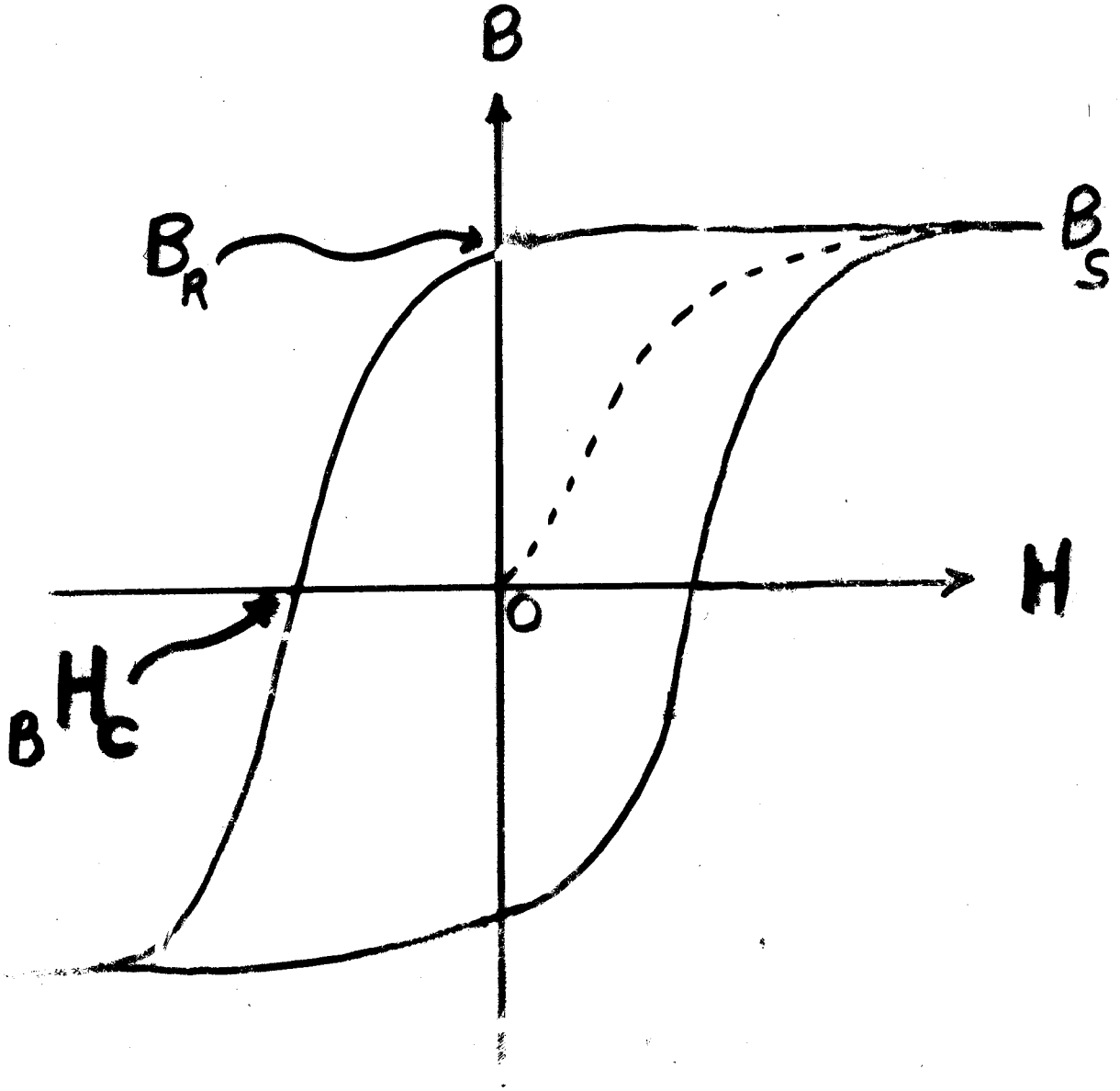


HYSTERESIS LOOP

$$10^{-3} < H_c < 2 \times 10^4$$

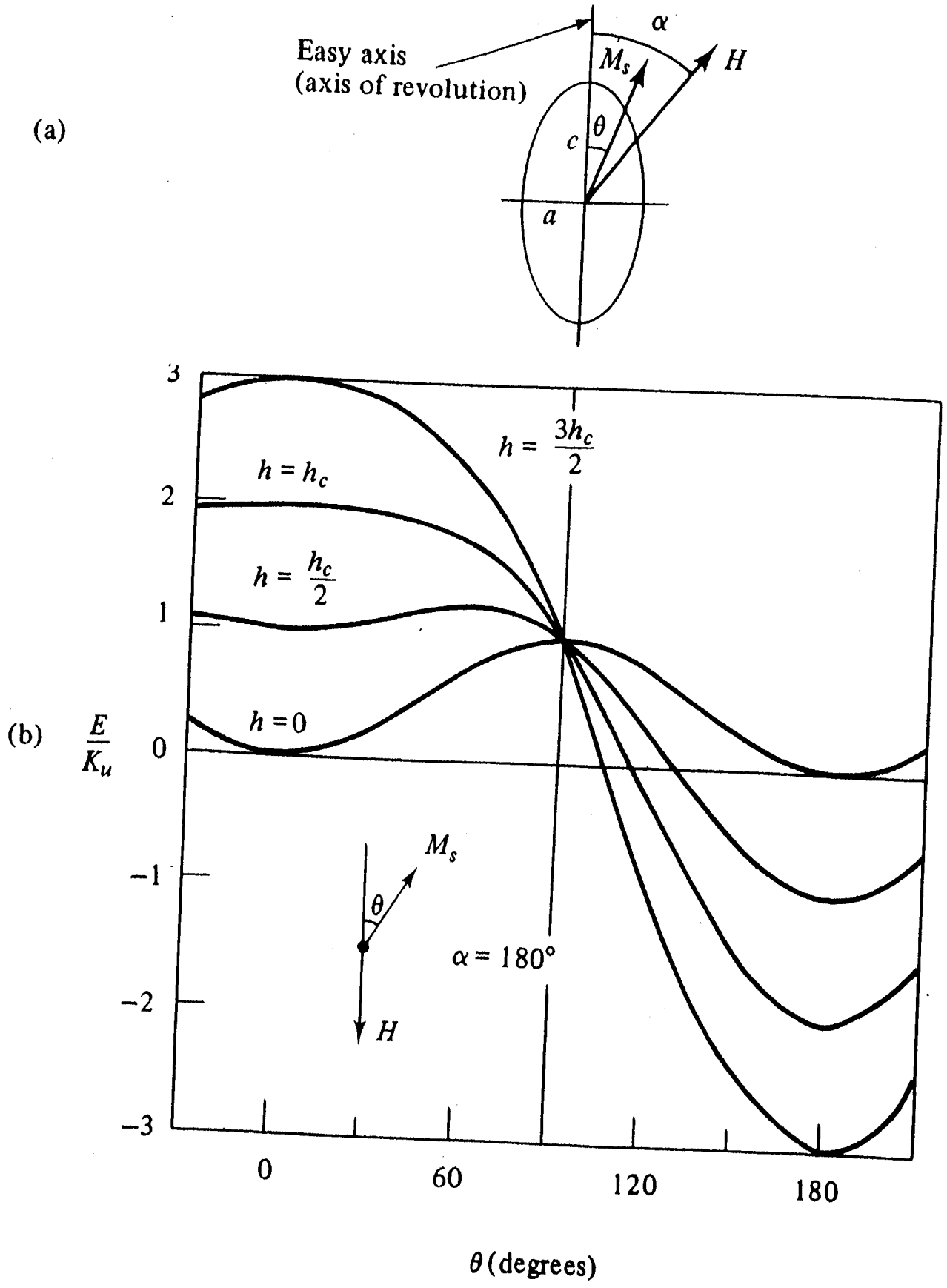


Fig. 9.37 Rotation of magnetization in an ellipsoid. h = reduced field.

