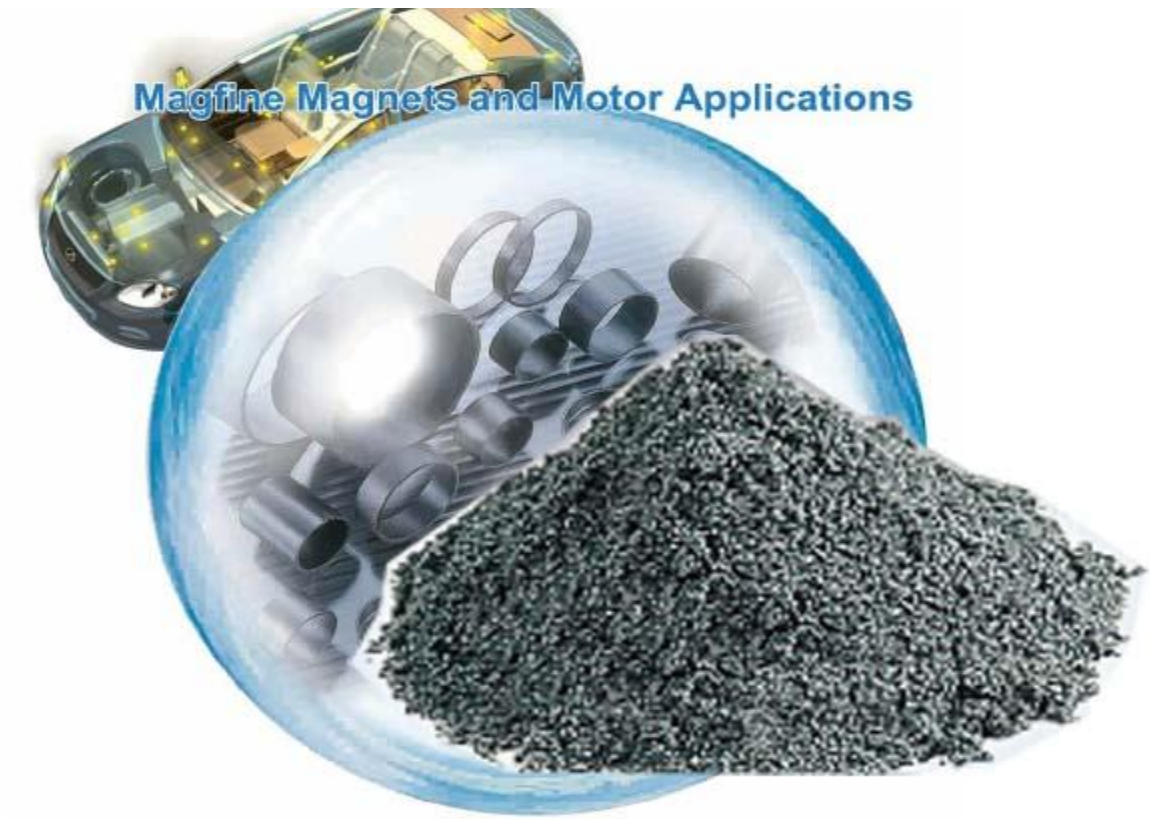
MAGFINE®
TECHNICAL DATASHEET

World's Strongest Bonded Magnet
MAGFINE®



AICHI STEEL CORPORATION

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MAGFINE®

Company Outline

As a material maker for the Toyota Group, Aichi Steel has continued to supply new materials that support the reduction in weight and increase in performance of motor vehicles. As motor vehicles become increasingly electrified and connected, the growing need for lighter high performance electric motors is increasing attention on high powered bonded magnets. The world's strongest bonded magnet, MagFine, developed by Aichi Steel, is attracting attention as the core material for realizing the next generation of revolutionary motors.

