arrow. The lower arrow indicates that a second end pole **432** proximate first portion **422** of the gap has the polarity of a north pole, and the end pole of the second magnet **430** opposite the north pole has the polarity of a south pole. The arrow also indicates the direction of magnetic flux propagation through the second magnet **430**. The direction **464** of the B-field, the magnetic-flux density, as well as the magnetization field, in the third magnet **460** is shown by the horizontal arrow. The horizontal arrow indicates that a third end pole **462** proximate the first portion **422** of the gap has the polarity of a south pole, and the end pole of the third magnet **460** opposite the south pole has the polarity of a north pole. The arrow also indicates the direction of magnetic flux propagation through the first magnet **460**.

With further reference to FIG. **4**A, in accordance with an embodiment of the present invention, at least one of the at least three magnets **410**, **430** and **460** may be a high-field-strength, permanent magnet, which may be composed of a material such as neodymium iron boron, NdFeB. The grade of the NdFeB material used for at least one magnet of the three magnets **410**, **430** and **460** may have a grade between about grade 48 and about grade 54; however, a grade of about grade 50 provides a very stable magnet. The at least three magnets **410**, **430** and **460** and the structure are configured to produce a magnetic-flux density in the second portion **424** of the gap sufficient to erase recorded information from a portion of at least one magnetic-recording disk, for example, magnetic-recording disk **120**, in a disk-stack of the HDD **100** when the HDD **100** is inserted into the second portion **424** of the gap. The at least three magnets **410**, **430** and **460** and the structure are configured to direct the magnetic-flux density in a substantially radial direction of the portion of the magnetic-recording disk, similar to radial direction **350** of the magnetic-recording disk **324** of FIG. **3**B as previously described, in the HDD **100** in the second portion **424** of the gap.

With further reference to FIG. **4**A and as previously described in FIGS. **3**A and **3**B for similar embodiments of the present invention, in accordance with an embodiment of the present invention, the third magnet **460** is disposed across the second portion **424** of the gap opposite the first magnet **410** and the second magnet **430** with a end pole of the third magnet **462** of opposite polarity to the end poles **412** and **432** of the first magnet **410** and the second magnet **430**, respectively. The at least three magnets **410**, **430** and **460** and the structure are configured to produce a magnetic-flux density sufficient to erase recorded information from portions of a plurality of magnetic-recording disks, for example, similar to disks **320**, **322**, **324** in **326** as previously described for FIG. **3**A, in a disk-stack of the HDD **100**. The at least three magnets **410**, **430** and **460** and the structure are configured to produce the magnetic-flux density such that the magnetic-flux density is applied to a localized portion of the magnetic-recording disk to suppress eddy currents in the magnetic-recording disk of the HDD **100**, as previously described above. The magnetic-flux density produced by the at least three magnets **410**, **430** and **460** and the structure is configured to erase recorded information from the magnetic-recording disk, for example, similar to magnetic-recording disk **324**, disposed in the second portion **424** of the gap without degrading the magnetization of a drive-motor magnet, for example, similar to drive-motor magnets **330** and **334**, in the drive motor disposed in the third portion of the gap, for example, similar to the third portion **340** described above for FIGS. **3**A and **3**B. The intensity of a field component of the magnetic-flux density directed along the radial direction, for example, similar to radial direction **350**, in the plane of the magnetic-recording disk, for example, similar to magnetic-recording disk **324**, produced by the at least three magnets **410**, **430** and **460** and the structure has a gradient as a function of distance along the radial direction at a transition region, similar to the transition region described above for FIG. **3**B, between the second portion **424** of the gap and the third portion, for example, similar to the third portion **340** described above for FIGS. **3**A and **3**B, of the gap such that the gradient allows erasing recorded information from the magnetic-recording disk in close proximity to the drive-motor magnet, for example, similar to drive-motor magnets **330** and **334**, in the drive motor without degrading the magnetization of the drive-motor magnet in the drive motor.

With reference now to FIGS. **4**B and **4**C, in accordance with an embodiment of the present invention, an elevation view **400**B of a left side and an elevation view **400**C of a front side of the bulk eraser **401** of FIG. **4**A are shown. The bulk eraser **401** includes a first magnet **410** disposed opposite a second magnet **430** across a first portion **422** of a gap, for example, similar to gap **202** shown in FIG. **2**A. The first magnet **410** has first end pole **412** disposed proximate the first portion **422** of the gap and first pole-tip portion **416** disposed proximate the second portion **424** of the gap. The second magnet **430** has the second end pole **432** disposed proximate the first portion **422** of the gap and second pole-tip portion **436** disposed proximate the second portion **424** of the gap. The first and second end poles **412** and **432** have same polarity, as described above. The bulk eraser **401** also includes a first magnetic shield **440**, which is disposed on the first end pole **412** in proximity to the first portion **422** of the gap, and a second magnetic shield **450**, which is disposed on the second end pole **432** in proximity to the first portion **422** of the gap. The bulk eraser **401** also includes a third magnet **460**, which is disposed proximate to the second portion **424** of the gap. The third magnet **460** has a third end pole **462**, which is disposed proximate the second portion **424** of the gap. The third end pole **462** has a polarity opposite to the first and second end poles **412** and **432**. The bulk eraser **401** also includes the pole piece **470**, which is disposed on the third end pole **462** in proximity to the second portion **424** of the gap. The pole piece **470** has a third pole-tip portion **472**. The first pole-tip portion **416**, the second pole-tip portion **436**, and the third pole-tip portion **472** define a second portion **424** of the gap located between the first pole-tip portion **416**, the second pole-tip portion **436**, and the third pole-tip portion **472** and are configured such that magnetic-flux density in the second portion **424** of the gap lies substantially parallel to a plane of the magnetic-recording disk, for example, similar to plane **3**B-**3**B of the magnetic-recording disks **324** as shown in FIG. **3**B, in a disk-stack of the hard-disk drive to erase recorded information from a portion on the magnetic-recording disk, for example, similar to the portion of the magnetic-recording disk **324** that lies between contour **370** and the outside perimeter of the magnetic-recording disk **324** as shown in FIG. **3**B, when the hard-disk drive is inserted into the second portion **424** of the gap. The first pole-tip portion **416**, the second pole-tip portion **436**, and the third pole-tip portion **472** are configured such that the magnetic-flux density in the second portion **424** of the gap lies in a substantially radial direction, for example, similar to radial direction **350** as shown in FIG. **3**B, of the portion of the magnetic-recording disk of the hard-disk drive. The first pole-tip portion **416**, the second pole-tip portion **436**, and the third pole-tip portion **472** are configured to suppress magnetic-flux density in a third portion of the gap, for example, similar to the third portion **340** described above for FIGS. **3**A and **3**B, such that the magnetization of the drive-motor magnet of the drive motor in the hard-disk drive is not degraded when located within the third portion.

With further reference to FIGS. **4**B and **4**C, in accordance with an embodiment of the present invention, the end poles **412** and **432** of the first magnet **410** and the second magnet **430** are north poles so that the magnetic-flux-density vectors are directed towards the third pole-tip portion **472** from the first pole-tip portion **416** and the second pole-tip portion **436**. Thus, the first pole-tip portion **416** is configured to direct magnetic flux emanating from the first pole-tip portion **416** to the third pole-tip portion **472** and to concentrate magnetic-flux density in the second portion **424** of the gap, similar to gap **202** shown in FIG. **2**B, substantially parallel to a plane of the magnetic-recording disk, for example, similar to plane **3**B-**3**B of the magnetic-recording disks **324**, in the HDD **100** in the second portion **424** of the gap. The second pole-tip portion **436** is configured to direct magnetic flux emanating from the second pole-tip portion **436** to the third pole-tip portion **472** and to concentrate magnetic-flux density in the second portion **424** of the gap substantially parallel to a plane of the magnetic-recording disk, for example, similar to each of the magnetic-recording disks **320**, **322**, **324** and **326** of the disk-stack shown in FIG. **3**A, in the HDD **100** in the second portion **424** of the gap. The third pole-tip portion **472** is configured to receive the magnetic flux emanating from the first pole-tip portion **416** and the magnetic flux emanating from the second pole-tip portion **436** and to concentrate magnetic-flux density in the second portion **424** of the gap substantially parallel to a plane of the magnetic-recording disk, for example, similar to plane **3**B-**3**B of the magnetic-recording disks **324**, in the HDD **100** in the second portion **424** of the gap.

Alternatively, the end poles **412** and **432** of the first magnet **410** and the second magnet **430** may be south poles so that the magnetic-flux-density vectors are directed towards the first pole-tip portion **416** and the second pole-tip portion **436** from the third pole-tip portion **472**. Thus, the third pole-tip portion **472** may be configured to direct a first portion of magnetic flux emanating from the third pole-tip portion **472** to the first pole-tip portion **416** and to direct a second portion of magnetic flux emanating from the third pole-tip portion **472** to the second pole-tip portion **436** and to concentrate magnetic-flux density in the second portion **222** of the gap, similar to gap **202** shown in FIG. **2**B, substantially parallel to a plane of the magnetic-recording disk, for example, similar to plane **3**B-**3**B of the magnetic-recording disks **324**, in the HDD in the second portion **222** of the gap. The first pole-tip portion **416** may be configured to receive the first portion of magnetic flux emanating from the third pole-tip portion **472** and to concentrate magnetic-flux density in the second portion **424** of the gap substantially parallel to a plane of the magnetic-recording disk, for example, similar to each of the magnetic-recording disks **320**, **322**, **324** and **326** of the disk-stack shown in FIG. **3**A, in the HDD **100** in the second portion **424** of the gap. The second pole-tip portion **436** may be configured to receive the second portion of magnetic flux emanating from the third pole-tip portion **472** and to concentrate magnetic-flux density in the second portion **424** of the gap substantially parallel to a plane of the magnetic-recording disk, for example, similar to plane **3**B-**3**B of the magnetic-recording disks **324**, in the HDD **100** in the second portion **424** of the gap.

With further reference to FIGS. **4**B and **4**C, in accordance with an embodiment of the present invention, the pole piece **470** is shaped to concentrate magnetic-flux density in the second portion **424** of the gap substantially parallel to the plane of the magnetic-recording disk, for example, similar to magnetic-recording disk **324** shown in FIG. **3**B, in the disk-stack of the hard-disk drive in the second portion **424** of the gap. The bulk eraser **401** further includes a yoke **480** having a first yoke portion **480***a* and a second yoke portion **480***b*. The first yoke portion **480***a* is magnetically coupled with the first magnet **410**, the third magnet **460** and the pole piece **470**. The second yoke portion **480***b* is magnetically coupled with the second magnet **430**, the third magnet **460** and the pole piece **470**. The yoke **480** is configured to suppress stray magnetic flux and to increase magnetic-flux density in the second portion **424** of the gap. Alternative embodiments of the present invention for the yoke that provide further suppression of stray magnetic flux and further increase the magnetic-flux density in the second portion **424** of the gap are shown in FIG. **5** and are next described.

With reference now to FIG. **5**, in accordance with an embodiment of the present invention, a perspective view **500** of an alternative embodiment of a bulk eraser **501** is shown. The bulk eraser **501** includes seven magnets **510**, **530**, **560**, **582**, **586**, **592** and **596** and a structure magnetically coupled with the seven magnets **510**, **530**, **560**, **582**, **586**, **592** and **596** to produce magnetic-flux density in a gap sufficient to erase recorded information from a portion of the magnetic-recording disk, for example, magnetic-recording disk **120**, in a disk-stack of the HDD, for example, HDD **100**. The bulk eraser **501** includes a first magnet **510** disposed opposite a second magnet **530** across a first portion **522** of a gap, for example, similar to gap **202** shown in FIG. **2**A. The first magnet **510** has a first end pole **512** disposed proximate the first portion **522** of the gap and a first pole-tip portion **516** disposed proximate a second portion **524** of the gap. The second magnet **530** has a second end pole **532** disposed proximate the first portion **522** of the gap and a second pole-tip portion **536** disposed proximate the second portion **524** of the gap. The first and second end poles **512** and **532** have same polarity. The direction **514** of the B-field, the magnetic-flux density, as well as the magnetization field, in the first magnet **510** is shown by the upper arrow in the right leg of the first yoke portion **580***a*. The upper arrow indicates that a first end pole **512** proximate the first portion **522** of the gap has the polarity of a north pole, and the end pole of the first magnet **510** opposite the north pole has the polarity of a south pole. The arrow also indicates the direction of magnetic flux propagation through the first magnet **510**. Similarly, the direction **534** of the B-field, the magnetic-flux density, as well as the magnetization field, in the second magnet **530** is shown by the lower arrow in the right leg of the second yoke portion **580***b*. The lower arrow indicates that a second end pole **532** proximate first portion **522** of the gap has the polarity of a north pole, and the end pole of the second magnet **530** opposite the north pole has the polarity of a south pole. The arrow also indicates the direction of magnetic flux propagation through the second magnet **530**. The direction **564** of the B-field, the magnetic-flux density, as well as the magnetization field, in the third magnet **560** is shown by the horizontal arrow at the middle of the yoke **580**. The horizontal arrow indicates that a third end pole **562** proximate the first portion **522** of the gap has the polarity of a south pole, and the end pole of the third magnet **560** opposite the south pole has the polarity of a north pole. The arrow also indicates the direction of magnetic flux propagation through the third magnet **560**.