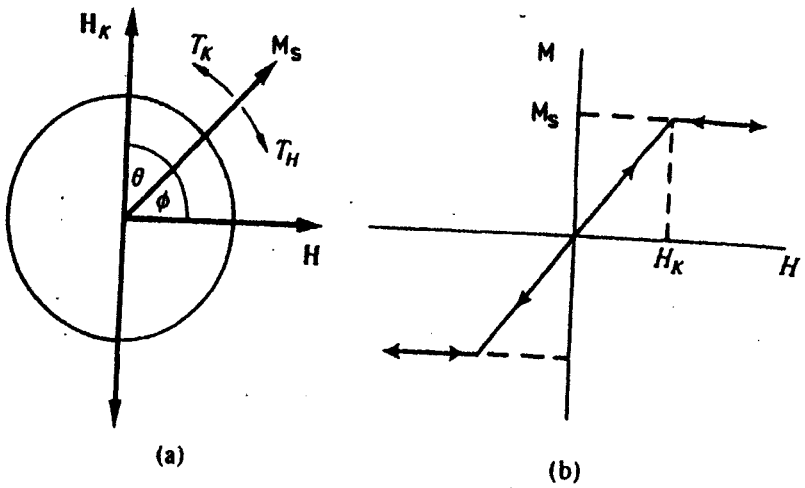


Fig. 13.5. (a) A spherical single-domain particle with anisotropy field H_K and with the magnetic field H perpendicular to the easy axis; (b) magnetization curve obtained for the situation depicted in (a).

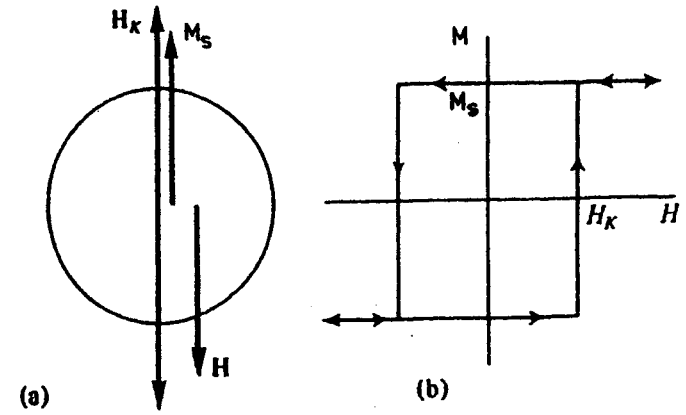


Fig. 13.6 (a) A spherical single-domain particle with anisotropy field H_K and with the magnetic field H parallel to the easy axis; (b) magnetization curve obtained for the situation depicted in (a).