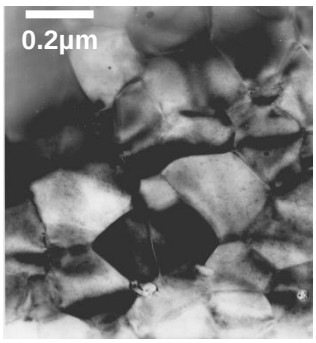
1 MAGFINE® Technology

What is MAGFINE® ?

The anisotropic NdFeB bonded magnet MAGFINE® (MF) is a superior bonded magnet with the world's strongest magnetism of 25MGOe and heat resistance to 150C. Discovered in 1982, the world's strongest NdFeB magnets have been produced by sintering or as isotropic bonded magnets. Due to the poorer magnetic properties of isotropic bonded magnets, the development of anisotropic bonded magnets has been awaited for 20 years. Aichi Steel discovered the fundamental process (d-HDDR) for making anisotropic magnet powder and have succeeded in commercializing an anisotropic bonded magnet.

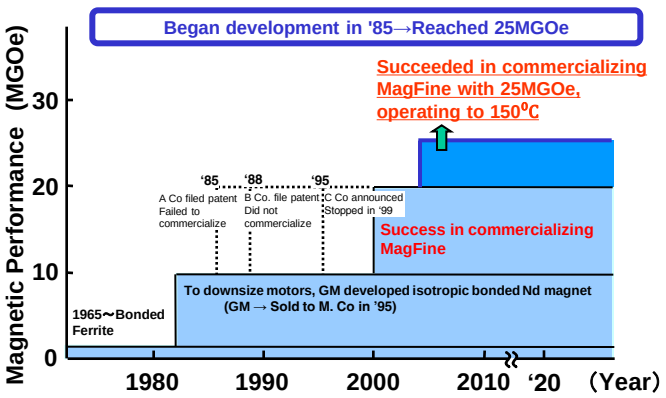
The name MAGFINE comes from the word **Mag**net and the **Fine** microstructure of the powder which is created by our d-HDDR process.

■Microstructure of MAGFINE® Powder

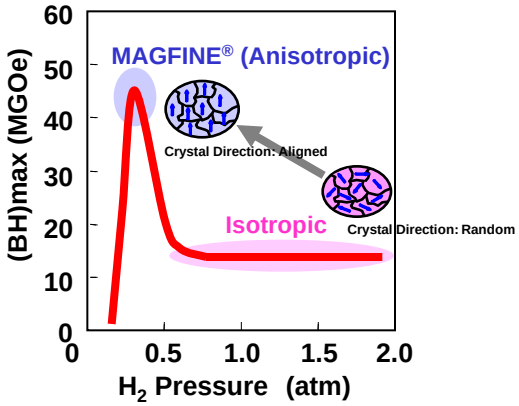


■History of Anisotropic Bonded Magnets

GM withdrew in '95
→Aichi Steel (Toyota) succeeded in '03



■Principle of d－HDDR



Principle of d－HDDR (discovered1996)

Controlling the speed of the absorption/desorption reaction between NdFeB allow and Hydrogen to a critical speed makes it possible to realize the miniaturization and anisotropy of the crystal grains, producing a superior magnetic powder.

MAGFINE®

Operating Temperature of 150℃ without Dy or Ga (2010)

Until now, the rare earth elements Dy and Ga have been added to increase the maximum operating temperature. Now by utilizing fine grain crystals and non-magnetic grain boundary film combined with the development of our micro-capsule technology, we have succeeded in mass-producing a low cost magnet that is heat resistant to 150℃ without using Dy, Ga.