With further reference to FIG. **5**, in accordance with an embodiment of the present invention, the bulk eraser **501** also includes a first magnetic shield **540**, which is disposed on the first end pole **512** in proximity to the first portion **522** of the gap, and a second magnetic shield **550**, which is disposed on the second end pole **532** in proximity to the first portion **522** of the gap. The bulk eraser **501** also includes a third magnet **560**, which is disposed proximate to a second portion **524** of the gap. The third magnet **560** has a third end pole **562**, which is disposed proximate the second portion **524** of the gap. The third end pole **562** has a polarity opposite to the first and second end poles **512** and **532**. The bulk eraser **501** also includes a pole piece **570**, which is disposed on the third end pole **562** in proximity to the second portion **524** of the gap. The pole piece **570** has a third pole-tip portion **572**. The first pole-tip portion **516**, the second pole-tip portion **536**, and the third pole-tip portion **572** define a second portion **524** of the gap located between the first pole-tip portion **516**, the second pole-tip portion **536**, and the third pole-tip portion **572** and are configured such that magnetic-flux density in the second portion **524** of the gap lies substantially parallel to a plane of the magnetic-recording disk, for example, similar to plane **3**B-**3**B of the magnetic-recording disks **324** as shown in FIG. **3**B, in a disk-stack of the hard-disk drive to erase recorded information from a portion on the magnetic-recording disk, for example, similar to the portion of the magnetic-recording disk **324** that lies between contour **370** and the outside perimeter of the magnetic-recording disk **324** as shown in FIG. **3**B, when the hard-disk drive is inserted into the second portion **524** of the gap. The first pole-tip portion **516**, the second pole-tip portion **536**, and the third pole-tip portion **572** are configured such that the magnetic-flux density in the second portion **524** of the gap lies in a substantially radial direction, for example, similar to radial direction **350** as shown in FIG. **3**B, of the portion of the magnetic-recording disk of the hard-disk drive. The first pole-tip portion **516**, the second pole-tip portion **536**, and the third pole-tip portion **572** are configured to suppress magnetic-flux density in a third portion of the gap, for example, similar to the third portion **340** described above for FIGS. **3**A and **3**B, such that the magnetization of the drive-motor magnet of the drive motor in the hard-disk drive is not degraded when located within the third portion.

With further reference to FIG. **5**, in accordance with an embodiment of the present invention, the bulk eraser **501** further includes a yoke **580** having a first yoke portion **580***a* and a second yoke portion **580***b*. The first yoke portion **580***a* is magnetically coupled with the first magnet **510**, the third magnet **560** and the pole piece **570**. The second yoke portion **580***b* is magnetically coupled with the second magnet **530**, the third magnet **560** and the pole piece **570**. The yoke **580** is configured to suppress stray magnetic flux and to increase magnetic-flux density in the second portion **524** of the gap. The first yoke portion **580***a* may further include a fourth magnet **582** disposed in and magnetically coupled with the first yoke portion **580***a* with polarity assisting magnetic-flux circulation in a first magnetic circuit including the first magnet **510**, the third magnet **560**, the pole piece **570**, the second portion **524** of the gap and the first yoke portion **580***a* including the fourth magnet **582**. The direction **584** of the B-field, the magnetic-flux density, as well as the magnetization field, in the fourth magnet **582** is shown by the upper arrow in the left leg of the first yoke portion **580***a*. The fourth magnet **582** may be composed of a high-field-strength, permanent-magnet material, such as NdFeB. The fourth magnet **582** is configured to suppress stray magnetic flux and to increase magnetic-flux density in the second portion **524** of the gap. The first yoke portion **580***a* may further include a sixth magnet **590** disposed in and magnetically coupled with the first yoke portion **580***a* with polarity assisting magnetic-flux circulation in the first magnetic circuit further including the first yoke portion **580***a* further including the sixth magnet **590**. The direction **592** of the B-field, the magnetic-flux density, as well as the magnetization field, in the sixth magnet **590** is shown by the upper arrow in the top leg of the first yoke portion **580***a*. The sixth magnet **590** may be composed of a high-field-strength, permanent-magnet material, such as NdFeB. The sixth magnet **590** is configured to suppress stray magnetic flux and to increase magnetic-flux density in the second portion **524** of the gap.

With further reference to FIG. **5**, in accordance with an embodiment of the present invention, the second yoke portion **580***b* of the bulk eraser **501** may further include a fifth magnet **586** disposed in and magnetically coupled with the second yoke portion **580***b* with a polarity assisting magnetic-flux circulation in a second magnetic circuit including the second magnet **530**, the third magnet **560**, the pole piece **570**, the second portion **524** of the gap and the second yoke portion **580***b* including the fifth magnet **586**. The direction **588** of the B-field, the magnetic-flux density, as well as the magnetization field, in the fifth magnet **586** is shown by the lower arrow in the left leg of the second yoke portion **580***b*. The fifth magnet **586** may be composed of a high-field-strength, permanent-magnet material, such as NdFeB. The fifth magnet **586** is configured to suppress stray magnetic flux and to increase magnetic-flux density in the second portion **524** of the gap. The second yoke portion **580***b* may further include a seventh magnet **594** disposed in and magnetically coupled with the second yoke portion **580***b* with polarity assisting magnetic-flux circulation in the second magnetic circuit further including the second yoke portion **580***b* further including the seventh magnet **594**. The direction **596** of the B-field, the magnetic-flux density, as well as the magnetization field, in the seventh magnet **594** is shown by the lower arrow in the bottom leg of the second yoke portion **580***b*. The seventh magnet **594** may be composed of a high-field-strength, permanent-magnet material, such as NdFeB. They seventh magnet **594** is configured to suppress stray magnetic flux and to increase magnetic-flux density in the second portion **524** of the gap. At least one magnet of the magnets **510**, **530**, **560**, **582**, **586**, **590** and **592** may be a high-field-strength, permanent magnet, which may be composed of a material such as neodymium iron boron, NdFeB. The grade of the NdFeB material used for at least one magnet of the magnets **510**, **530**, **560**, **582**, **586**, **590** and **592** may have a grade between about grade 48 and about grade 54; however, a grade of about grade 50 provides a very stable magnet.

With further reference to FIGS. **4**A-**4**C and **5**, in accordance with embodiments of the present invention, the bulk eraser includes a first magnet having a first end pole and a first pole-tip portion and a second magnet having a second end pole and a second pole-tip portion such that the first and second magnets are disposed on opposite sides of a first portion of a gap, and such that the first end pole and the second end pole have same polarity. The bulk eraser also includes a third magnet having a third end pole of opposite polarity to the first end pole and the second end pole, and having a pole piece with a third pole-tip portion such that the first pole-tip portion, the second pole-tip portion, and the third pole-tip portion define a second portion of the gap located between the first pole-tip portion, the second pole-tip portion, and the third pole-tip portion. Also, the bulk eraser includes a structure. The structure includes a yoke having a first yoke portion and a second yoke portion. The first yoke portion is magnetically coupled with the first magnet, the third magnet and the pole piece. The first yoke portion further includes a first plurality of magnets disposed in and magnetically coupled with the first yoke portion with a polarity assisting magnetic-flux circulation in a first magnetic circuit including the first magnet, the third magnet, the pole piece, the second portion of the gap and the first yoke portion including the first plurality of magnets. The structure also includes the second yoke portion magnetically coupled with the second magnet the third magnet and the pole piece. The second yoke portion further includes a second plurality of magnets disposed in and magnetically coupled with the second yoke portion with a polarity assisting magnetic-flux circulation in a second magnetic circuit including the second magnet, the third magnet, the pole piece, the second portion of the gap and the second yoke portion including the second plurality of magnets. In accordance with embodiments of the present invention, the structure is configured to suppress stray magnetic flux and to increase magnetic-flux density in the second portion of the gap for erasing recorded information from a portion on the magnetic-recording disk when the hard-disk drive is inserted into the second portion of the gap.

With reference now to FIG. **6**, in accordance with an embodiment of the present invention, a perspective view **600** of the pole piece **470** of the bulk eraser **401** of FIGS. **4**A-**4**C, similar to the pole piece **570** of the bulk eraser **501** of FIG. **5**, disposed on a third end pole **462** of a third magnet **460** disposed in proximity to the second portion **424** of the gap for concentrating the magnetic-flux density to erase recorded information from the portion of the magnetic-recording disk in the HDD, for example, magnetic-recording disk **120** in HDD **100**, inserted into the second portion **424** of the gap. The first pole-tip portion **416**, the second pole-tip portion **436**, and the third pole-tip portion **472** of the bulk eraser **401** are configured to confine the magnetic-flux density in the second portion **424** of the gap to a region of the magnetic-recording disk sufficiently localized such that strength of eddy currents in the magnetic-recording disk are suppressed when rotating the magnetic-recording disk to erase recorded information on the magnetic-recording disk. The shape of the third pole-tip portion **472** is instrumental in confining the magnetic-flux density in the second portion **424** of the gap to a region of the magnetic-recording disk sufficiently localized such that strength of eddy currents in the magnetic-recording disk are suppressed when rotating the magnetic-recording disk to erase recorded information on the magnetic-recording disk. A narrow third pole-tip portion **472** confines the magnetic-flux density in the second portion **424** of the gap to such a sufficiently localized region of the magnetic-recording disk. The shape of the third pole-tip portion **472** is determined by the shape of the pole piece **470** disposed on the third magnet **460**, which is next described. The pole piece **470** has a wide base **670** to provide as much magnetic flux as possible to the yoke **480** and a narrow third pole-tip portion **472** to concentrate the magnetic-flux density in a narrow band about the radial direction, for example, similar to radial direction **350** of FIG. **3**B, of the magnetic-recording disk when inserted into the second portion **424** of the gap. A pyramid-like shape can provide these functions as next described.

With further reference to FIG. **6**, in accordance with an embodiment of the present invention, the pole piece **470** may include a body selected from the group of bodies consisting of a pyramid, a substantially pyramidally shaped body, a frustum of a rectangular pyramid and a frustum of a substantially pyramidally shaped body having essentially a shape of the frustum of the rectangular pyramid wherein at least one of planar lateral faces of the frustum of the rectangular pyramid is substituted by a concave surface to provide a lateral facing surface **672** of the substantially pyramidally shaped body. A first base **670** of the body is disposed on the third end pole **462** of the third magnet **460**, and an apical portion, for example, the third pole-tip portion **472**, of the body is disposed proximate the second portion **424** of the gap. As shown in FIG. **6**, a plinth portion of the body may be interposed between the first base **670** of the body and the third end pole **462** of the third magnet **460**; the plinth portion **674** provides greater mechanical stability in mounting the pole piece **470** on the third end pole **462**. The apical portion of a body selected from the group of bodies consisting of the frustum of the rectangular pyramid and the frustum of the substantially pyramidally shaped body may be configured as an apical planar surface of the body. For example, in the case of the frustum of a pyramid, the apical planar surface is provided by a second base of the frustum of the pyramid adjacent to an apex of a pyramid from which the frustum of the pyramid is derived. The apical portion of the body is elongated in a direction perpendicular to the plane of the magnetic-recording disk to spread magnetic-flux density uniformly over a plurality of planes of a plurality of magnetic-recording disks in the disk-stack of the hard-disk drive in the second portion **424** of the gap. Thus, at least three magnets **410**, **430** and **460** and the structure including the third pole-tip portion **472** of the pole piece **470** are configured to produce magnetic-flux density such that the magnetic-flux density is applied to a localized portion of the magnetic-recording disk, aided by the narrow width of the third pole-tip portion **472**, to suppress eddy currents in the magnetic-recording disk of the HDD **100**, as previously described above.