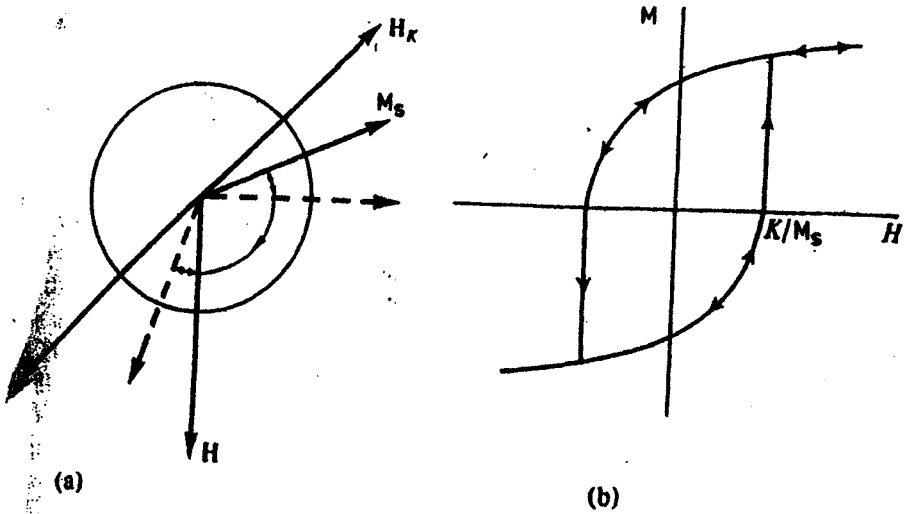
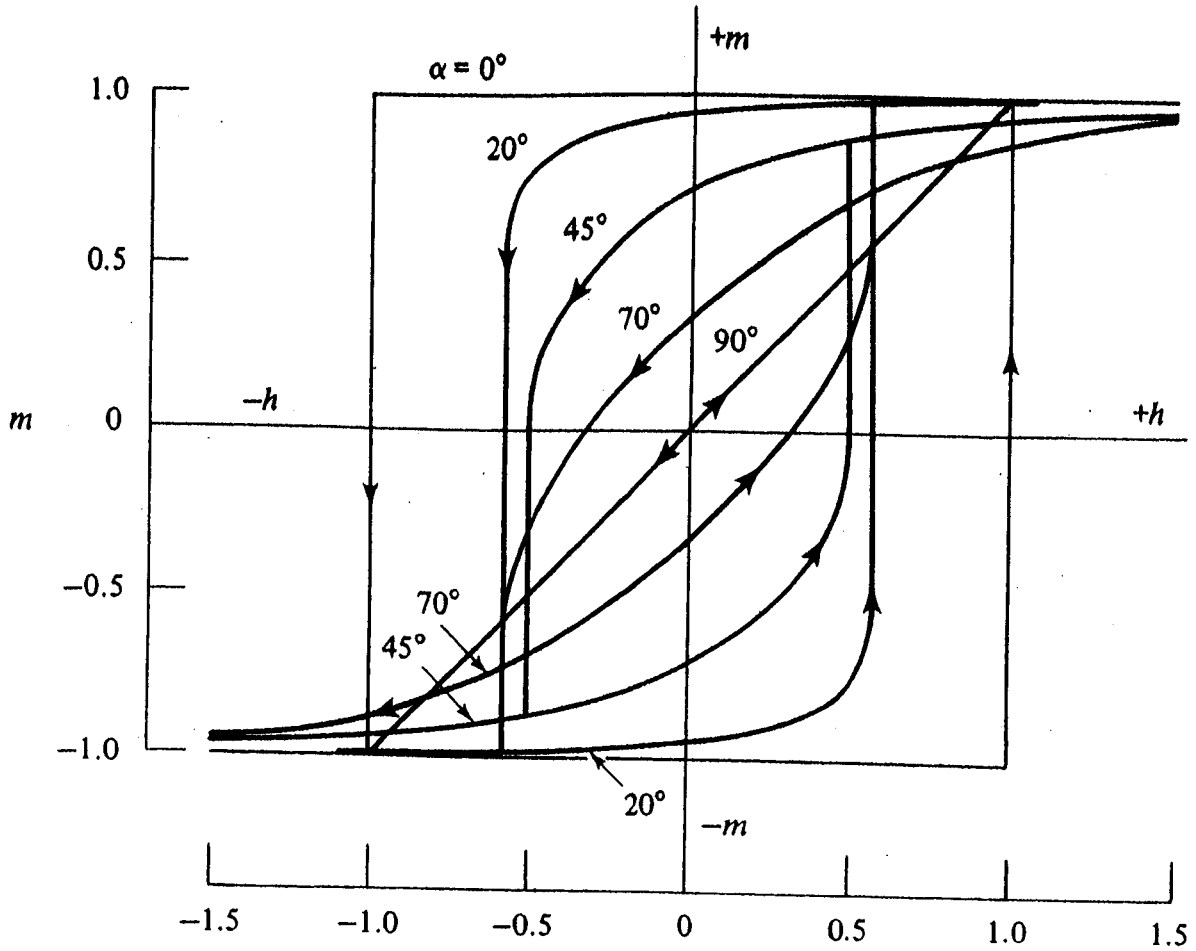
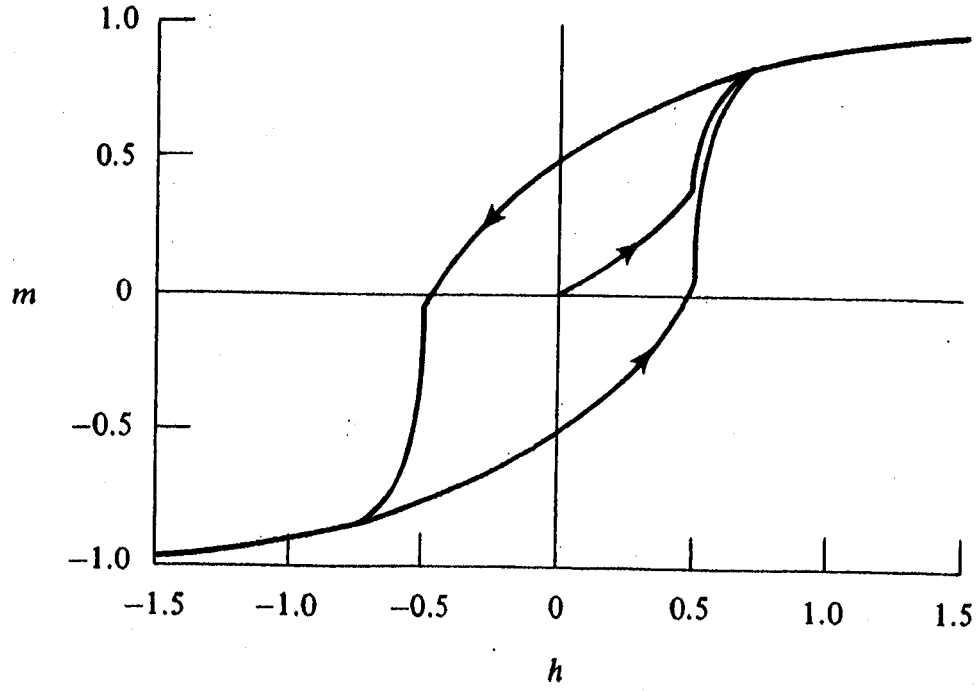


Fig. 13.7 (a) A spherical single-domain particle with anisotropy field H_K and with the magnetic field H at an arbitrary angle to the easy axis; (b) magnetization curve obtained for the situation depicted in (a).



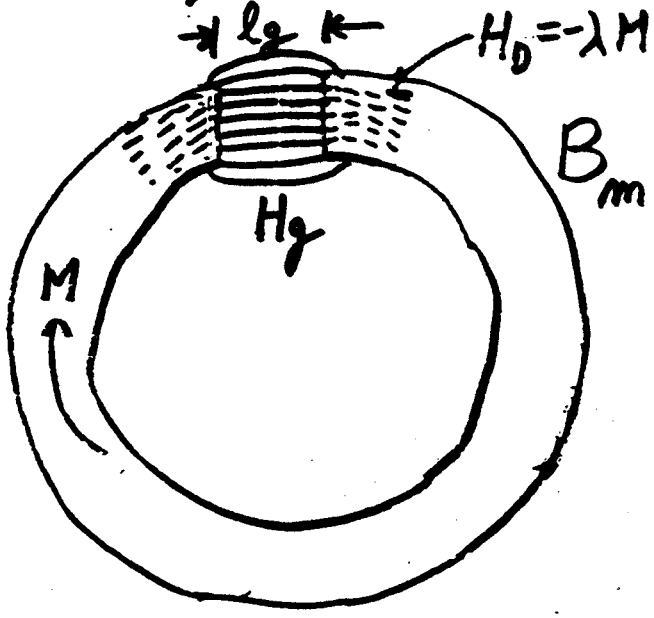
Hysteresis loops for uniaxial anisotropy. (α = angle between field and easy axis.)



Hysteresis loop of an assembly of single-domain, uniaxial particles having their easy axes randomly oriented. Stoner and Wohlfarth [7.23], Rhodes [9.31].