Price of Rare Earth Elements
Nd：$42/kg　　Dy:$250/kg
Ga:$440/kg　　Co:$48/kg

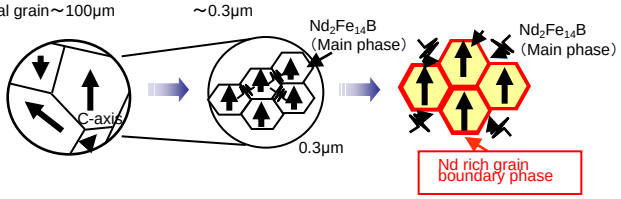
Nd Sintered: Dy5%Co3%
Isotropic ： Co4%

■ Miniaturization＋Non-magnetic grain boundary

Mother Material
Nd volume of NdFeB alloy27-27.5%
Crystal grain～100μm

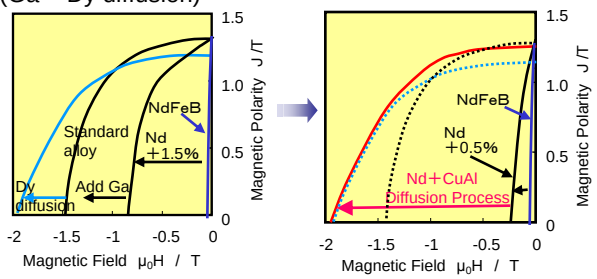
d－HDDR process
Fine crystal grain
～0.3μm

Low melting point alloy (NdCuAl)
Grain boundary diffusion process



Previous Method
(Ga + Dy diffusion)

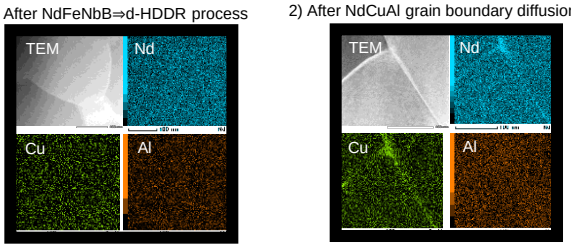
New Alloy Dy, Ga free



TEM observation (EDS Map) Toyota Central R&D Labs

1) After NdFeNbB⇒d-HDDR process

2) After NdCuAl grain boundary diffusion process

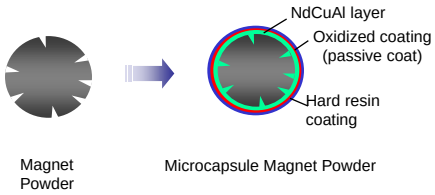


Nd, Cu concentrate in grain boundary forming grain boundary phase

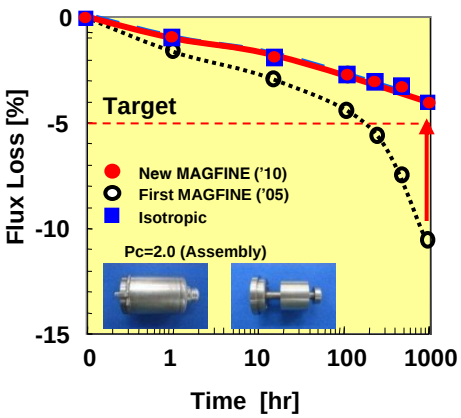
Micro-capsule technology improves reliability (2010)

In addition, we developed technology to encapsulate the magnetic powder giving superior reliability to isotropic magnets even without coating.