With reference now to FIG. **7**, in accordance with an embodiment of the present invention, a perspective view **700** of the second magnet **430** of the bulk eraser **401** of FIGS. **4**A-**4**C, similar to the second magnet **530** of the bulk eraser **501** of FIG. **5**, is shown. FIG. **7** shows a detailed view of the second magnet **430** of the bulk eraser **401**, which is disposed in proximity to a first portion **422** of the gap, and the second pole-tip portion **436** of the second magnet **430**, which is disposed proximate the second portion **424** of the gap for concentrating the magnetic-flux density to erase recorded information from the portion of the magnetic-recording disk in the HDD, for example, magnetic-recording disk **120** of HDD **100**, when inserted into the second portion **424** of the gap. As shown in FIG. **7**, the second magnet **430** has a second end pole **432** and that in conjunction with the second pole-tip portion **436** forms a pocket in which second magnetic shield **450** is disposed. The first magnet **410** has a first end pole **412** that forms a similar pocket in which the first magnetic shield **440** is disposed. The first magnetic shield **440** and the second magnetic shield **450** may be composed of a high magnetic-permeability material. Moreover, the first magnetic shield **440** and the second magnetic shield **450** may be composed of a material selected from the group consisting of low-carbon steel, such as Hyperco Steel, permalloy and supermalloy. The magnetic shields **440** and **450** provide greater protection for the drive-motor magnet disposed in the first portion **422** of the gap by directing magnetic flux away from the drive-motor magnet. Thus, the magnetic-flux density produced by the at least three magnets **410**, **430** and **460** and the structure, including the first magnetic shield **440** in the second magnetic shield **450**, is configured to erase recorded information from the magnetic-recording disk, for example, similar to magnetic-recording disk **324**, disposed in the second portion **424** of the gap without degrading the magnetization of a drive-motor magnet, for example, similar to drive-motor magnets **330** and **334**, in the drive motor disposed in the third portion of the gap, for example, similar to the third portion **340** described above for FIGS. **3**A and **3**B. The intensity of a field component of the magnetic-flux density directed along the radial direction, for example, similar to radial direction **350**, in the plane of the magnetic-recording disk, for example, similar to magnetic-recording disk **324**, produced by the at least three magnets **410**, **430** and **460** and the structure has a gradient as a function of distance along the radial direction at a transition region, similar to the transition region described above for FIG. **3**B, between the second portion **424** of the gap and the third portion, for example, similar to the third portion **340** described above for FIGS. **3**A and **3**B, of the gap such that the gradient allows erasing recorded information from the magnetic-recording disk in close proximity to the drive-motor magnet, for example, similar to drive-motor magnets **330** and **334**, in the drive motor without degrading the magnetization of the drive-motor magnet in the drive motor. Modeling results for the gradient in the magnetic-flux density at the transition region in an alternative embodiment of the present invention, which utilizes five magnets, are next described.

With reference now to FIG. **8**, in accordance with an embodiment of the present invention, a plot **800** of the intensities of the magnetic field intensity as a function of radial distance from center of a disk in the plane of each of four magnetic-recording disks in a disk-stack of a HDD inserted into the second portion of the gap of a bulk eraser is shown. The bulk eraser is configured with five magnets, similar to magnets **510**, **530**, **560**, **582** and **586** of the bulk eraser **501** of FIG. **5**, to erase recorded information from magnetic-recording disks in a disk-stack of an HDD in the second portion of the gap, similar to the second portion **524** of the gap of the bulk eraser **501**. Ordinate **804** of the plot **800** of the intensities of the magnetic field intensity (magnetic-flux density) is given in units of Oersteds (Oe) to erase a magnetic-recording disk. Abscissa **808** of the plot **800** is given in units of millimeters (mm) of disk radius. The direction of the abscissa **808** is from right to left rather than left to right to facilitate comparison with the earlier plots of the distribution of magnetic field intensity (magnetic-flux density) of FIGS. **3**A and **3**B. The location of the OD of the disk along the radius of the magnetic-recording disk is indicated by the vertical line **870**. The location of the ID of the disk along the radius of the magnetic-recording disk is indicated by the vertical line **872**. The location of the OD of the drive motor along the radius of the magnetic-recording disk is indicated by the vertical line **880**. The erase field necessary to erase recorded information from the magnetic-recording disk is indicated by the horizontal line **850**, which is approximately 7500 Oe. The critical field to degrade the magnetization of a drive-motor magnet is indicated by the horizontal line **860**, which is approximately 3000 Oe.

With further reference to FIG. **8**, in accordance with an embodiment of the present invention, four plots **810**, **820**, **830** and **840**, one for each of four disks in a disk-stack, are given for the magnitude of the magnetic-flux-density vector along a radial direction of the magnetic-recording disk in the HDD that is oriented substantially parallel to the central flux-propagation direction in the bulk eraser. Plot **810** is for disk **1** in the disk-stack; plot **820** is for disk **2** in the disk-stack; plot **830** is for disk **3** in the disk-stack; and, plot **840** is for disk **4** in the disk-stack. Each of the plots **810**, **820**, **830** and **840** shows the behavior of the magnitude of the magnetic-flux-density vector along the radial direction as a function of distance from the center of each of the disks: disk **1**, disk **2**, disk **3** and disk **4**, respectively. As shown in FIG. **8**, each of the plots **810**, **820**, **830** and **840** crosses the horizontal line **850** corresponding to the erase field necessary to erase recorded information from the magnetic-recording disk at about a radius **852** of 21 mm. Therefore, any portion of the magnetic-recording disk greater than a radius of 21 mm will be erased. Thus, the radius of 21 mm corresponds roughly to the location of a contour in the magnitude of the magnetic-flux-density vector similar to contour **370** shown in FIG. **3**B. On the other hand, any portion of the magnetic-recording disk less than a radius of 21 mm will not be erased. Therefore, the region between where each of the plots **810**, **820**, **830** and **840** crosses the horizontal line **850**, at about 21 mm, and the vertical line **880**, which designates the location of the OD of the drive motor, corresponds roughly to the transition region in the gap, similar to the transition region in the gap shown in FIG. **3**B.

With further reference to FIG. **8**, in accordance with an embodiment of the present invention, it is desirable to make the transition region as small as possible to minimize the amount of time required to erase portions of a disk that lie between the crossing of the plots **810**, **820**, **830** and **840**, at about 21 mm, and the vertical line **872** corresponding to the ID of a disk. This can be accomplished by making the gradient of the magnetic-flux density as a function of radius as great as possible in this transition region, which can be effectuated by making the magnetic-flux density in the erasing region greater than 21 mm as high as possible while minimizing the magnetic-flux density at the location of the drive motor. Moreover, as shown in FIG. **8**, the plots **810**, **820**, **830** and **840** cross the horizontal line **860** corresponding to the critical field for degrading the magnetization of drive-motor magnets at about 10 mm. Thus, to erase the maximum portion of the disks, it is desirable to employ a stroke length that brings the OD of the motor right up to the crossing point where the plots cross the horizontal line **860** corresponding to the critical field for degrading the magnetization of the drive-motor magnets. In accordance with embodiments of the present invention, the intensity of a field component of the magnetic-flux density directed along the radial direction in the plane of the magnetic-recording disk produced by five magnets, similar to magnets **510**, **530**, **560**, **582** and **586**, and the structure has a gradient as a function of distance along the radial direction at a transition region, similar to the transition region described above for FIG. 3B, between the second portion of the gap and the third portion of the gap such that the gradient allows erasing recorded information from the magnetic-recording disk in close proximity to the drive-motor magnet, for example, similar to drive-motor magnets **330** and **334**, in the drive motor without degrading the magnetization of the drive-motor magnet in the drive motor. Similarly, as shown by the modeling results of FIG. **8**, the first pole-tip portion, the second pole-tip portion, and the third pole-tip portion of the bulk eraser utilizing the five magnets, similar to magnets **510**, **530**, **560**, **582** and **586** of bulk eraser **501**, are configured to suppress magnetic-flux density in a third portion of the gap such that the magnetization of the drive-motor magnet of the drive motor in the hard-disk drive is not degraded when located within the third portion.

Sub-Section C: Description of Embodiments of the Present Invention for a Method of Manufacturing of a Hard-Disk Drive Using a Bulk Eraser for Erasing Recorded Information on a Magnetic-Recording Disk

With reference now to FIGS. **9**A and **9**B, in accordance with an embodiment of the present invention, a flow chart **900** illustrates the method of manufacturing of a HDD using a bulk eraser for erasing recorded information on a magnetic-recording disk. At **910**, a bulk eraser that produces magnetic-flux density in a second portion of a gap sufficient to erase recorded information from a portion of the magnetic-recording disk, a HDD having an enclosure, a disk-stack having at least one magnetic-recording disk rotatably mounted on a spindle, and a drive motor having a rotor attached to the spindle for rotating the magnetic-recording disk inside the enclosure are provided. At **920**, a plurality of magnets and a structure of the bulk eraser are configured such that magnetic-flux density is oriented substantially parallel to a central plane in the second portion of the gap and in a substantially radial direction of the portion of the magnetic-recording disk when the HDD is inserted into the second portion of the gap. At **930**, the magnetic-recording disk is rotated in the HDD. At **940**, the HDD is inserted into the second portion of the gap of the bulk eraser such that a plane of the magnetic-recording disk of the HDD is oriented substantially parallel to the central plane in the second portion of the gap such that magnetic-flux density is oriented in the substantially radial direction of the portion of the magnetic-recording disk. At **950**, recorded information is erased from the portion of the magnetic-recording disk in the HDD located in the second portion of the gap. At **960**, the HDD is removed from the second portion of the gap.

With reference now to FIG. **10**, in accordance with an embodiment of the present invention, a flow chart **1000** illustrates further embodiments of the present invention for a method of manufacturing of a HDD using a bulk eraser for erasing recorded information on a magnetic-recording disk. At **1010**, pole pieces of the structure and pole-tip portions of the pole pieces are configured such that magnetic-flux density in the second portion of the gap is oriented substantially parallel to a central flux-propagation direction in the second portion of the gap. At **1020**, the magnetic-recording disk in the HDD is oriented such that a radial direction of the portion of the magnetic-recording disk is oriented substantially parallel to the central flux-propagation direction in the second portion of the gap.

With reference now to FIG. **11**, in accordance with an embodiment of the present invention, a flow chart **1100** illustrates further embodiments of the present invention for a method of manufacturing of a HDD using a bulk eraser for erasing recorded information on a magnetic-recording disk. At **1110**, the HDD is inserted into the second portion of the gap with an insertion speed that is sufficient to assure complete erasure of recorded information on the magnetic-recording disk in the HDD. At **1120**, the insertion of the hard disk drive into the second portion of the gap is such that an insertion speed into the gap is less than or equal to 1 centimeter per second.

With reference now to FIG. **12**, in accordance with an embodiment of the present invention, a flow chart **1200** illustrates further embodiments of the present invention for a method of manufacturing of a HDD using a bulk eraser for erasing recorded information on a magnetic-recording disk. At **1210**, the HDD is removed from the second portion of the gap with a speed that is sufficient to assure complete erasure of recorded information on the magnetic-recording disk in the HDD. At **1220**, the removal of the hard disk drive from the second portion of the gap is such that the removal speed from the gap is less than or equal to 1 centimeter per second.

With reference now to FIG. **13**, in accordance with an embodiment of the present invention, a flow chart **1300** illustrates further embodiments of the present invention for a method of manufacturing of a HDD using a bulk eraser for erasing recorded information on a magnetic-recording disk. At **1310**, the magnetic-recording disk in the HDD is rotated with the drive motor at a rotation speed that is sufficient to assure complete erasure of recorded information on the magnetic-recording disk in the HDD without stalling the drive motor. At **1320**, the rotation of the magnetic-recording disk in the hard disk drive is such that the rotation speed of the magnetic-recording disk is less than or equal to 2 Hertz.

With reference now to FIG. **14**, in accordance with an embodiment of the present invention, a flow chart **1400** illustrates further embodiments of the present invention for a method of manufacturing of a HDD using a bulk eraser for erasing recorded information on a magnetic-recording disk. At **1410**, a low speed drive-motor-driver circuit is provided on-board in the HDD to provide power to the drive motor to rotate the magnetic-recording disk at a slow speed to prevent stalling of the drive motor. At **1420**, power is provided to the low speed drive-motor-driver circuit on-board in the HDD. At **1430**, the power provided is such that a cable and connector, attached to an external power supply, is attached to the HDD.

With reference now to FIG. **15**, in accordance with an embodiment of the present invention, a flow chart **1500** illustrates further embodiments of the present invention for a method of manufacturing of a HDD using a bulk eraser for erasing recorded information on a magnetic-recording disk. At **1510**, the second portion of the gap is provided with sufficient clearance to accommodate the HDD upon inserting and removing the HDD from the second portion of the gap. At **1520**, the clearance in the second portion of the gap is such that the clearance of the second portion of the gap is less than or equal to about 2.6 centimeters.

With reference now to FIG. **16**, in accordance with an embodiment of the present invention, a flow chart **1600** illustrates further embodiments of the present invention for a method of manufacturing of a HDD using a bulk eraser for erasing recorded information on a magnetic-recording disk. At **1610**, a fixture is provided for rapidly and reproducibly aligning the HDD in the second portion of the gap. At **1620**, the fixture is such that the fixture limits a stroke length upon inserting the HDD into the second portion of the gap such that the magnetic-flux density produced by the plurality of magnets and the structure is configured to erase recorded information from the portion of the magnetic-recording disk disposed in the second portion of the gap without degrading the magnetization of a drive-motor magnet in the drive motor disposed in a third portion of the gap.

With reference now to FIG. **17**, in accordance with an embodiment of the present invention, a flow chart **1700** illustrates further embodiments of the present invention for a method of manufacturing of a HDD using a bulk eraser for erasing recorded information on a magnetic-recording disk. At **1710**, two magnets of the plurality of magnets are disposed with opposing polarity across a first portion of the gap. At **1720**, a separation between the two magnets of the plurality of magnets in the first portion of the gap is adjusted such that the first portion of the gap has sufficient clearance to accommodate the HDD upon inserting and removing the HDD from the second portion of the gap and the magnetic-flux density produced by the plurality of magnets and the structure is sufficient to erase recorded information from a plurality of magnetic-recording disks of the disk-stack when the HDD is inserted into the second portion of the gap.