PERMANENT MAGNET

$\Rightarrow$ External FIELD



l_g, H_g, A_g

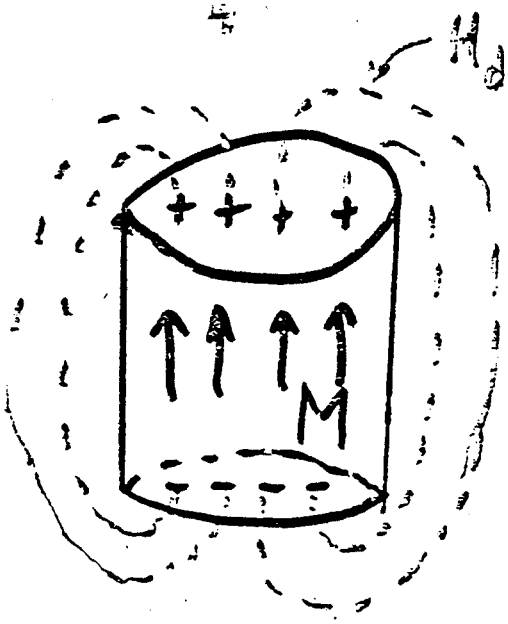
$H_D = H_D(\text{geometry})$

OPEN CIRCUIT $\Rightarrow$

FREE Poles

DEMAGNETIZATION FIELDS

$$H_d = -N_x M_x - N_y M_y - N_z = -N \cdot M$$



$$B = H + 4\pi M$$

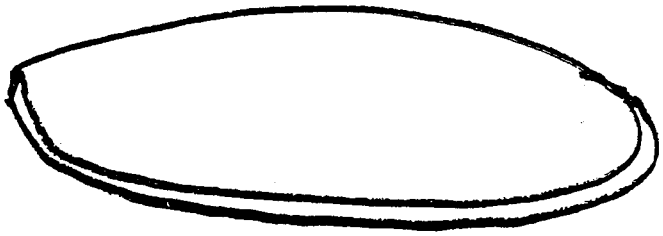
$$\nabla \cdot B = 0$$

$$N_x + N_y + N_z \equiv 4\pi$$

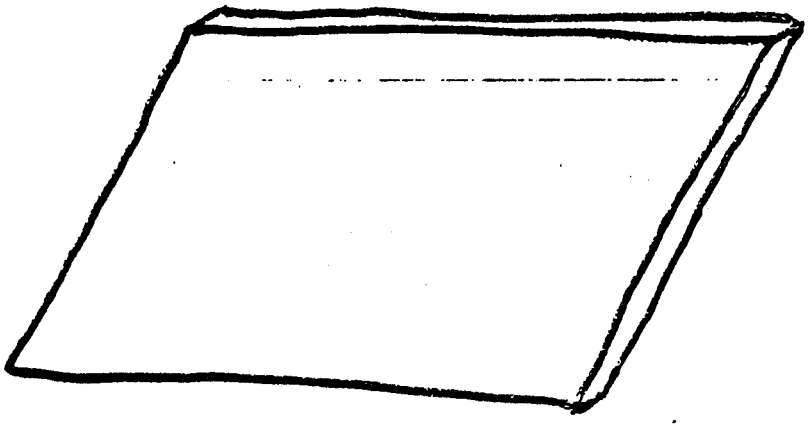
N = DEMAGNETIZING FACTOR
= f(Geometry only)

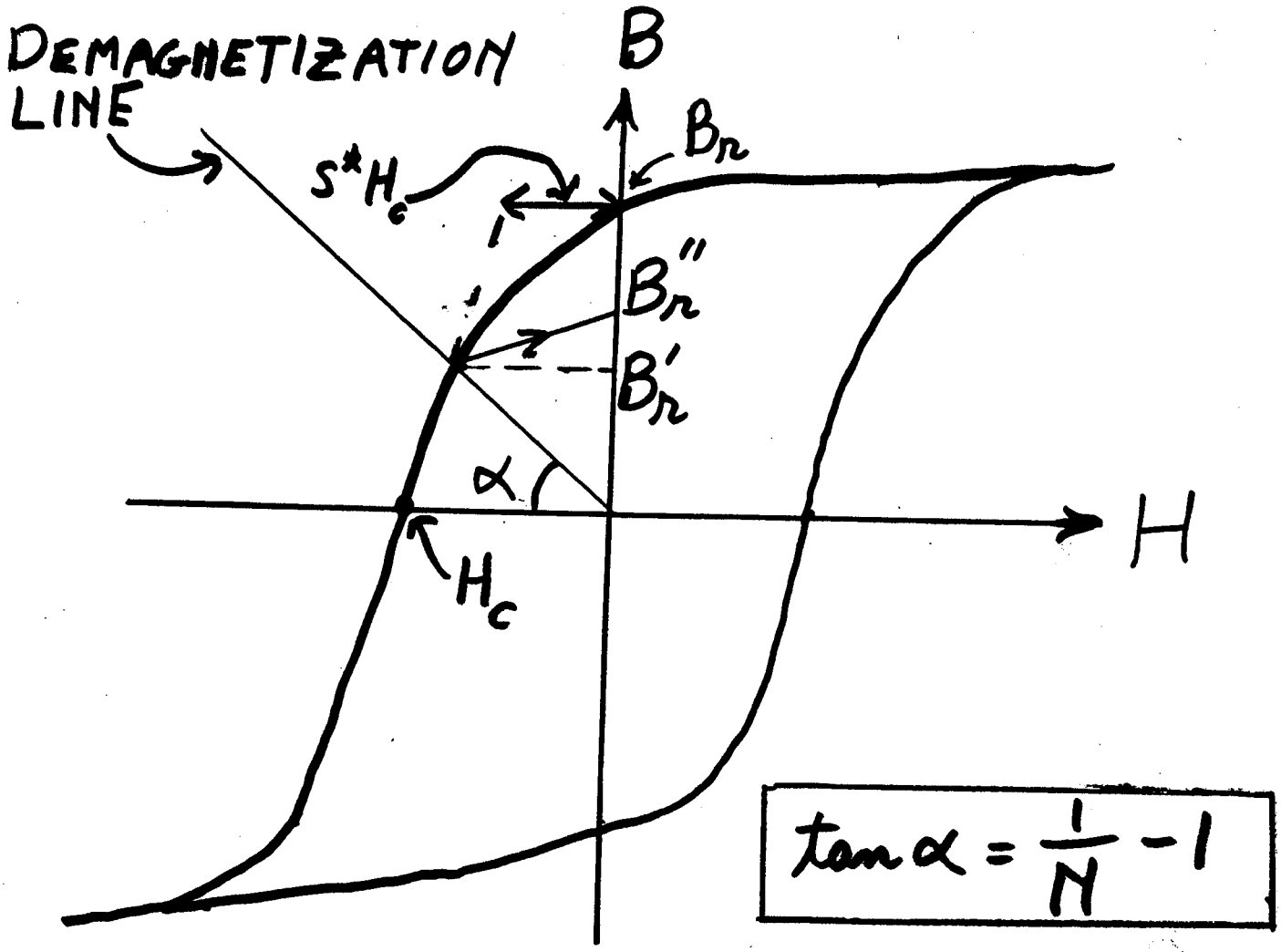
$N_z = 0$

$N_x = N_y = 2\pi$



$N_z = 4\pi, \quad N_x = N_y = 0$



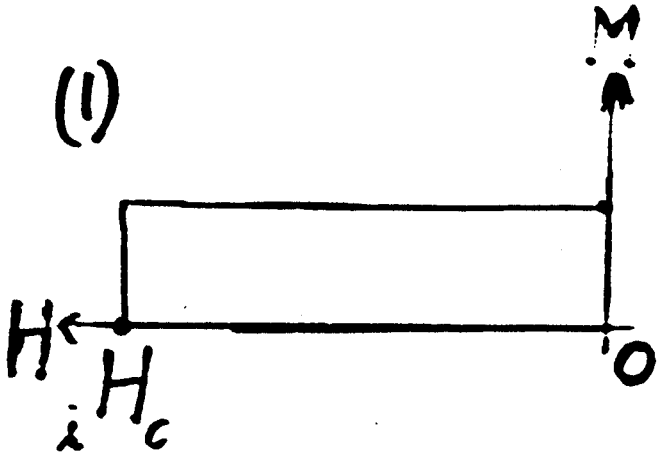


REDUCED REMNANCE, B_r', due to DEMAGNETIZATION N.

B_r'' = PARTIAL RECOVERY when magnetic circuit closed by playback head core.