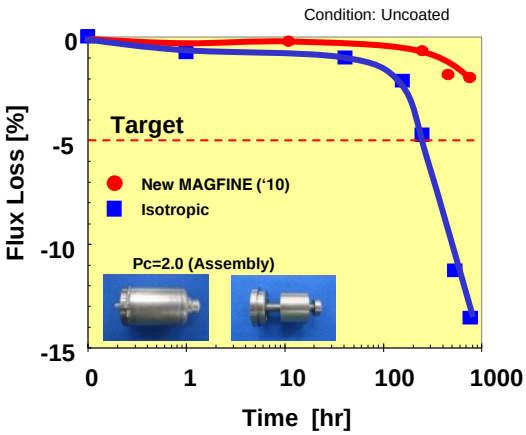
■ Microcapsule Technology



1) Oxidation Resistance　Flux Loss at 150^{0}C



2) Corrosion Resistance　Flux Loss at 80^{0}C 95%RH



MAGFINE®

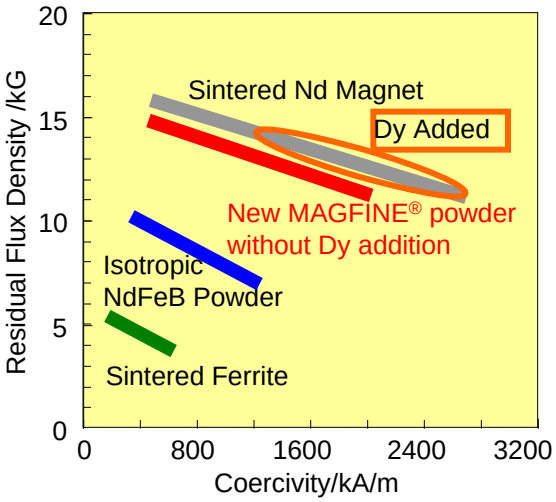
MAGFINE® Magnet Lineup

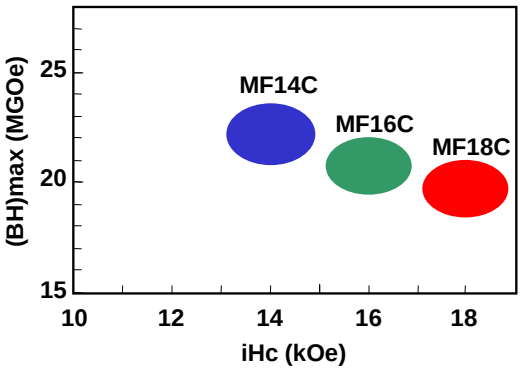
The mechanism of anisotropy has been clarified, the d-HDDR process has advanced and the performance of the magnet powder has been increased. In 2010, Aichi Steel developed a new series of heat resistant MAGFINE® powders without the use of Dy. These are known as MF15P and MF18P.

Magnets made by compression molding of these powders are MF14C, MF16C and MF18C.

MF18C is a heat resistant MagFine able to be used up to 150^{0}C.

■2010 Lineup





■ MAGFINE® Lineup

		MAGFINE®					Isotropic
		Powder		Compression			Compres−−sion
		MF15P	MF18P	MF14C	MF16C	MF18C	
(BH) max	MGOe	38.0	35.0	22.0	20.0	19.5	10.0
Br	kG	13.2	12.5	9.8	9.5	9.5	7.0
iHc	kOe	14.0	17.0	14.0	16.0	18.0	9.5
A	%/℃	—	—	-0.11	-0.11	-0.11	-0.13
B	%/℃	—	—	-0.56	-0.47	-0.46	-0.33