With reference now to FIGS. **18**A and **18**B, in accordance with an embodiment of the present invention, a flow chart **1800** illustrates the method of reworking a HDD in manufacturing the HDD using a bulk eraser for erasing a servo pattern on a magnetic-recording disk. At **1810**, a bulk eraser that produces magnetic-flux density in a second portion of a gap sufficient to erase a first servo pattern from a portion of the magnetic-recording disk, a HDD having an enclosure, a disk-stack having at least one magnetic-recording disk rotatably mounted on a spindle, and a drive motor having a rotor attached to the spindle for rotating the magnetic-recording disk inside the enclosure are provided. At **1820**, a plurality of magnets and a structure of the bulk eraser are configured such that magnetic-flux density is oriented substantially parallel to a central plane in the second portion of the gap and in a substantially radial direction of the portion of the magnetic-recording disk when the HDD is inserted into the second portion of the gap. At **1830**, the magnetic-recording disk is rotated in the HDD. At **1840**, the HDD is inserted into the second portion of the gap of the bulk eraser such that a plane of the magnetic-recording disk of the HDD is oriented substantially parallel to the central plane in the second portion of the gap such that magnetic-flux density is oriented in the substantially radial direction of the portion of the magnetic-recording disk. At **1850**, the first servo pattern is erased from the portion of the magnetic-recording disk in the HDD located in the second portion of the gap. At **1860**, the HDD is removed from the second portion of the gap. At **1870**, a second servo pattern is written on the magnetic-recording disk in the HDD to replace the first servo pattern.

With reference now to FIGS. **19**A and **19**B, in accordance with an embodiment of the present invention, a flow chart **1900** illustrates the method of preserving security of recorded information in a HDD in a computer system using a bulk eraser. At **1910**, the HDD is removed from the computer system. At **1920**, a bulk eraser that produces magnetic-flux density in a second portion of a gap sufficient to erase recorded information from a portion of the magnetic-recording disk, a HDD having an enclosure, a disk-stack having at least one magnetic-recording disk rotatably mounted on a spindle, and a drive motor having a rotor attached to the spindle for rotating the magnetic-recording disk inside the enclosure are provided. At **1930**, a plurality of magnets and a structure of the bulk eraser are configured such that magnetic-flux density is oriented substantially parallel to a central plane in the second portion of the gap and in a substantially radial direction of the portion of the magnetic-recording disk when the HDD is inserted into the second portion of the gap. At **1940**, the magnetic-recording disk is rotated in the HDD. At **1950**, the HDD is inserted into the second portion of the gap of the bulk eraser such that a plane of the magnetic-recording disk of the HDD is oriented substantially parallel to the central plane in the second portion of the gap such that magnetic-flux density is oriented in the substantially radial direction of the portion of the magnetic-recording disk. At **1960**, recorded information is erased from the portion of the magnetic-recording disk in the HDD located in the second portion of the gap. At **1970**, the HDD is removed from the second portion of the gap.

Section II:

Sub-Section A: Physical Description of Embodiments of the Present Invention for a Combined Thermal-Assister and Bulk Eraser

With reference now to FIG. **20**, a plot **2000** of the coercivity, H_C, of the magnetic-recording medium of a magnetic-recording disk measured along the easy axis of magnetization perpendicular to the recording surface of the magnetic-recording disk as a function of temperature is shown. Ordinate **2004** of the plot **2000** is the coercivity, H_C, measured along the easy axis of magnetization perpendicular to the recording surface given in units of Oersteds (Oe). Abscissa **2008** of the plot **2000** is temperature given in units of degrees centigrade (° C.). The data points **2010**, **2011**, **2012**, **2013**, **2014**, **2015** and **2016** correspond to the values of the coercivity, H_C, measured at several temperatures. FIG. **20** illustrates the drop from a first value **2020** of the coercivity, H_C, measured at a first temperature **2030**, about equal to room temperature (RT), 25° C., without limitation thereto, to a second value **2025** of the coercivity, H_C, as measured at a second temperature **2035**, about equal to 65° C., without limitation thereto, at which recorded information may be erased from the magnetic-recording disk in the HDD, in accordance with an embodiment of the present invention. For embodiments of the present invention, a first value of the coercivity, H_C, measured at a first temperature and a second value of the coercivity, H_C, measured at a second temperature need not be measured at the temperatures shown in FIG. **20**, as a first temperature less than the second temperature are within the spirit and scope of embodiments of the present invention. The specific values, **2020** and **2025**, of the coercivity, H_C, at the temperatures **2030** and **2035**, respectively, are only one example that elucidates embodiments of the present invention. The value **2025** of the coercivity, H_C, at about 65° C. decreases by about 21% from the value **2020** of the coercivity, H_C, at about room temperature, 25° C. These measurements of the coercivity were obtained from a study of magnetic viscosity of a typical PMR magnetic-recording medium, which might be used in a PMR disk of a HDD. However, the trend evident from the plot **2000** applies without limitation to magnetic-recording media more generally, as might also be encountered in the application of embodiments of the present invention. If the time variable associated with the measurement of magnetic viscosity is removed, then the easy axis coercivity, H_O, is reduced from 8248 Oe at about room temperature to 7349 Oe at about 65° C., an 11% reduction.

With reference now to FIG. **21**, in accordance with an embodiment of the present invention, a plot **2100** of the intensities of the magnetic field intensity (magnetic-flux density) as a function of radial distance from center of a disk in the plane of each of four magnetic-recording disks in a disk-stack of a HDD inserted into a bulk eraser of the combined bulk thermal-assister and bulk eraser is shown. FIG. **21** illustrates the expected improvement in the erasure of the magnetic-recording disk upon heating the magnetic-recording disk with the bulk thermal-assister in comparison with the erasure of the magnetic-recording disk without heating the magnetic-recording disk. Ordinate **2104** of the plot **2100** of the intensities of the magnetic field intensity is given in units of Oersteds (Oe) to erase a magnetic-recording disk. Abscissa **2108** of the plot **2100** is given in units of millimeters (mm) of the magnetic-recording-disk radius. The direction of the abscissa **2108** is from right to left rather than left to right to facilitate comparison with the earlier plots of the distribution of magnetic field intensity for similar disks of FIGS. **3**A and **3**B. The location of the OD of the disk along the radius of the magnetic-recording disk is indicated by vertical line **2170**. The location of the ID of the disk along the radius of the magnetic-recording disk is indicated by vertical line **2172**. The location of the OD of the drive motor along the radius of the magnetic-recording disk is indicated by vertical line **2180**. The erase field necessary to erase recorded information from the magnetic-recording disk at the first temperature, which may be equal to about RT, is indicated by horizontal line **2150**, which is approximately 7500 Oe. As described above in the discussion of FIG. **20**, the easy axis coercivity, H_O, is reduced by about 11% on increasing the temperature to the second temperature, taken to be about equal to 65° C. Therefore, it is reasonable to assume that the erase field necessary to erase recorded information from the magnetic-recording disk at the second temperature is also reduced by the same reduction, 11%, as the easy axis coercivity, H_O. The erase field necessary to erase recorded information from the magnetic-recording disk at the second temperature, for example, taken to be about equal to 65° C., is indicated by horizontal line **2154**, which is approximately 6750 Oe.

With further reference to FIG. **21**, in accordance with an embodiment of the present invention, the critical field to degrade the magnetization of a drive-motor magnet of a drive motor at the first temperature, which may be taken as equal to about RT, is indicated by horizontal line **2160**, which is approximately 3000 Oe. As the entire HDD may be heated to produce a temperature of the magnetic-recording disk equal to the second temperature, the actual temperature of drive-motor magnet in the worse case may be about equal to the second temperature with a corresponding lowering of the critical field to degrade the magnetization of a drive-motor magnet to a level somewhat less than the level indicated by horizontal line **2160**, which may create a risk of demagnetizing a portion of the drive-motor magnet unless certain precautions are taken. Therefore, for alternative embodiments of the present invention, which are subsequently described, the actual temperature of the drive-motor magnet is made to lie at some temperature, a fourth temperature, less than the second temperature of the magnetic-recording disk to minimize this risk of demagnetizing a portion of the drive-motor magnet.

With further reference to FIG. **21**, in accordance with an embodiment of the present invention, four plots **2110**, **2120**, **2130** and **2140**, one for each of four disks in a disk-stack, are given for the magnitude of the magnetic-flux-density vector along a radial direction of the magnetic-recording disk in the HDD that is oriented substantially parallel to the central flux-propagation direction in the bulk eraser. Plot **2110** is for disk **1** in the disk-stack; plot **2120** is for disk **2** in the disk-stack; plot **2130** is for disk **3** in the disk-stack; and, plot **2140** is for disk **4** in the disk-stack. Each of the plots **2110**, **2120**, **2130** and **2140** shows the behavior of the magnitude of the magnetic-flux-density vector along the radial direction as a function of distance from the center of each of the disks: disk **1**, disk **2**, disk **3** and disk **4**, respectively. As shown in FIG. **21**, each of the plots **2110**, **2120**, **2130** and **2140** crosses horizontal line **2150** corresponding to the erase field at about the first temperature, which may be equal to about RT, necessary to erase recorded information from the magnetic-recording disk at about a first radius **2152** of about, for example, 21.5 mm. In addition, each of the plots **2110**, **2120**, **2130** and **2140** crosses horizontal line **2154** corresponding to the erase field at the about second temperature, for example, which may be about equal to 65° C., necessary to erase recorded information from the magnetic-recording disk at about a second radius **2156** of about, for example, 19.6 mm. Therefore, at a first temperature, any portion of the magnetic-recording disk greater than a first radius, for example, first radius **2152** at about 21.5 mm, will be erased; and, any portion of the magnetic-recording disk less than the first radius will not be erased. On the other hand, at a second temperature greater than the first temperature any portion of the magnetic-recording disk greater than a second radius, for example, second radius **2156** at about 19.6 mm, will be erased; and, any portion of the magnetic-recording disk less than the second radius will not be erased. Thus, for the example embodiments of the present invention described above, the efficiency of the combined bulk thermal-assister and bulk eraser may be increased to about 81% from about 70%, which is the efficiency of a bulk eraser without a means of thermal assistance. Therefore, the erased portion of the magnetic-recording disk may be increased by raising the temperature of the magnetic-recording medium to lower the coercivity and correspondingly the required erase field, in accordance with embodiments of the present invention, which are next described in greater detail.

With further reference to FIG. **21**, in accordance with an embodiment of the present invention, erasure at a second temperature greater than a first temperature has three useful effects: lowering the coercivity, as described above; reducing the energy barrier, which must be overcome to switch the magnetization state of a domain upon application of the erase field; and, reducing the time required to switch a domain orientation from its initially magnetized state to a new state upon application of the erase field. All three of these effects work in concert with one another to reduce the overall time required for erasing recorded information on a magnetic-recording disk with the combined bulk thermal-assister and bulk eraser. Because there is less recorded information on the magnetic-recording disk for a second radius less than a first radius the time required for the magnetic-recording head to erase the remaining recorded information on the magnetic-recording disk at tracks proximate to the ID and less than the second radius of the magnetic-recording disk is reduced compared with the time required for the magnetic-recording head to erase remaining recorded information on the magnetic-recording disk at tracks proximate to the ID and less than the first radius of the magnetic-recording disk. Consequently, the total manufacturing time for rework associated with erasing all the recorded information from the magnetic-recording disk is reduced, which results in a significant manufacturing cost reduction for the manufacture of an HDD, for embodiments of the present invention.

With reference now to FIG. **22**, in accordance with first example embodiment of the present invention, a block diagram **2200** of a combined bulk thermal-assister and bulk eraser **2201** with an optional chiller is shown. FIG. **22** illustrates the work-flow of a magnetic-recording disk **2210***b* in a HDD **2210** initially at a first temperature, which upon passing through a bulk thermal-assister **2201***a* is heated by a thermal-assist means **2220**, is optionally passed through a chiller **2201***c* which is configured to lower a temperature of a drive-motor magnet of a drive motor of the HDD to a fourth temperature less than a second temperature of the magnetic-recording disk **2210***b*, and is subsequently passed through a bulk eraser **2201***b* at the second temperature at which recorded information is erased from the magnetic-recording disk **2210***b*. The combined bulk thermal-assister and bulk eraser **2201** for erasing recorded information on the magnetic-recording disk **2210***b* includes the bulk thermal-assister **2201***a* and the bulk eraser **2201***b*. The bulk thermal-assister **2201***a* is configured to produce a temperature in the magnetic-recording disk **2210***b* in the HDD **2210** when the HDD **2210** is disposed in the bulk eraser **2201***b* such that the temperature is about equal to a second temperature greater than a first temperature of the magnetic-recording disk **2210***b* in the HDD **2210**. The bulk eraser **2201***b* is configured to erase recorded information from the magnetic-recording disk **2210***b* at the second temperature in the HDD **2210**. The second temperature lowers a coercivity of the magnetic-recording disk **2210***b* in the HDD **2210** so that, when recorded information is erased from the magnetic-recording disk **2210***b* in the HDD **2210** at the second temperature, recorded information on the magnetic-recording disk **2210***b* is erased from a second magnetic-recording track in closer proximity to an inside diameter of the magnetic-recording disk **2210***b* than a first magnetic-recording track from which recorded information on the magnetic-recording disk **2210***b* may be erased, if recorded information were erased from the magnetic-recording disk **2210***b* in the HDD **2210** at the first temperature.