PERMANENT MAGNETS

(1)

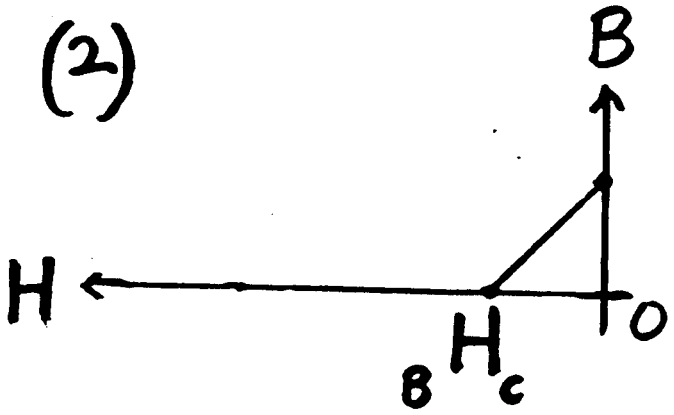


$$B = H + 4\pi M$$

$$\Rightarrow$$

$$_B H_c = -4\pi M$$

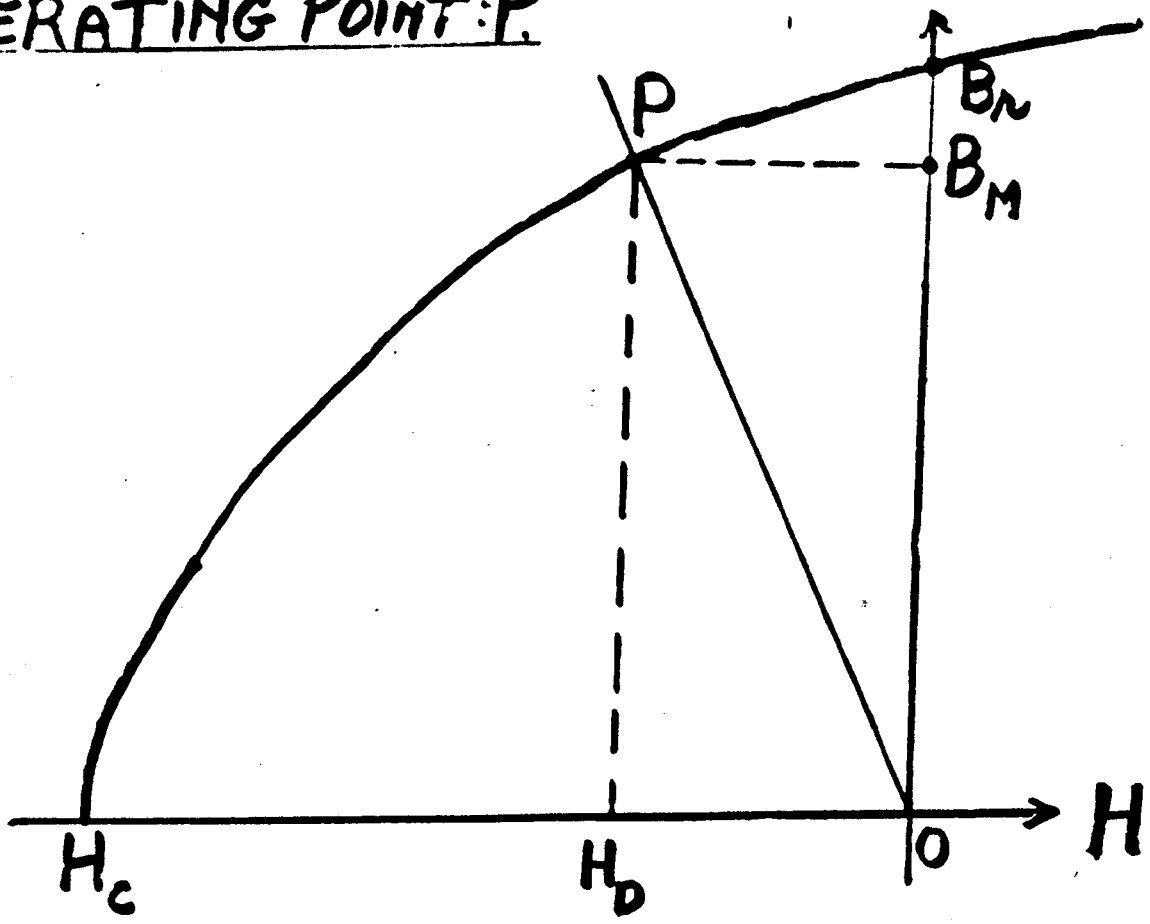
(2)



ENERGY Storage $\propto (BH)_{max}$ of (2).

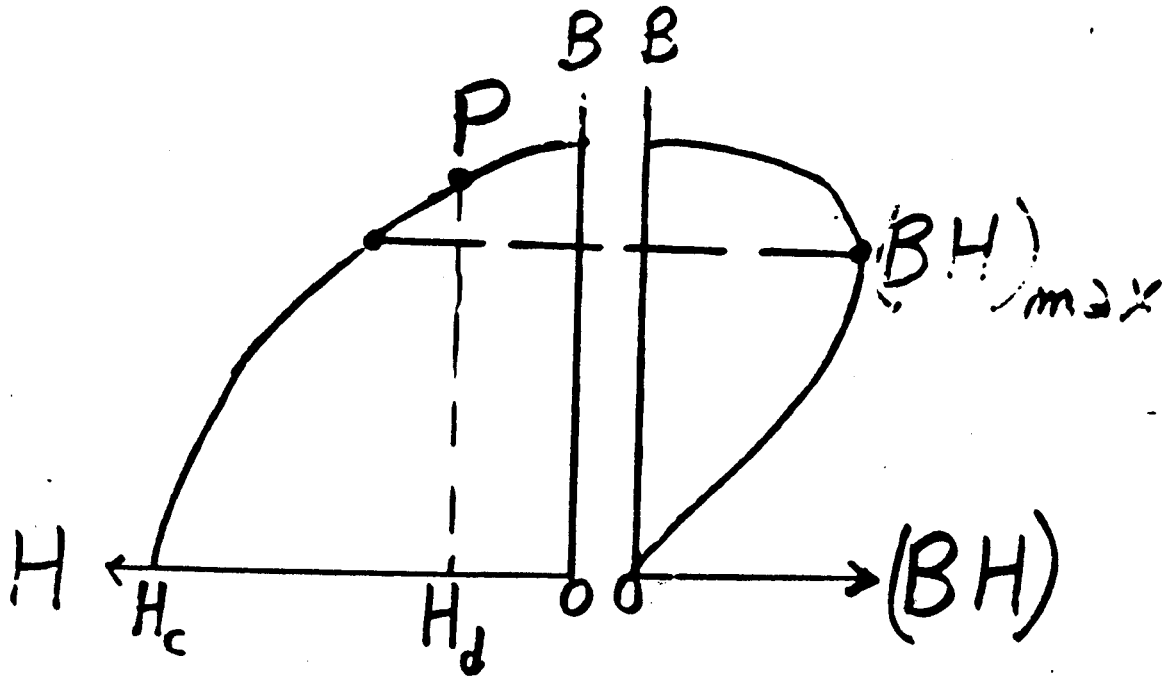
Stability re: H_D and LINEARITY $= f(_I H_c)$