2-1. Powder Magnetic Characteristics

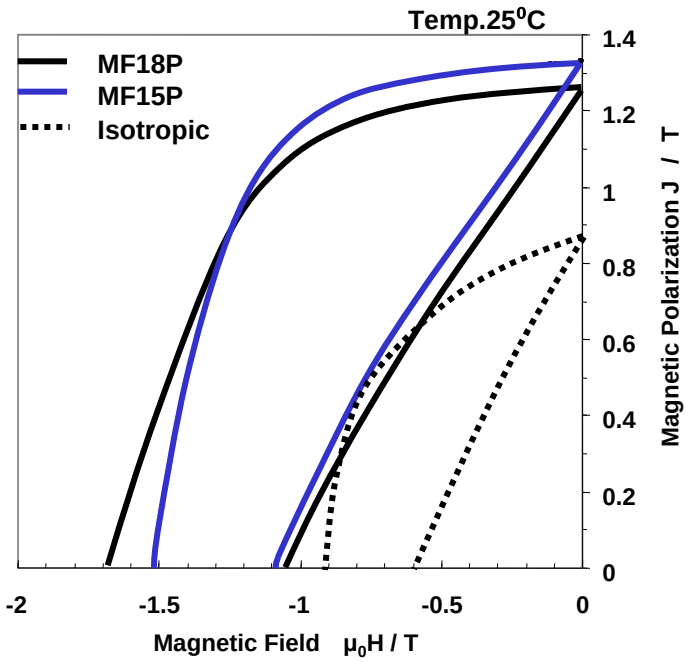
A. Specifications

Product name		MF15P	MF18P	Isotropic
Br	(T)	1.27-1.39	1.20-1.30	0.92
	(kG)	12.7-13.9	12.0-13.0	9.2
	Typical	13.2 kG	12.5 kG	-
H_{CJ}	(kA/m)	1035-1274	1193-1432	764
	(kOe)	13.0-16.0	15.0-18.0	9.6
	Typical	14.0 kOe	17.0 kOe	-
$(BH)_{max}$	(kJ/m^3)	295-350	239-302	136
	MGOe	37.0-44.0	30.0-38.0	17.1
	Typical	41	35	-

Measurement method

- **Capsule: φ5 mm x 7.5mm**
- **Particle size: ≦212 μm**
- **Weight of magnet powder: 150 ±5 mg**
- **Alignment field: 1.8T at 100 deg.C,**
- **Magnetization field : 45kOe**
- **Device: VSM (BHV-525H, Riken Denshi Co., Tokyo, Japan)**
- **Magnet powder was fixed with paraffin.**
- **Magnet Properties were calculated using 0.17 as demagnetizing factor.**

B. Demagnetization Curve

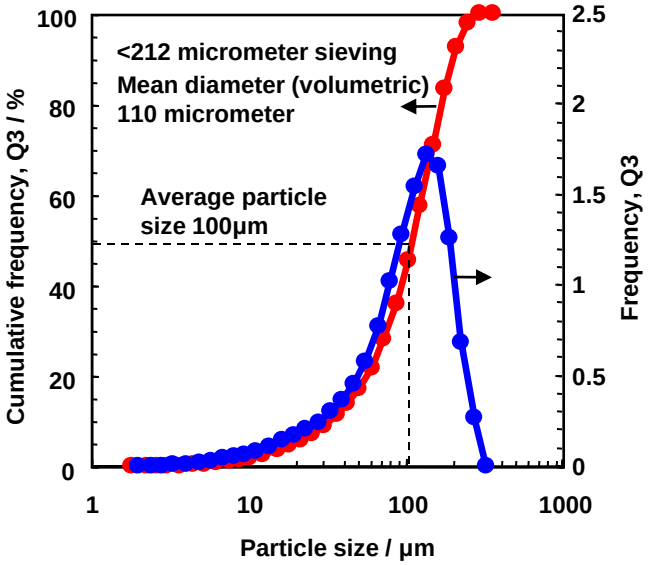


Typical Demagnetization Curve

2-2. Powder Particle Distribution and Shape

A. Particle Distribution

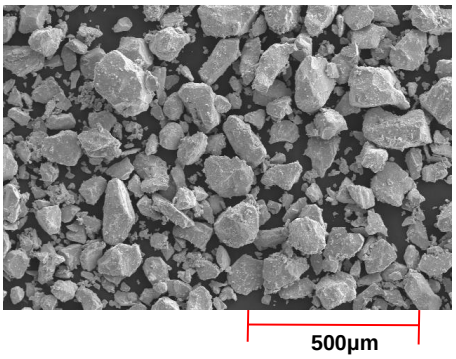
Product name	MF15P	MF18P
Distribution	<212μm	<212μm
X10/μm	25-60μm	25-60μm
X50/μm	90-130μm	90-130μm
X90/μm	170-220μm	170-220μm
VMD/μm	90-140μm	90-140μm



measurement instrument:

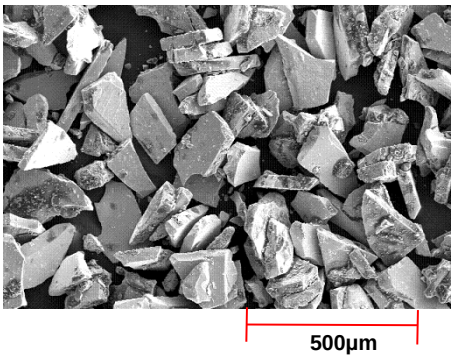
Laser diffraction particle size analysis