With further reference to FIG. **22**, in accordance with a first example embodiment of the present invention, the bulk thermal-assister **2201***a* of the combined bulk thermal-assister and bulk eraser **2201** may further include at least one thermal-assist means **2220** selected from the group, without limitation thereto, consisting of an oven, a heater, a heat lamp, and a hot-air blower. As suggested by FIG. **22**, the bulk thermal-assister **2201***a* of the combined bulk thermal-assister and bulk eraser **2201** may include a heating station on an assembly line separate from the bulk eraser **2201***b*. In addition, the combined bulk thermal-assister and bulk eraser **2201** may optionally include the chiller **2201***c*. The chiller **2201***c* is configured to lower a temperature of an enclosure **2210***a* of the HDD **2210** to a third temperature less than the second temperature of the magnetic-recording disk **2210***b*. As the enclosure is in communication with the drive motor (not shown) of the HDD **2210**, the chiller **2201***c* is also configured to lower a temperature of the drive-motor magnet of the HDD to a fourth temperature less than the second temperature of the magnetic-recording disk **2210***b*. In accordance with embodiments of the present invention, the chiller **2201**C may include a fan, without limitation thereto. As suggested by FIG. **22**, the chiller **2201***c* may further include a chilling station on the assembly line separate from the bulk eraser. Thus, the bulk thermal-assister **2201***a*, the bulk eraser **2201***b* and the chiller **2201***c* may be implemented as separate stations on an assembly line with the HDD **2210** passing from one station to the next, which is next described.

With further reference to FIG. **22**, in accordance with an embodiment of the present invention, the block diagram **2200** may be viewed as an operational schematic for an assembly line with the blocks representing the bulk thermal-assister **2201***a*, the bulk eraser **2201***b* and the chiller **2201***c* corresponding to separate stations on an assembly line and the arrows between the blocks representing the passage of HDD **2210** from one station to the next. Moreover, as described herein, in accordance with alternative embodiments of the present invention, the respective block diagrams **2300-2600** and **2800-2900** of FIGS. **23-26** and **28-29** may be viewed as operational schematics of assembly lines with the respective blocks representing separate stations on the respective assembly lines and the arrows between the blocks representing the passage of an HDD from one station to the next. The HDD **2210**, which is provided to the assembly line as indicated by the first arrow on the left of FIG. **22**, has the enclosure **2210***a*, a disk-stack having at least one magnetic-recording disk **2210***b* rotatably mounted on a spindle (not shown), and a drive motor (not shown) having a rotor (not shown) attached to the spindle for rotating the magnetic-recording disk **2210***b* inside the enclosure **2210***a*. The thermal-assist means **2220** for producing a second temperature of the magnetic-recording disk **2210***b* in the HDD **2210**, when the HDD **2210** is disposed in the bulk eraser **2201***b*, greater than a first temperature about equal to ambient temperature of the magnetic-recording disk **2210***b*, before producing the second temperature, is provided on the assembly line inside the bulk thermal-assister **2201***a* at a heating station. The thermal-assist means is utilized to provide heat **2224**, indicated by the wavy arrows in FIG. **22**, which raises the temperature of the magnetic-recording disk **2210***b* in the HDD **2210** so that the second temperature is at least 20° C. above the first temperature to lower a coercivity of the magnetic-recording disk **2210***b* in the HDD **2210**, so that the erase field is correspondingly lowered as described above in the discussion of FIGS. **20** and **21**. A bulk eraser **2201***b* that produces magnetic-flux density **2250** sufficient to erase recorded information from a portion of the magnetic-recording disk **2210***b* is provided on the assembly line at an erasing station. The magnetic-recording disk **2210***b* in the HDD **2210** is spun-up so that it is rotating for the subsequent erasing operation. The HDD **2210** is inserted into the bulk eraser **2201***b* at the erasing station, as indicated by the arrow preceding the bulk eraser **2201***b*. After inserting the HDD **2210** into the bulk eraser **2201***b*, recorded information is erased at the second temperature corresponding to the reduced erase field from the portion of the magnetic-recording disk **2210***b* in the HDD **2210**. After erasure, the HDD **2210** is removed from the bulk eraser **2201***b*, as indicated by the arrow after the bulk eraser **2201***b* on the right of FIG. **22**.

With further reference to FIG. **22**, in accordance with an alternative embodiment of the present invention, an optional chiller **2201***c* may be provided at a chilling station intermediate between the heating station implemented with the bulk thermal-assister **2201***a* and the erasing station implemented with the bulk eraser **2201***b*. The HDD may be placed on the chiller after the HDD **2210** is removed from the bulk thermal-assister **2201***a*, as indicated by the arrow between the bulk thermal-assister **2201***a* and the chiller **2201***c*. By lowering a temperature of the enclosure of the HDD to a third temperature less than the second temperature of the magnetic-recording disk, the temperature of a drive-motor magnet of a drive motor of the HDD is lowered to a fourth temperature less than the second temperature of the magnetic-recording disk. The HDD **2210** is then inserted into the bulk eraser **2201***b* at the erasing station. Since the temperature of the drive-motor magnet of the HDD is at a fourth temperature less than the second temperature of the magnetic-recording disk, the risk of degrading the magnetic field of the drive-motor magnet is lessened, as described above in the discussion of FIG. **21**.

With further reference to FIG. **22**, in accordance with first example embodiment of the present invention, the bulk eraser **2201***b* may include a plurality of magnets, for example, a first magnet **2230** and a second magnet **2240**, without limitation thereto, as embodiments of the present invention may include one or more magnets, and, in particular, more than two magnets or two sources of magnetic flux. The bulk eraser **2201***b* includes a structure (not shown), which may be similar to the structures described above in the discussion of FIGS. **2**A-**2**B, **4**A-**4**C and **5**, without limitation thereto, magnetically coupled with the plurality of magnets to produce magnetic-flux density **2250** in a gap **2254**, wherein the gap **2254** may have various portions (not shown), which may be similar to various portions of gaps described above in the discussion of FIGS. **2**A-**5**, without limitation thereto. Moreover, the magnetic-flux density in various portions (not shown) of the gap **2254** may have various orientations and magnitudes similar to the magnetic-flux density as shown by the distributions of magnetic-flux density of FIGS. **3**A-**3**B, without limitation thereto. The direction **2234** of the B-field, the magnetic-flux density, as well as the magnetization field, in the first magnet **2230** may be as shown by the black arrow within the block designating the first magnet **2230**. The black arrow within the block designating the first magnet **2230** also indicates the direction of magnetic flux propagation through the first magnet **2230**. Similarly, the direction **2244** of the B-field, the magnetic-flux density, as well as the magnetization field, in the second magnet **2240** may be as shown by the black arrow within the block designating the second magnet **2240**. The black arrow within the block designating the second magnet **2240** similarly indicates the direction of magnetic flux propagation through the second magnet **2240**. As shown in FIGS. **22**-**29**, the magnetic-flux density appears with a perpendicular orientation relative to the disks of the HDD's shown therein, without limitation thereto, as the magnetic-flux density may be directed substantially parallel to the surface of a disk as previously described in the discussions of FIGS. **2**A-**7**. Throughout the following, for embodiments of the present invention described in FIGS. **21**-**31**, the respective bulk erasers described therein may incorporate any of the embodiments for bulk erasers previously described in Section I. Although embodiments of the present invention may incorporate the bulk erasers described in Section I, embodiments of the present invention are not limited, thereto. Rather, embodiments of the present invention may incorporate a generic bulk eraser, known in the art, being within the spirit and scope of embodiments of the present invention. However, embodiments of the present invention incorporating the bulk erasers described in Section I are particularly useful; representative example embodiments of the present invention which incorporate the bulk erasers described in Section I are next described.

With further reference to FIGS. **20**-**22** and FIGS. **2**A-**3**B, in accordance with embodiments of the present invention, the combined bulk thermal-assister and bulk eraser **2201** for erasing recorded information on the magnetic-recording disk **2210***b* includes the bulk thermal-assister **2201***a* and the bulk eraser **2201***b*. The bulk thermal-assister **2201***a* is configured to produce a temperature in the magnetic-recording disk **2210***b* in the HDD **2210** when the HDD **2210** is disposed in the bulk eraser **2201***b* such that the temperature is about equal to a second temperature, for example, second temperature **2035**, greater than a first temperature, for example, first temperature **2030**, of the magnetic-recording disk **2210***b* in the HDD **2210**. The bulk eraser **2201***b* may further include a plurality of magnets and a structure, for example, similar to the magnets and structure shown in FIGS. **2**A and **2**B, magnetically coupled with the plurality of magnets to produce magnetic-flux density **2250** in the gap **2254**. The gap **2254**, for example, similar to the gap **202** of FIG. **2**B, may have a first portion, a second portion and a third portion, for example, similar to first portion **222**, second portion **224** and third portion **340** of FIGS. **2**A-**3**B. The two magnets **2230** and **2240**, for example, similar to first magnet **210** and second magnet **230** of FIGS. **2**A-**3**A, are disposed with opposing polarity across the first portion, for example, similar to first portion **222**, of the gap **2254**. The plurality of magnets and the structure are configured to produce a magnetic-flux density in the second portion of the gap **2254** sufficient to erase recorded information from a portion of at least one magnetic-recording disk **2210***b* at the second temperature in a disk-stack of the HDD **2210** when the HDD **2210** is inserted into the second portion of the gap **2254**. The plurality of magnets and the structure are configured to direct the magnetic-flux density in a substantially radial direction of the portion of the magnetic-recording disk **2210***b* in the HDD **2210** in the second portion, for example, second portion **224**, of the gap **2254**. The second temperature lowers a coercivity of the magnetic-recording disk **2210***b* in the HDD **2210** so that, when recorded information is erased from the magnetic-recording disk **2210***b* in the HDD **2210** at the second temperature, recorded information on the magnetic-recording disk **2210***b* is erased from a second magnetic-recording track in closer proximity to an inside diameter of the magnetic-recording disk **2210***b* than a first magnetic-recording track from which recorded information on the magnetic-recording disk **2210***b* may be erased, if recorded information were erased from the magnetic-recording disk **2210***b* in the HDD **2210** at the first temperature.

With further reference to FIGS. **20**-**22** and FIGS. **2**A-**3**B, in accordance with embodiments of the present invention, the magnetic-flux density **2250** produced by the plurality of magnets and the structure is configured to erase recorded information from the magnetic-recording disk **2210***b* disposed in the second portion, for example, similar to second portion **224**, of the gap **2254** without degrading magnetization of a drive-motor magnet, for example, similar to drive-motor magnet **330** of FIG. **3**A, in the drive motor disposed in the third portion, for example, similar to third portion **340**, of the gap **2254**. The plurality of magnets may be configured to produce a magnetic-flux density **2250** sufficient to erase recorded information from a portion of at least one magnetic-recording disk **2210***b* containing servo information in a disk-stack of the HDD **2210**. The plurality of magnets may also be configured to produce a magnetic-flux density **2250** sufficient to erase recorded data from a portion of at least one magnetic-recording disk **2210***b* containing recorded data in a disk-stack of the HDD **2210** to preserve security of the recorded data.

With further reference to FIG. **22** and FIGS. **4**A-**7**, in accordance with an alternative embodiment of the present invention, the bulk eraser **2201***b* may alternatively include at least three magnets, for example, similar to the three magnets **410**, **430** and **460** of FIGS. **4**A and **4**B, and a structure magnetically coupled with the at least three magnets to produce magnetic-flux density **2250** in the gap **2254**, wherein the gap **2254**, for example, similar to gap **202** of FIG. **2**B, has a first portion, a second portion and a third portion, for example, similar to first portion **422**, a second portion **424** of FIGS. **4**A and **4**B, and a third portion **340** of FIGS. **3**A and **3**B. The first magnet **2230** and a second magnet **2240**, similar to the two magnets **410** and **430**, respectively, are disposed with opposing end poles of same polarity across the first portion, similar to first portion **422**, of the gap **2254**. The at least three magnets, similar to the three magnets **410**, **430** and **460**, and the structure are configured to produce a magnetic-flux density in the second portion, similar to second portion **424**, of the gap **2254** sufficient to erase recorded information from a portion of at least one magnetic-recording disk **2210***b* at the second temperature, for example, second temperature **2035**, in a disk-stack of the HDD **2210** when the HDD **2210** is inserted into the second portion, similar to second portion **424**, of the gap **2254**. The at least three magnets, similar to the three magnets **410**, **430** and **460**, and the structure are also configured to direct the magnetic-flux density in a substantially radial direction of the portion of the magnetic-recording disk **2210***b* in the HDD **2210** in the second portion, similar to second portion **424**, of the gap **2254**. The second temperature lowers a coercivity of the magnetic-recording disk **2210***b* in the HDD **2210** so that, when recorded information is erased from the magnetic-recording disk **2210***b* in the HDD **2210** at the second temperature recorded information on the magnetic-recording disk **2210***b* is erased from a second magnetic-recording track in closer proximity to an inside diameter of the magnetic-recording disk **2210***b* than a first magnetic-recording track from which recorded information on the magnetic-recording disk **2210***b* may be erased, if recorded information were erased from the magnetic-recording disk **2210***b* in the HDD **2210** at the first temperature, for example, first temperature **2030**.