OPERATING POINT: P



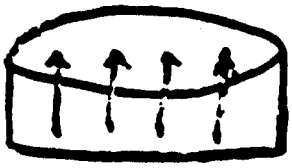
$$B = H_{app.} + H_D + 4\pi M$$

H_D Shifts B_r to B_M.



i.e. WANT H_d LARGER ⇒

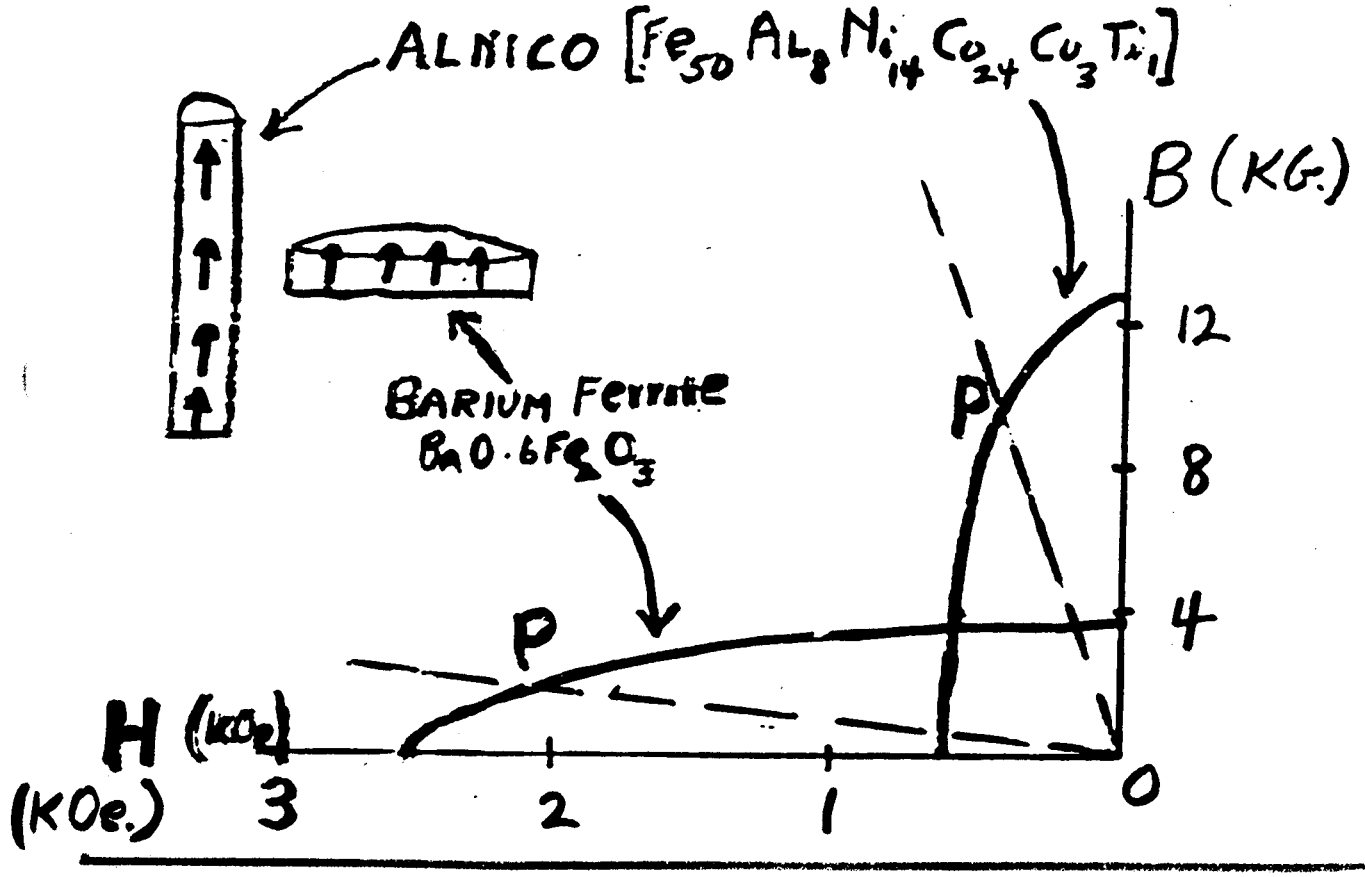
MAGNET THICKER OR Shorter

[NOTE:  requires large H_c

COMMON-USE-PERMANENT MAGNETS

$$BaCO_3 + 6Fe_2O_3 \xrightarrow{1100^\circ C} BaO \cdot 6Fe_2O_3 + CO_2$$

	B_r	${}_BH_c$	$(BH)_{max.}$	${}_iH_c$
Barium Ferrite	3,950	2400	3.5	2470
Alnico -5	13,000	640	5.5	SINTERED - CAST-