B. Shape



MF15P, MF18P

shape: granular



Reference) Isotropic power

shape: flake

*measurement method: HR-SEM

3-1. Injection Magnet Characteristics

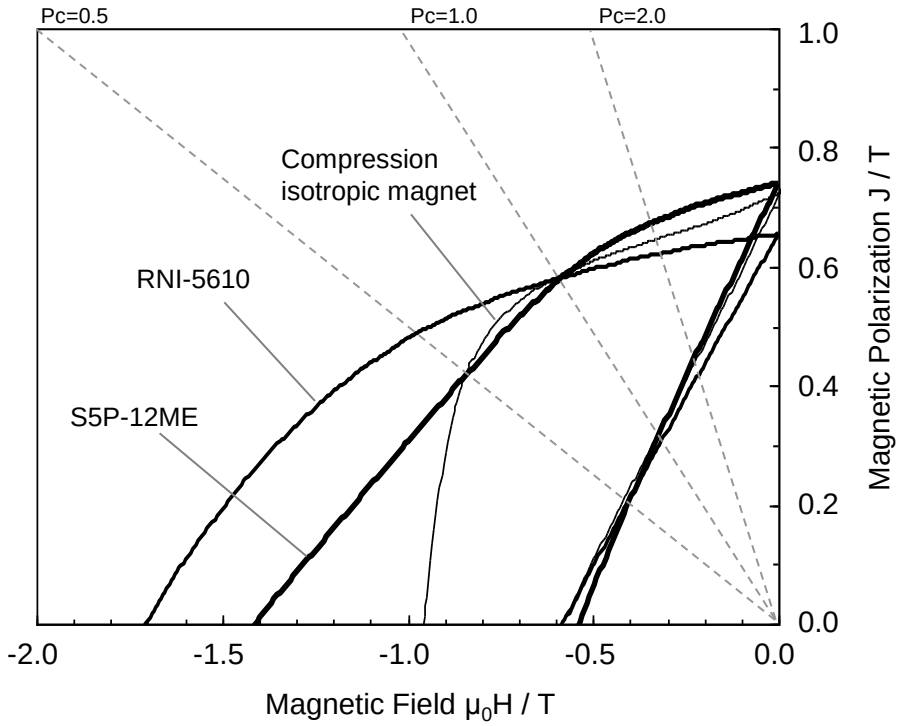
A. Specifications

These values are representative. They are not guaranteed values.