With further reference to FIG. **22** and FIGS. **4**A-**7**, in accordance with an alternative embodiment of the present invention, the at least three magnets, similar to the three magnets **410**, **430** and **460**, and the structure are configured to produce the magnetic-flux density **2250** such that the magnetic-flux density **2250** is applied to a localized portion of the magnetic-recording disk **2210***b* to suppress eddy currents in the magnetic-recording disk **2210***b* of the HDD **2210**. The magnetic-flux density **2250** produced by the at least three magnets, similar to the three magnets **410**, **430** and **460**, and the structure is configured to erase recorded information from the magnetic-recording disk **2210***b* disposed in the second portion, similar to second portion **424**, of the gap **2254** without degrading magnetization of a drive-motor magnet, similar to drive-motor magnet **330** of FIG. **3**A, in the drive motor disposed in the third portion, similar to third portion **340**, of the gap **2254**. The intensity of a field component of the magnetic-flux density directed along the radial direction in the plane of the magnetic-recording disk **2210***b* produced by the at least three magnets, similar to the three magnets **410**, **430** and **460**, and the structure has a gradient as a function of distance along the radial direction at a transition region between the second portion, similar to second portion **424**, of the gap **2254** and the third portion, similar to third portion **340**, of the gap **2254** such that the gradient allows erasing recorded information from the magnetic-recording disk **2210***b* in close proximity to the drive-motor magnet, similar to drive-motor magnet **330** of FIG. **3**A, in the drive motor without degrading magnetization of the drive-motor magnet in the drive motor.

With reference now to FIG. **23**, in accordance with a second example embodiment of the present invention, a block diagram **2300** of a combined bulk thermal-assister and bulk eraser **2301** wherein a bulk thermal-assister **2301***a* is integrated with a bulk eraser **2301***b* is shown. The combined bulk thermal-assister and bulk eraser **2301** includes the bulk thermal-assister **2301***a* and the bulk eraser **2301***b*. FIG. **23** illustrates the work-flow of a magnetic-recording disk **2310***b* in a HDD **2310** initially at a first temperature, for example, first temperature **2030**, which upon passing into the integrated combined bulk thermal-assister and bulk eraser **2301** is heated by a thermal-assist means **2320** and is erased at a second temperature, for example, second temperature **2035**. The HDD **2310**, similar in all respects to HDD **2210** of FIG. **22**, includes an enclosure **2310***a* and the magnetic-recording disk **2310***b* inside the enclosure **2310***a*. The bulk thermal-assister **2301***a* is similar in all respects to bulk thermal-assister **2201***a* described above in the discussion of FIG. **22**, except the bulk thermal-assister **2301***a* is integrated with the bulk eraser **2301***b*. Thus, the bulk thermal-assister **2301***a* of the combined bulk thermal-assister and bulk eraser **2300** further includes at least one thermal-assist means **2320**. The thermal-assist means **2320** is utilized to provide heat **2324**, indicated by the wavy arrows in FIG. **23**, which raises the temperature of the magnetic-recording disk **2310***b* in the HDD **2310** so that the second temperature is greater than the first temperature to lower a coercivity of the magnetic-recording disk **2310***b* in the HDD **2310**, so that the erase field is correspondingly lowered as described above in the discussion of FIGS. **20** and **21**. In an alternative embodiment of the present invention, the second temperature is at least 20° C. above the first temperature to lower a coercivity of the magnetic-recording disk **2310***b* in the HDD **2310**, so that the erase field is correspondingly lowered.

With further reference to FIG. **23**, in accordance with the second example embodiment of the present invention, the bulk eraser **2301***b* is similar in all respects to bulk eraser **2201***b* described above in the discussion of FIG. **22**, except the bulk eraser **2301***b* is integrated with the bulk thermal-assister **2301***a*. The bulk eraser **2301***b* may include a plurality of magnets, for example, a first magnet **2330** and a second magnet **2340**, without limitation thereto, as embodiments of the present invention may include one or more magnets, and, in particular, more than two magnets or two sources of magnetic flux. The bulk eraser **2301***b* includes a structure (not shown), which may be similar to the structures described above in the discussion of FIGS. **2**A-**2**B, **4**A-**4**C and **5**, without limitation thereto, as the bulk eraser **2301***b* may be of a generic type. The structure is magnetically coupled with the plurality of magnets to produce magnetic-flux density **2350** in a gap **2354**, wherein the gap **2354** may have various portions (not shown), which may be similar to various portions of gaps described above in the discussion of FIGS. **2**A-**5**, without limitation thereto. The direction **2334** of the B-field, the magnetic-flux density, as well as the magnetization field, in the first magnet **2330** may be as shown by the black arrow within the block designating the first magnet **2330**. Similarly, the direction **2344** of the B-field, the magnetic-flux density, as well as the magnetization field, in the second magnet **2340** may be as shown by the black arrow within the block designating the second magnet **2340**.

With reference now to FIG. **24**, in accordance with a third example embodiment of the present invention, a block diagram **2400** of a combined bulk thermal-assister and bulk eraser **2401** having a chiller **2401***c* integrated with the bulk eraser is shown. The combined bulk thermal-assister and bulk eraser **2401** includes a bulk thermal-assister **2401***a*, a bulk eraser **2401***b* and the chiller **2401***c*. FIG. **24** illustrates the work-flow of a magnetic-recording disk **2410***b* in a HDD **2410** initially at a first temperature, for example, first temperature **2030**, which upon passing through the bulk thermal-assister **2401***a* is heated by a thermal-assist means **2420**, subsequently passes into the bulk eraser **2401***b* and is chilled by the bulk eraser **2401***b* integrated with the chiller **2401***c* so that the drive-motor magnet, similar to drive-motor magnet **330** of FIG. **3**A, of the drive motor is at a fourth temperature less than the second temperature, for example, second temperature **2035**. Thereupon, at the second temperature recorded information is erased from the magnetic-recording disk **2410***b*. The chiller **2401***c* is similar in all respects to chiller **2201***c* described above in the discussion of FIG. **22**, except the chiller **2401***c* is integrated with the bulk eraser **2401***b*. Similarly, the HDD **2410** is similar in all respects to HDD **2210** of FIG. **22** and includes an enclosure **2410***a* and the magnetic-recording disk **2410***b* inside the enclosure **2410***a*. Furthermore, the bulk thermal-assister **2401***a* is similar in all respects to bulk thermal-assister **2201***a* described above in the discussion of FIG. **22**. The bulk thermal-assister **2401***a* of the combined bulk thermal-assister and bulk eraser **2401** further includes at least one thermal-assist means **2420**. The thermal-assist means **2420** is utilized to provide heat **2424**, indicated by the wavy arrows in FIG. **24**, which raises the temperature of the magnetic-recording disk **2410***b* in the HDD **2410** so that the second temperature is greater than the first temperature to lower a coercivity of the magnetic-recording disk **2410***b* in the HDD **2410**, so that the erase field is correspondingly lowered as described above in the discussion of FIGS. **20** and **21**. In an alternative embodiment of the present invention, the second temperature is at least 20° C. above the first temperature to lower a coercivity of the magnetic-recording disk **2410***b* in the HDD **2410**, so that the erase field is correspondingly lowered.

With further reference to FIG. **24**, in accordance with the third example embodiment of the present invention, the bulk eraser **2401***b* is similar in all respects to bulk eraser **2201***b* described above in the discussion of FIG. **22**, except the bulk eraser **2401***b* is integrated with the chiller **2401***c*. The bulk eraser **2401***b* may include a plurality of magnets, for example, a first magnet **2430** and a second magnet **2440**, without limitation thereto, as embodiments of the present invention may include one or more magnets, and, in particular, more than two magnets or two sources of magnetic flux. The bulk eraser **2401***b* includes a structure (not shown), which may be similar to the structures described above in the discussion of FIGS. **2**A-**2**B, **4**A-**4**C and **5**, without limitation thereto, as the bulk eraser **2401***b* may be of a generic type. The structure is magnetically coupled with the plurality of magnets to produce magnetic-flux density **2450** in a gap **2454**, wherein the gap **2454** may have various portions (not shown), which may be similar to various portions of gaps described above in the discussion of FIGS. **2**A-**5**, without limitation thereto. The direction **2434** of the B-field, the magnetic-flux density, as well as the magnetization field, in the first magnet **2430** may be as shown by the black arrow within the block designating the first magnet **2430**. Similarly, the direction **2444** of the B-field, the magnetic-flux density, as well as the magnetization field, in the second magnet **2440** may be as shown by the black arrow within the block designating the second magnet **2440**.

With reference now to FIG. **25**, in accordance with a fourth example embodiment of the present invention, a block diagram **2500** of a combined bulk thermal-assister and bulk eraser **2501** having a chiller **2501***c* wherein a bulk thermal-assister **2501***a* and the chiller **2501***c* are both integrated with a bulk eraser **2501***b* is shown. The combined bulk thermal-assister and bulk eraser **2501** includes the bulk thermal-assister **2501***a*, the bulk eraser **2501***b* and the chiller **2501***c*. FIG. **25** illustrates the work-flow of a magnetic-recording disk **2510***b* in a HDD **2510** initially at a first temperature, for example, first temperature **2030**, which upon passing into the integrated combined bulk thermal-assister and bulk eraser **2501** is heated by a thermal-assist means **2520** and is erased at a second temperature, for example, second temperature **2035**, and is chilled by the bulk eraser **2501***b* integrated with the chiller **2501***c* so that the drive-motor magnet, similar to drive-motor magnet **330** of FIG. **3**A, of the drive motor is at a fourth temperature less than the second temperature. The chiller **2501***c* is similar in all respects to chiller **2201***c* described above in the discussion of FIG. **22**, except the chiller **2501***c* is integrated with the bulk eraser **2501***b*. Similarly, the HDD **2510** is similar in all respects to HDD **2210** of FIG. **22** and includes an enclosure **2510***a* and the magnetic-recording disk **2510***b* inside the enclosure **2510***a*. Also, the bulk thermal-assister **2501***a* is similar in all respects to bulk thermal-assister **2201***a* described above in the discussion of FIG. **22**, except the bulk thermal-assister **2501***a* is also integrated with the bulk eraser **2501***b*. The bulk thermal-assister **2501***a* of the combined bulk thermal-assister and bulk eraser **2501** further includes at least one thermal-assist means **2520**. The thermal-assist means **2520** is utilized to provide heat **2524**, indicated by the wavy arrows in FIG. **25**, which raises the temperature of the magnetic-recording disk **2510***b* in the HDD **2510** so that the second temperature is greater than the first temperature to lower a coercivity of the magnetic-recording disk **2510***b* in the HDD **2510**, so that the erase field is correspondingly lowered as described above in the discussion of FIGS. **20** and **21**. In an alternative embodiment of the present invention, the second temperature is at least 20° C. above the first temperature to lower a coercivity of the magnetic-recording disk **2510***b* in the HDD **2510**, so that the erase field is correspondingly lowered.

With further reference to FIG. **25**, in accordance with the fourth example embodiment of the present invention, the bulk eraser **2501***b* is similar in all respects to bulk eraser **2201***b* described above in the discussion of FIG. **22**, except the bulk eraser **2501***b* is integrated with the chiller **2501***c* and the bulk thermal-assister **2501***a*. The bulk eraser **2501***b* may include a plurality of magnets, for example, a first magnet **2530** and a second magnet **2540**, without limitation thereto, as embodiments of the present invention may include one or more magnets, and, in particular, more than two magnets or two sources of magnetic flux. The bulk eraser **2501***b* includes a structure (not shown), which may be similar to the structures described above in the discussion of FIGS. **2**A-**2**B, **4**A-**4**C and **5**, without limitation thereto, as the bulk eraser **2501***b* may be of a generic type. The structure is magnetically coupled with the plurality of magnets to produce magnetic-flux density **2550** in a gap **2554**, wherein the gap **2554** may have various portions (not shown), which may be similar to various portions of gaps described above in the discussion of FIGS. **2**A-**5**, without limitation thereto. The direction **2534** of the B-field, the magnetic-flux density, as well as the magnetization field, in the first magnet **2530** may be as shown by the black arrow within the block designating the first magnet **2530**. Similarly, the direction **2544** of the B-field, the magnetic-flux density, as well as the magnetization field, in the second magnet **2540** may be as shown by the black arrow within the block designating the second magnet **2540**.

With reference now to FIG. **26**, in accordance with a fifth example embodiment of the present invention, a block diagram **2600** of a bulk eraser **2601** with a thermal-assist means is shown. FIG. **26** illustrates the work-flow of a magnetic-recording disk **2610***b* in a HDD **2610** initially at a first temperature, for example, first temperature **2030**, which upon passing into the bulk eraser **2601** with the thermal-assist means is heated by the thermal-assist means and is erased at a second temperature, for example, second temperature **2035**, which may be at least 20° C. above the first temperature. The bulk eraser **2601** with thermal-assist means includes a thermal-assist means and the bulk eraser **2601**. The thermal-assist means is for producing a temperature in the magnetic-recording disk **2610***b* in the HDD **2610** when the HDD **2610** is disposed in the bulk eraser **2601** such that the temperature is about equal to a second temperature, which may be at least 20° C. above a first temperature of the magnetic-recording disk **2610***b* in the HDD **2610**. The bulk eraser **2601** is configured to erase recorded information from the magnetic-recording disk **2610***b* at the second temperature in the HDD.