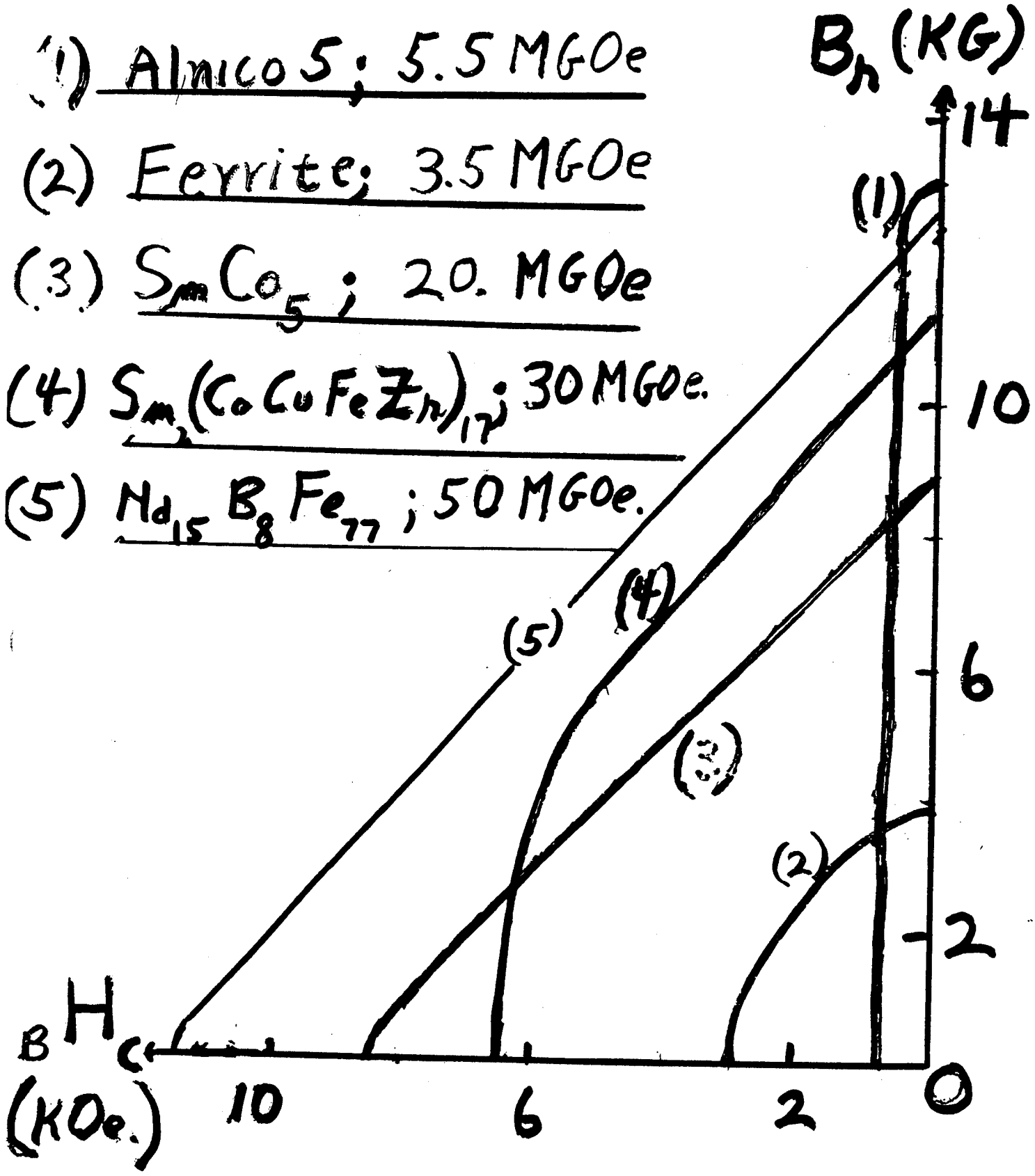
(1) Almico 5 ; 5.5 MGOe

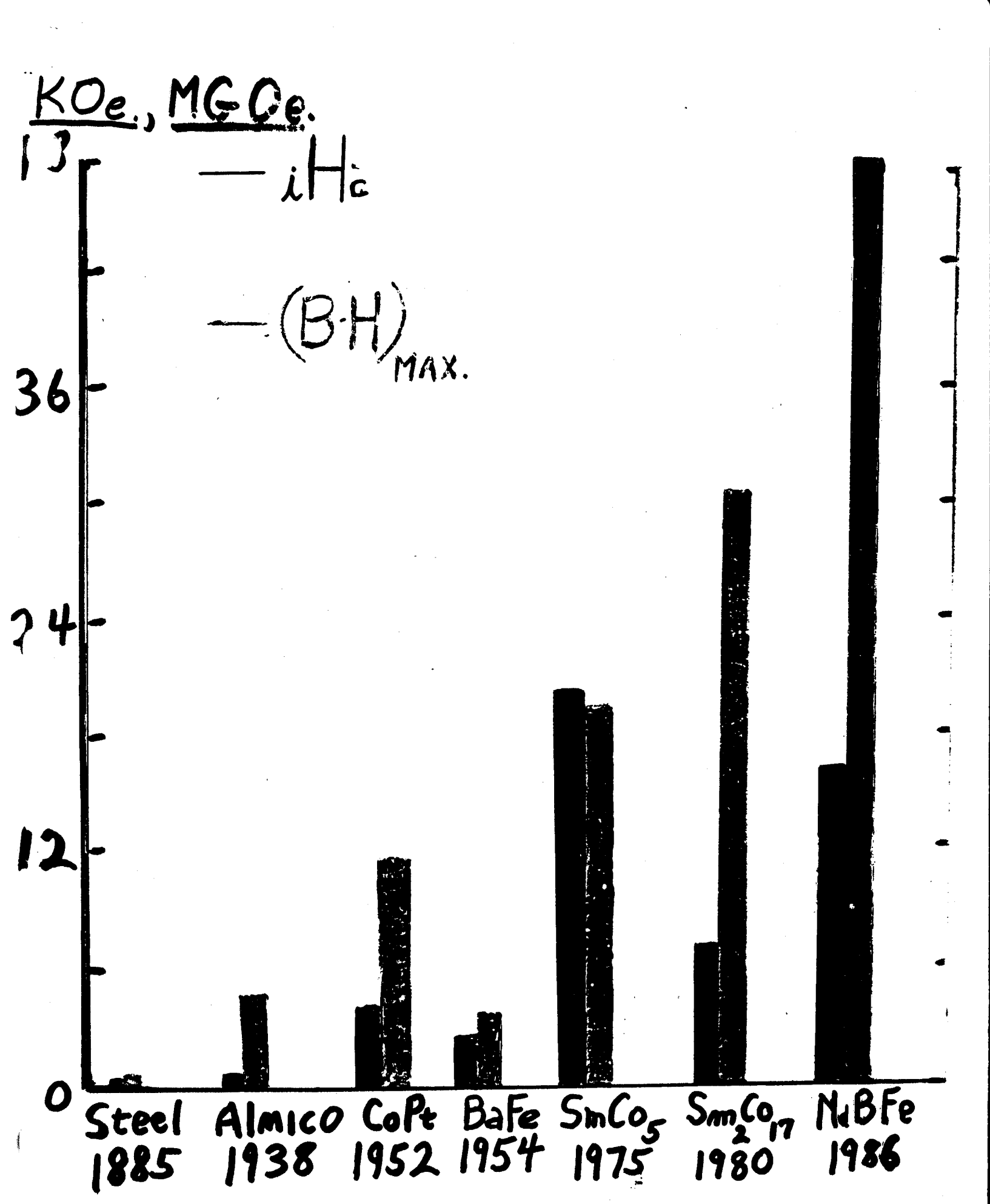
(2) Ferrite; 3.5 MGOe

(3) $Sm Co_5$; 20. MGOe

(4) $Sm_2(Co\,Cu\,Fe\,Zn)_{17}$; 30 MGOe.

(5) $Nd_{15}\,B_8\,Fe_{77}$; 50 MGOe.




KOe., MGOe.
13
36
24
12
0
$_iH_c$
$(B\cdot H)_{MAX.}$
Steel 1885
Almico 1938
CoPt 1952
BaFe 1954
$SmCo_5$ 1975
Sm_2Co_{17} 1980
NdBFe 1986

$SmCo_5$ - 1973

RARE EARTH (Sm) ⇒

crystallography - hcp

large ANISOTROPY - 10^8 ergs/cm^3

Co_5 ⇒ MAGNETIZATION, $B_r = 9000$ G.

FINE-GRAINED (1-10 μm) MATERIAL
WALL NUCLEATION CONTROLLED

⇒ HIGH COERCIVE FORCE ; $H_c = 15$ kOe.

$(BH)_{MAX} \sim 20$ MG.Oe.

Curie Temp ~ 750°C

$SmCo_5$ -

Powder Metallurgy

1) Melt Alloy

2) Crush and Ball Mill ⇒ Powder

3) Field Aligned and Compacted.

4) Sintered at 1100°C in Argon ($\frac{1}{2}$ hr.