Product name	**RNI-5214**	**RNI-5610**	**RNI-5214V**	**RNI-5610V**	S5B-18MF	S5P-13MF	S5B-17ME	S5P-12ME
Magnetic powder	**MF15P**		**MF18P**		**MF15P+SmFeN**		**MF18P+SmFeN**	
Resin	**PA12**	**PPS**	**PA12**	**PPS**	**PA12**	**PPS**	**PA12**	**PPS**
Compound Name	RNI-5214	RNI-5610	RNI-5214V	RNI-5610V	S5B-18MF	S5P-13MF	S5B-17ME	S5P-12ME
B_r [kG]	7.9 – 8.4	6.5 – 7.0	7,6 – 8.1	6.4 – 6.9	8.9 – 9.4	7.3 – 7.8	8.6 – 9.1	7.1 – 7.6
$_iH_c$ [kOe]	13.0 – 14.0	13.0 – 14.0	16.0 – 17.0	16.0 – 17.0	12.0 – 13.0	12.5 – 13.5	13.5 – 14.5	14.0 – 15.0
$_bH_c$ [kOe]	6.2 – 7.2	5.5 – 6.0	6.3 – 7.3	5.5 – 6.0	7.0 – 8.0	6.0 – 7.0	7.0 – 8.0	6.0 – 7.0
$(BH)_{max}$ [MGOe]	14.5 – 15.5	10.0 – 11.0	14.0 – 15.0	9.5 – 10.5	17.5 – 18.5	12.5 – 13.5	16.5 – 17.5	11.5 – 12.5
Temperature coefficient of B_r [%/deg.C]	-0.11 (RT-120 deg.C)		-0.14 (RT-150 deg.C)		-0.11 (RT-150 deg.C)		-0.11 (RT-150 deg.C)	
Temperature coefficient of $_iH_c$ [%/deg.C]	-0.56 (RT-120 deg.C)		-0.49 (RT-150 deg.C)		-0.46 (RT-150 deg.C)		-0.47 (RT-150 deg.C)	
Recoil permeability [%]	1.10-1.20		1.10-1.20		1.10-1.20		1.10-1.20	
Density [g/cm^3]	5.0 – 5.2	4.6 – 4.7	5.0 – 5.2	4.6 – 4.7	5.4 - 5.6	5.0 – 5.2	5.4 - 5.6	5.0 – 5.2
Coefficient of thermal expansion [1/K]*	4.41×10^{-5}	2.69×10^{-5}	4.41×10^{-5}	2.69×10^{-5}	6.62×10^{-5}	2.00×10^{-5}	6.62×10^{-5}	2.00×10^{-5}
Modulus of elasticity [GPa]					11.8	29.6	11.8	29.6
Tensile strength [MPa]			52	38	27.3	40.4	27.3	40.4
Flexural strength [MPa]	102	83	93	86	51	52	51	52
Poisson's retio			0.28	0.27	0.36	0.27	0.36	0.27
Compression strength [MPa] (0.2% proof stress)	90	125	90	125	45	110	45	110
Young's modulus [GPa]	32.6	24.8	32.6	24.8	14.9	24.3	14.9	24.3
Electronic resistivity [μΩm]	100 – 200							

*Measurement temperature 30 ~150℃
**Measurement condition PA12 temp. 270℃, load 10kg
PPS temp. 300℃, load 10kg