The first temperature may be an ambient temperature of the magnetic-recording disk **2610***b* in the HDD **2610** before the HDD **2610** is prepared for erasure of the recorded information in the bulk eraser **2601**. For example, the first temperature may be an ambient temperature about equal to RT, about 25° C.

With further reference to FIG. **26**, in accordance with the fifth example embodiment of the present invention, the HDD **2610**, similar in all respects to HDD **2210** of FIG. **22**, includes an enclosure **2610***a* and the magnetic-recording disk **2610***b* inside the enclosure **2610***a*. The thermal-assist means may be incorporated as part of the HDD **2610**, which is shown in the enlarged view of the dashed circle **27** in FIG. **27**. The thermal-assist means is utilized to provide heat **2624**, indicated by the wavy arrows in FIG. **26**, which raises the temperature of the magnetic-recording disk **2610***b* in the HDD **2610** so that the second temperature, for example, second temperature **2035**, is greater than the first temperature, for example, first temperature **2030**, to lower a coercivity of the magnetic-recording disk **2610***b* in the HDD **2610**, so that the erase field is correspondingly lowered as described above in the discussion of FIGS. **20** and **21**. In an alternative embodiment of the present invention, the second temperature is at least 20° C. above the first temperature to lower a coercivity of the magnetic-recording disk **2610***b* in the HDD **2610**, so that the erase field is correspondingly lowered.

With further reference to FIG. **26**, in accordance with the fifth example embodiment of the present invention, the bulk eraser **2601** is similar in all respects to bulk eraser **2201***b* described above in the discussion of FIG. **22**, except the bulk eraser **2601** is integrated, during the erasure operation, with the thermal-assist means, for example, a thermal-assist means incorporated in the HDD **2610**. The bulk eraser **2601** may include a plurality of magnets, for example, a first magnet **2630** and a second magnet **2640**, without limitation thereto, as embodiments of the present invention may include one or more magnets, and, in particular, more than two magnets or two sources of magnetic flux. The bulk eraser **2601** includes a structure (not shown), which may be similar to the structures described above in the discussion of FIGS. **2A-2B**, **4A-4C** and **5**, without limitation thereto, as the bulk eraser **2601** may be of a generic type. The structure is magnetically coupled with the plurality of magnets to produce magnetic-flux density **2650** in a gap **2654**, wherein the gap **2654** may have various portions (not shown), which may be similar to various portions of gaps described above in the discussion of FIGS. **2A-5**, without limitation thereto. The direction **2634** of the B-field, the magnetic-flux density, as well as the magnetization field, in the first magnet **2630** may be as shown by the black arrow within the block designating the first magnet **2630**. Similarly, the direction **2644** of the B-field, the magnetic-flux density, as well as the magnetization field, in the second magnet **2640** may be as shown by the black arrow within the block designating the second magnet **2640**.

With reference now to FIG. **27**, in accordance with the fifth example embodiment of the present invention, an enlarged view **2700** of the HDD **2610** shown in the dashed circle **27** of the block diagram of FIG. **26** that details an embodiment of the present invention for the thermal-assist means incorporated in the HDD **2610** is shown. Details of the arrangement of the HDD **2610** as the HDD **2610** is configured for erasure of recorded information form the magnetic-recording disk **2610***b* in the gap **2654** of the bulk eraser **2601** and the magnetic-flux density **2650** emanating into the gap **2654** from the pole ends of the magnets **2630** and **2640** of the bulk eraser **2601** are shown in FIG. **27**. As shown in FIG. **27**, the HDD **2610** further includes, in addition to the enclosure **2610***a* and the magnetic-recording disk **2610***b* inside the enclosure **2610***a*, a drive motor **2610***d* and a spindle **2610***c* attached to the rotor (not shown) of the drive motor **2610***d*. The thermal-assist means may include the drive motor **2610***d* of the HDD **2610**, which is operated to raise the second temperature, for example, second temperature **2035**, above the first temperature, for example, first temperature **2030**, of the magnetic-recording disk **2610***b* in the HDD **2610**. The temperature of the magnetic-recording disk **2610***b* may be raised to the second temperature through waste heat generated by the motor windings due to Joule heating produced by a motor current used to power the drive motor in its operation. For example, the thermal-assist means incorporated in the HDD **2610** including the drive motor **2610***d* of the HDD **2610** may be operated to produce a second temperature in the magnetic-recording disk **2610***b*, which may be at least 20° C. above the first temperature of the magnetic-recording disk **2610***b* in the HDD **2610**.

With reference now to FIG. **28**, in accordance with a sixth example embodiment of the present invention, a block diagram **2800** of a bulk eraser **2801** with a thermal-assist means having a chiller **2801***b* is shown. The bulk eraser with thermal-assist means **2801** having the chiller **2801***b* includes a bulk eraser **2801***a*, a thermal-assist means and the chiller **2801***b*. FIG. **28** illustrates the work-flow of a magnetic-recording disk **2810***b* in a HDD **2810** initially at a first temperature, for example, first temperature **2030**, which before passing into the bulk eraser **2801***a* is heated by the thermal-assist means, is passed through the chiller **2801***b* which is configured to lower a temperature of the drive-motor magnet of the HDD to a fourth temperature less than a second temperature, for example, second temperature **2035**, of the magnetic-recording disk **2810***b*, and is erased at the second temperature, which may be at least 20° C. above the first temperature. The thermal-assist means may be incorporated as part of the HDD **2810**, in similar fashion to the manner of the enlarged view of the dashed circle **27** of FIG. **26** shown in FIG. **27**. The thermal-assist means is utilized to provide heat **2824**, indicated by the wavy arrows in FIG. **28**, which raises the temperature of the magnetic-recording disk **2810***b* in the HDD **2810** so that the second temperature is greater than the first temperature to lower a coercivity of the magnetic-recording disk **2810***b* in the HDD **2810**, so that the erase field is correspondingly lowered as described above in the discussion of FIGS. **20** and **21**. In an alternative embodiment of the present invention, the second temperature is at least 20° C. above the first temperature to lower a coercivity of the magnetic-recording disk **2810***b* in the HDD **2810**, so that the erase field is correspondingly lowered.

With further reference to FIG. **28**, in accordance with the sixth example embodiment of the present invention, similar to FIG. **27**, the HDD **2810** further includes, in addition to an enclosure **2810***a* and the magnetic-recording disk **2810***b* inside the enclosure **2810***a*, a drive motor **2810***d* and a spindle **2810***c* attached to the rotor (not shown) of the drive motor **2810***d*. The thermal-assist means may include the drive motor **2810***d* of the HDD **2810**, which is operated to raise the second temperature, for example, second temperature **2035**, above the first temperature, for example, first temperature **2030**, of the magnetic-recording disk **2810***b* in the HDD **2810**. For example, the thermal-assist means incorporated in the HDD **2810** including the drive motor **2810***d* of the HDD **2810** may be operated to produce a second temperature in the magnetic-recording disk **2810***b*, which may be at least 20° C. above the first temperature of the magnetic-recording disk **2810***b* in the HDD **2810**.

With further reference to FIG. **28**, in accordance with the sixth example embodiment of the present invention, the bulk eraser **2801***a* is similar in all respects to bulk eraser **2201***b* described above in the discussion of FIG. **22**, except the bulk eraser **2801***a* is integrated, during the erasure operation, with the thermal-assist means, for example, a thermal-assist means incorporated in the HDD **2810**. The bulk eraser **2801***a* may include a plurality of magnets, for example, a first magnet **2830** and a second magnet **2840**, without limitation thereto, as embodiments of the present invention may include one or more magnets, and, in particular, more than two magnets or two sources of magnetic flux. The bulk eraser **2801***a* includes a structure (not shown), which may be similar to the structures described above in the discussion of FIGS. **2**A-**2**B, **4**A-**4**C and **5**, without limitation thereto, as the bulk eraser **2801***a* may be of a generic type. The structure is magnetically coupled with the plurality of magnets to produce magnetic-flux density **2850** in a gap **2854**, wherein the gap **2854** may have various portions (not shown), which may be similar to various portions of gaps described above in the discussion of FIGS. **2**A-**5**, without limitation thereto. The direction **2834** of the B-field, the magnetic-flux density, as well as the magnetization field, in the first magnet **2830** may be as shown by the black arrow within the block designating the first magnet **2830**. Similarly, the direction **2844** of the B-field, the magnetic-flux density, as well as the magnetization field, in the second magnet **2840** may be as shown by the black arrow within the block designating the second magnet **2840**.

With further reference to FIG. **28**, in accordance with the sixth example embodiment of the present invention, the chiller **2801***b* may be configured to lower a temperature of the enclosure **2810***a* of the HDD **2810** to a third temperature less than the second temperature, for example, second temperature **2035**, of the magnetic-recording disk **2810***b*. The chiller **2801***b* may also be configured to lower a temperature of the drive-motor magnet of the drive motor **2810***d* of the HDD **2810** to a fourth temperature less than the second temperature of the magnetic-recording disk **2810***b*. As suggested by FIG. **28**, and similarly described above for the chiller **2201***c* of FIG. **22**, the chiller **2801***b* may include a chilling station on an assembly line separate from the bulk eraser **2801***a*.

With reference now to FIG. **29**, in accordance with a seventh example embodiment of the present invention, a block diagram **2900** of a bulk eraser with a thermal-assist means **2901** having a chiller integrated with a bulk eraser **2901***a* is shown. The bulk eraser with thermal-assist means **2901** includes the bulk eraser **2901***a*, a thermal-assist means and a chiller **2901***b*, which is integrated with the bulk eraser **2901***a*. FIG. **29** illustrates the work-flow of a magnetic-recording disk **2910***b* in a HDD **2910** initially at a first temperature, for example, first temperature **2030**, which before passing into the bulk eraser **2901***a* is heated by the thermal-assist means, is erased at a second temperature, for example, second temperature **2035**, which may be at least 20° C. above the first temperature, and is chilled by the bulk eraser **2901***a* integrated with the chiller **2901***b* so that a drive-motor magnet of a drive motor **2910***d* is at a fourth temperature less than the second temperature. The thermal-assist means may be incorporated as part of the HDD **2910**, in similar fashion to the manner of the enlarged view of the dashed circle **27** of FIG. **26** shown in FIG. **27**. The thermal-assist means is utilized to provide heat **2924**, indicated by the wavy arrows in FIG. **29**, which raises the temperature of the magnetic-recording disk **2910***b* in the HDD **2910** so that the second temperature is greater than the first temperature to lower a coercivity of the magnetic-recording disk **2910***b* in the HDD **2910**, so that the erase field is correspondingly lowered as described above in the discussion of FIGS. **20** and **21**. In an alternative embodiment of the present invention, the second temperature is at least 20° C. above the first temperature to lower a coercivity of the magnetic-recording disk **2910***b* in the HDD **2910**, so that the erase field is correspondingly lowered.

With further reference to FIG. **29**, in accordance with the seventh example embodiment of the present invention, similar to FIG. **27**, the HDD **2910** further includes, in addition to an enclosure **2910***a* and the magnetic-recording disk **2910***b* inside the enclosure **2910***a*, the drive motor **2910***d* and a spindle **2910***c* attached to the rotor (not shown) of the drive motor **2910***d*. The thermal-assist means may include the drive motor **2910***d* of the HDD **2910**, which is operated to raise the second temperature, for example, second temperature **2035**, above the first temperature, for example, first temperature **2030**, of the magnetic-recording disk **2910***b* in the HDD **2910**. For example, the thermal-assist means incorporated in the HDD **2910** including the drive motor **2910***d* of the HDD **2910** may be operated to produce a second temperature in the magnetic-recording disk **2910***b*, which may be at least 20° C. above the first temperature of the magnetic-recording disk **2910***b* in the HDD **2910**.

With further reference to FIG. **29**, in accordance with the seventh example embodiment of the present invention, the bulk eraser **2901***a* is similar in all respects to bulk eraser **2201***b* described above in the discussion of FIG. **22**, except the bulk eraser **2901***a* is integrated with the chiller **2901***b*, and, during the erasure operation, is also integrated with the thermal-assist means, for example, a thermal-assist means incorporated in the HDD **2910**. The bulk eraser **2901***a* may include a plurality of magnets, for example, a first magnet **2930** and a second magnet **2940**, without limitation thereto, as embodiments of the present invention may include one or more magnets, and, in particular, more than two magnets or two sources of magnetic flux. The bulk eraser **2901***a* includes a structure (not shown), which may be similar to the structures described above in the discussion of FIGS. **2**A-**2**B, **4**A-**4**C and **5**, without limitation thereto, as the bulk eraser **2901***a* may be of a generic type. The structure is magnetically coupled with the plurality of magnets to produce magnetic-flux density **2950** in a gap **2954**, wherein the gap **2954** may have various portions (not shown), which may be similar to various portions of gaps described above in the discussion of FIGS. **2**A-**5**, without limitation thereto. The direction **2934** of the B-field, the magnetic-flux density, as well as the magnetization field, in the first magnet **2930** may be as shown by the black arrow within the block designating the first magnet **2930**. Similarly, the direction **2944** of the B-field, the magnetic-flux density, as well as the magnetization field, in the second magnet **2940** may be as shown by the black arrow within the block designating the second magnet **2940**.