Difficulties

a) Reactivity of Samarium

b) Crystal Structure damage (2). $H_c \downarrow$

c) Low Packing Density of Aligned Compact

Plastic Bonded Magnets

Aligned $SmCo_5$ particles embedded in flexible plastic Material

Sm_2Co_{17} - 1978 — 1983

$Sm_2Co_{10}Cu_{1.48}Fe_{3.16}Zr_{.194}$ (TDK JAPAN)

$B_r = 11,200$ G., $_iH_c = 6,740$ Oe.

$(BH)_{max} = 30$ MGOe, $T_c = 900°C$

METALLURGY - SAME AS $SmCo_5$ except

STEP ANNEAL -

850°C ⇒ 500Å CELLULAR STRUCTURE

600°C ⇒ 2nd PHASE (COPPER) IN CELL WALLS (DOMAIN WALL PINNING)

SAMARIUM, COBALT - EXPENSIVE.

MATERIALS - CAST

$Fe_{77}Nd_{15}B_8$ Permanent Magnet (SUMITOMO)

Mat'ls melted, ground, and sintered.

3 μm non-magnetic neodinium rich precip in iron rich host matrix -

coercive force mechanism - Wall nucleation

	Fe Nd B	Sm Co
$_B H_c$	12 kOe	6.5 kOe
$_I H_c$	15 kOe.	15 kOe.
B_r	12.4 kG.	10 kG.
$(BH)_{max}$	50 MGOe	30 MGOe
Temp Coeff. of remnance	-0.13%/K	+0.02%/K

MATERIALS - VERY INEXPENSIVE

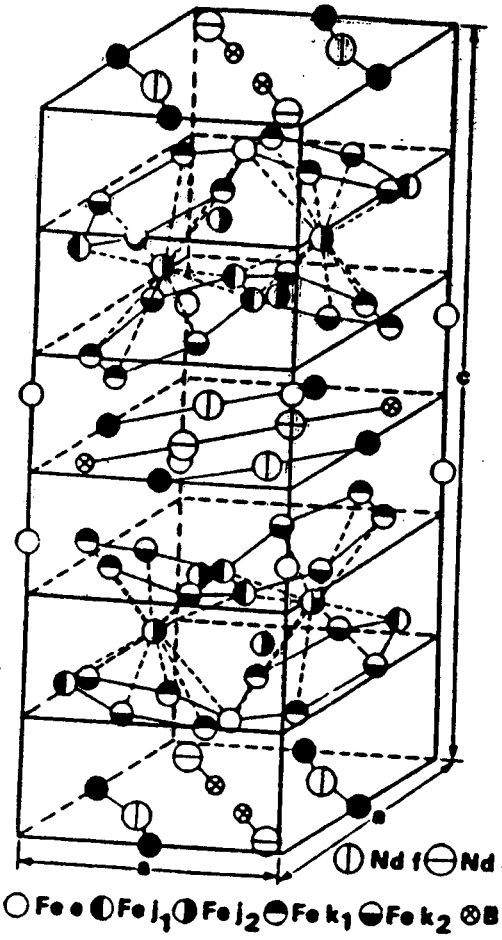


FIG. 1. Unit cell of $Nd_2Fe_{14}B$ ($P4_2/mnm$ space group). The c/a ratio in the figure is exaggerated to emphasize the puckering of the hexagonal iron nets.

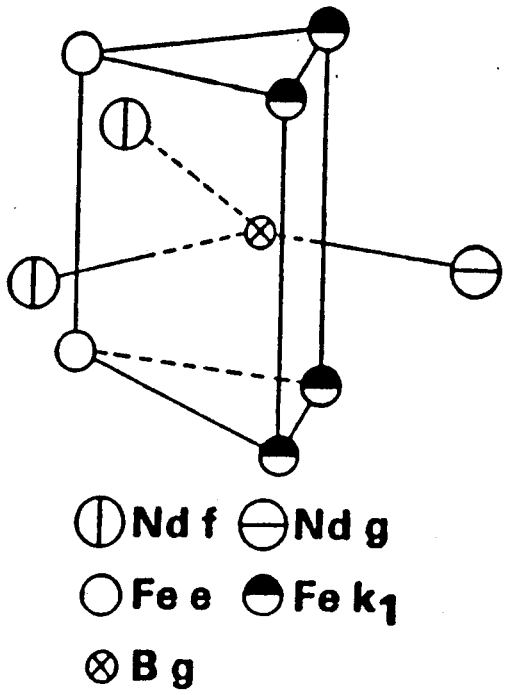


FIG. 2. Trigonal prism containing a boron atom in the $Nd_2Fe_{14}B$ structure. Distances between the B(g) atom and its nearest neighbors are B-Fe(k_1) = 2.09 Å, B-Fe(e) = 2.14 Å, B-Nd(g) = 2.86 Å, and B-Nd(f) = 3.34 Å. The vertical edge lengths are Fe(e)-Fe(e) = 2.75 Å, Fe(k_1)-Fe(k_1) = 3.12 Å. Distances in the triangular faces are Fe(e)-Fe(k_1) = 2.51 Å, Fe(k_1)-Fe(k_1) = 2.59 Å.

TABLE I. Atomic sites, occupancies, and coordinates x, y, and z (in units of the lattice constants $a = 8.80$ Å, $c = 12.19$ Å) for $Nd_2Fe_{14}B$ obtained from analysis of room-temperature neutron-diffraction data. The space group is $P4_2/mnm$. The quality-of-fit index for the nuclear structure is R (nuc) = 4.2%. These results imply a density of 7.60 g/cm^3 which agrees well with the measured value of 7.55 g/cm^3.

Atom	Site	Occupancy	x	y	z
Nd	f	4	0.266	0.266	0.0
Nd	g	4	0.139	−0.139	0.0
Fe	k_1	16	0.224	0.568	0.128
Fe	k_2	16	0.039	0.359	0.176
Fe	j_1	8	0.097	0.097	0.205
Fe	j_2	8	0.318	0.318	0.247
Fe	e	4	0.5	0.5	0.113
Fe	c	4	0.0	0.5	0.0
B	g	4	0.368	−0.368	0.0

$Nd_2Fe_{14}B$

TETRAGONAL PRISMS

1) CENTER - BORON

2) BASAL PLANES - 3 IRON ATOMS
[Stretched vertically from hexagonal nets]

3) LINK IRON PLANES ABOVE + BELOW

4) COORDINATE ALL RARE-EARTH + BORON
(more complete than Nd_2Fe_{17} - $\begin{cases} T_c = 310°C \\ 155°C \end{cases}$

5) ALSO IN TRANSITION METAL-METALLOID
{Fe-B, Co-B, Ni-B, Fe-C, Pd-Si
CRYSTALLINE AND AMORPHOUS}

MAGNETIC STRUCTURE

1) All Nd. + Fe MOMENTS FERROMAGNETIC

2) UNIAXIAL ANISOTROPY (|| c axis)

a) (CRYSTAL FIELD SPLITTING of 4f Nd. level)

b) (~ 10% from Fe sublattice itself -)

i.e., $\begin{cases} Gd_2^{3+}Fe_{14}B \Rightarrow H_c \sim 2\tfrac{1}{2}\ kOe. \\ Nd_2Fe_{14}B \Rightarrow H_c \sim 14\ kOe. \end{cases}$