With further reference to FIG. **29**, in accordance with the seventh example embodiment of the present invention, the chiller **2901***b* may be configured to lower a temperature of the enclosure **2910***a* of the HDD **2910** to a third temperature less than the second temperature, for example, second temperature **2035**, of the magnetic-recording disk **2910***b*. The chiller **2901***b* may also be configured to lower a temperature of the drive-motor magnet of the drive motor **2910***d* of the HDD **2910** to a fourth temperature less than the second temperature of the magnetic-recording disk **2910***b*. To employ this latter embodiment of the present invention, the magnetic-recording disk **2910***b* is heated by powering up the drive motor **2910***d*, after which the drive motor is powered down and cooled with the chiller **2901***b*, so that the magnetic recording disk is at a greater second temperature than the fourth temperature of the drive motor **2910***d* which, being in closer proximity to the chiller **2901***b*, cools faster than the magnetic-recording disk **2910***b*.

Sub-Section B: Description of Embodiments of the Present Invention for a Method of Erasing Recorded Information on a Magnetic-Recording Disk in a HDD Using a Bulk Eraser With Thermal-Assist Means

With reference now to FIGS. **30**A and **30**B, in accordance with an embodiment of the present invention, a flow chart **3000** illustrates the method of erasing recorded information on a magnetic-recording disk in a HDD using a bulk eraser with thermal-assist means. At **3010**, a HDD is provided having an enclosure, a disk-stack having at least one magnetic-recording disk rotatably mounted on a spindle, and a drive motor having a rotor attached to the spindle for rotating the magnetic-recording disk inside the enclosure. At **3020**, a thermal-assist means is provided for producing a second temperature of the magnetic-recording disk in the HDD when the HDD is disposed in the bulk eraser greater than a first temperature about equal to ambient temperature of the magnetic-recording disk before producing the second temperature. The thermal-assist means may be selected from the group consisting of an oven, a heater, a heat lamp, a hot-air blower, and the drive motor of the HDD operated to raise the second temperature above the first temperature of the magnetic-recording disk in the HDD. At **3030**, the thermal-assist means is utilized to raise the temperature of the magnetic-recording disk in the HDD so that the second temperature may be at least 20° C. above the first temperature to lower a coercivity of the magnetic-recording disk in the HDD. At **3040**, a bulk eraser is provided that produces magnetic-flux density sufficient to erase recorded information from a portion of the magnetic-recording disk. At **3050**, the magnetic-recording disk is rotated in the HDD. At **3060**, the HDD is inserted into the bulk eraser. At **3070**, recorded information is erased from the portion of the magnetic-recording disk at the second temperature in the HDD. At **3080**, the HDD is removed from the bulk eraser.

With reference now to FIG. **31**, in accordance with an embodiment of the present invention, a flow chart **3100** illustrates further embodiments of the present invention for a method of erasing recorded information on a magnetic-recording disk in a HDD using a bulk eraser with thermal-assist means. At **3110**, a temperature of an enclosure of the HDD is lowered to a third temperature less than the second temperature of the magnetic-recording disk. At **3120**, a temperature of a drive-motor magnet of the HDD is lowered to a fourth temperature less than the second temperature of the magnetic-recording disk.

The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and many modifications and variations are possible in light of the above teaching. The embodiments described herein were chosen and described in order to best explain the principles of the invention and its practical application, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It may be intended that the scope of the invention be defined by the claims appended hereto and their equivalents.

What is claimed is:

1. A combined bulk thermal-assister and bulk eraser for erasing recorded information on a magnetic-recording disk, said combined bulk thermal-assister and bulk eraser comprising:

a bulk thermal-assister, said bulk thermal-assister configured to produce a temperature in a magnetic-recording disk in a hard-disk drive when said hard-disk drive is disposed in said bulk eraser, wherein said temperature is about equal to a second temperature greater than a first temperature of said magnetic-recording disk in said hard-disk drive;

a bulk eraser, said bulk eraser configured to erase recorded information from said magnetic-recording disk at said second temperature in said hard-disk drive;

wherein said second temperature lowers a coercivity of said magnetic-recording disk in said hard-disk drive so that, when recorded information is erased from said magnetic-recording disk in said hard-disk drive at said second temperature, recorded information on said magnetic-recording disk is erased from a second magnetic-recording track in closer proximity to an inside diameter of said magnetic-recording disk than a first magnetic-recording track from which recorded information on said magnetic-recording disk may be erased, if recorded information were erased from said magnetic-recording disk in said hard-disk drive at said first temperature; and

a chiller, said chiller configured to lower a temperature of an enclosure of said hard-disk drive to a third temperature less than said second temperature of said magnetic-recording disk.

2. The combined bulk thermal-assister and bulk eraser of claim **1**, wherein said bulk thermal-assister further comprises at least one thermal-assist means selected from the group consisting of an oven, a heater, a heat lamp, and a hot-air blower.

3. The combined bulk thermal-assister and bulk eraser of claim **1**, wherein said bulk thermal-assister is integrated with said bulk eraser.

4. The combined bulk thermal-assister and bulk eraser of claim **1**, wherein said bulk thermal-assister further comprises a heating station on an assembly line separate from said bulk eraser.

5. The combined bulk thermal-assister and bulk eraser of claim **1**, further comprising a chiller, said chiller configured to lower a temperature of a drive-motor magnet of said hard-disk drive to a fourth temperature less than said second temperature of said magnetic-recording disk.

6. The combined bulk thermal-assister and bulk eraser of claim **1**, wherein said chiller further comprises a chilling station on an assembly line separate from said bulk eraser.

7. The combined bulk thermal-assister and bulk eraser of claim **1**, wherein said chiller is integrated with said bulk eraser.

8. A bulk eraser, for erasing recorded information on a magnetic-recording disk, with thermal-assist means, said bulk eraser with thermal-assist means comprising:

a thermal-assist means, said thermal-assist means for producing a temperature in a magnetic-recording disk in a hard-disk drive when said hard-disk drive is disposed in said bulk eraser, wherein said temperature is about equal to a second temperature at least 20° C. above a first temperature of said magnetic-recording disk in said hard-disk drive;

a bulk eraser, said bulk eraser configured to erase recorded information from said magnetic-recording disk at said second temperature in said hard-disk drive; wherein said first temperature is an ambient temperature of said magnetic-recording disk in said hard-disk drive; and a chiller, said chiller configured to lower a temperature of an enclosure of said hard-disk drive to a third temperature less than said second temperature of said magnetic-recording disk.

9. The bulk eraser with thermal-assist means of claim **8**, wherein thermal-assist means further comprises a drive motor of said hard-disk drive operated to raise said second temperature above said first temperature of said magnetic-recording disk in said hard-disk drive.

10. The bulk eraser with thermal-assist means of claim **8**, further comprising a chiller, said chiller configured to lower a temperature of a drive-motor magnet of said hard-disk drive to a fourth temperature less than said second temperature of said magnetic-recording disk.

11. The bulk eraser with thermal-assist means of claim **8**, wherein said chiller further comprises a chilling station on an assembly line separate from said bulk eraser.

12. The bulk eraser with thermal-assist means of claim **8**, wherein said chiller is integrated with said bulk eraser.

13. A combined bulk thermal-assister and bulk eraser for erasing recorded information on a magnetic-recording disk, said combined bulk thermal-assister and bulk eraser comprising:

a bulk thermal-assister, said bulk thermal-assister configured to produce a temperature in a magnetic-recording disk in a hard-disk drive when said hard-disk drive is disposed in said bulk eraser, wherein said temperature is about equal to a second temperature greater than a first temperature of said magnetic-recording disk in said hard-disk drive; and

a bulk eraser, said bulk eraser further comprising:

a plurality of magnets; and

a structure magnetically coupled with said plurality of magnets to produce magnetic-flux density in a gap, wherein said gap has a first portion, a second portion and a third portion and wherein two magnets are disposed with opposing polarity across said first portion of said gap;

wherein said plurality of magnets and said structure are configured to produce a magnetic-flux density in said second portion of said gap sufficient to erase recorded information from a portion of at least one magnetic-recording disk at said second temperature in a disk-stack of said hard-disk drive when said hard-disk drive is inserted into said second portion of said gap;

wherein said plurality of magnets and said structure are configured to direct said magnetic-flux density in a substantially radial direction of said portion of said magnetic-recording disk in said hard-disk drive in said second portion of said gap; and

wherein said second temperature lowers a coercivity of said magnetic-recording disk in said hard-disk drive so that, when recorded information is erased from said magnetic-recording disk in said hard-disk drive at said second temperature, recorded information on said magnetic-recording disk is erased from a second magnetic-recording track in closer proximity to an inside diameter of said magnetic-recording disk than a first magnetic-recording track from which recorded information on said magnetic-recording disk may be erased, if recorded information were erased from said magnetic-recording disk in said hard-disk drive at said first temperature; and

a chiller, said chiller configured to lower a temperature of an enclosure of said hard-disk drive to a third temperature less than said second temperature of said magnetic-recording disk.

14. The combined bulk thermal-assister and bulk eraser of claim **13**, wherein said magnetic-flux density produced by said plurality of magnets and said structure is configured to erase recorded information from said magnetic-recording disk disposed in said second portion of said gap without degrading magnetization of a drive-motor magnet in a drive motor disposed in said third portion of said gap.

15. The combined bulk thermal-assister and bulk eraser of claim **13**, wherein said plurality of magnets are configured to produce a magnetic-flux density sufficient to erase recorded information from a portion of at least one magnetic-recording disk containing servo information in a disk-stack of said hard-disk drive.

16. The combined bulk thermal-assister and bulk eraser of claim **13**, wherein said plurality of magnets are configured to produce a magnetic-flux density sufficient to erase recorded data from a portion of at least one magnetic-recording disk containing recorded data in a disk-stack of said hard-disk drive to preserve security of said recorded data.

17. A combined bulk thermal-assister and bulk eraser for erasing recorded information on a magnetic-recording disk, said combined bulk thermal-assister and bulk eraser comprising:

a bulk thermal-assister, said bulk thermal-assister configured to produce a temperature in a magnetic-recording disk in a hard-disk drive when said hard-disk drive is disposed in said bulk eraser, wherein said temperature is about equal to a second temperature greater than a first temperature of said magnetic-recording disk in said hard-disk drive; and

a bulk eraser, said bulk eraser further comprising:

at least three magnets; and

a structure magnetically coupled with said at least three magnets to produce magnetic-flux density in a gap, wherein said gap has a first portion, a second portion and a third portion, wherein a first magnet and a second magnet are disposed with opposing end poles of same polarity across said first portion of said gap;

wherein said at least three magnets and said structure are configured to produce a magnetic-flux density in said second portion of said gap sufficient to erase recorded information from a portion of at least one magnetic-recording disk at said second temperature in a disk-stack of said hard-disk drive when said hard-disk drive is inserted into said second portion of said gap;

wherein said at least three magnets and said structure are configured to direct said magnetic-flux density in a substantially radial direction of said portion of said magnetic-recording disk in said hard-disk drive in said second portion of said gap; and

wherein said second temperature lowers a coercivity of said magnetic-recording disk in said hard-disk drive so that, when recorded information is erased from said magnetic-recording disk in said hard-disk drive at said second temperature, recorded information on said magnetic-recording disk is erased from a second magnetic-recording track in closer proximity to an inside diameter of said magnetic-recording disk than a first magnetic-recording track from which recorded information on said magnetic-recording disk may be erased, if recorded information were erased from said magnetic-recording disk in said hard-disk drive at said first temperature; and

a chiller, said chiller configured to lower a temperature of an enclosure of said hard-disk drive to a third temperature less than said second temperature of said magnetic-recording disk.

18. The combined bulk thermal-assister and bulk eraser of claim **17**, wherein said at least three magnets and said structure are configured to produce said magnetic-flux density such that said magnetic-flux density is applied to a localized portion of said magnetic-recording disk to suppress eddy currents in said magnetic-recording disk of said hard-disk drive.

19. The combined bulk thermal-assister and bulk eraser of claim **17**, wherein said magnetic-flux density produced by said at least three magnets and said structure is configured to erase recorded information from said magnetic-recording disk disposed in said second portion of said gap without degrading magnetization of a drive-motor magnet in a drive motor disposed in said third portion of said gap.

20. The combined bulk thermal-assister and bulk eraser of claim **19**, wherein intensity of a field component of said magnetic-flux density directed along said radial direction in said plane of said magnetic-recording disk produced by said at least three magnets and said structure has a gradient as a function of distance along said radial direction at a transition region between said second portion of said gap and said third portion of said gap such that said gradient allows erasing recorded information from said magnetic-recording disk in close proximity to said drive-motor magnet in said drive motor without degrading magnetization of said drive-motor magnet in said drive motor.

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