B. Demagnetization Curve



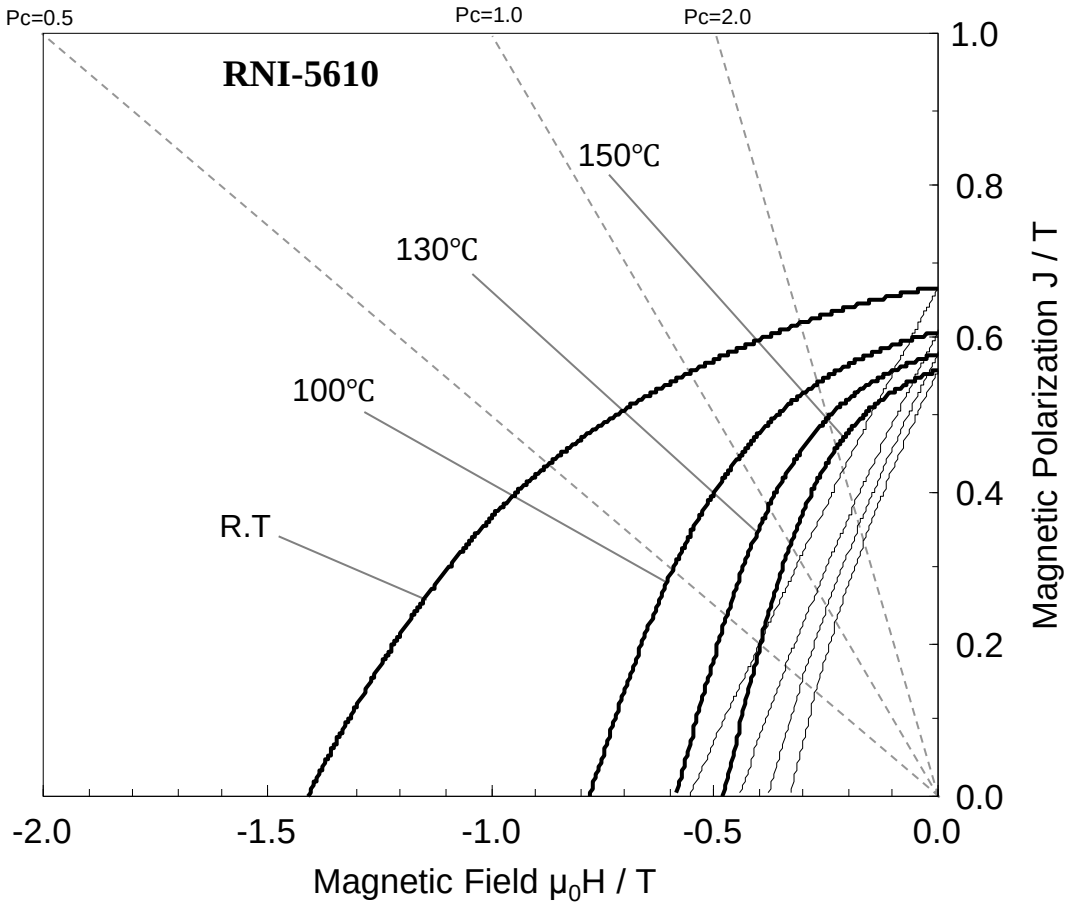
3-2. Magnetic Properties

①MF15P base compound

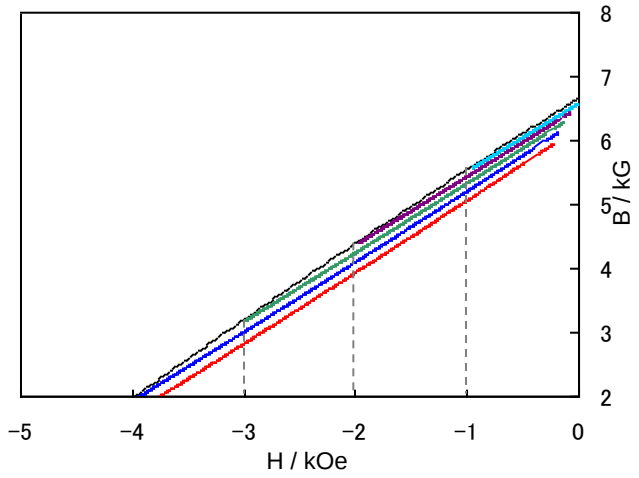
A. Magnetic Properties

	B_r		$_iH_c$		$_bH_c$		$(BH)_{max}$	
	T	kG	kA/m	kOe	kA/m	kOe	kJ/cm³	MGOe
RNI-5214 (PA12)	0.79-0.84	7.9-8.4	1034-1114	13.0-14.0	493-573	6.2-7.2	115-123	14.5-15.5
RNI-5610 (PPS)	0.65-0.70	6.5-7.0	1034-1114	13.0-14.0	437-477	6.2-7.2	79-87	10.0-11.0

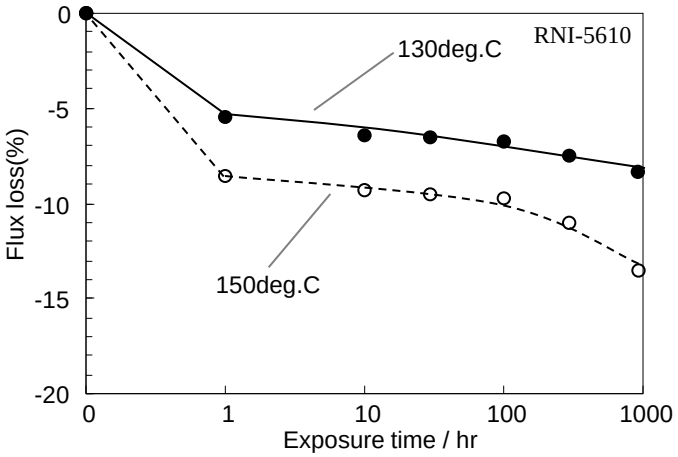
B. Demagnetization Curve



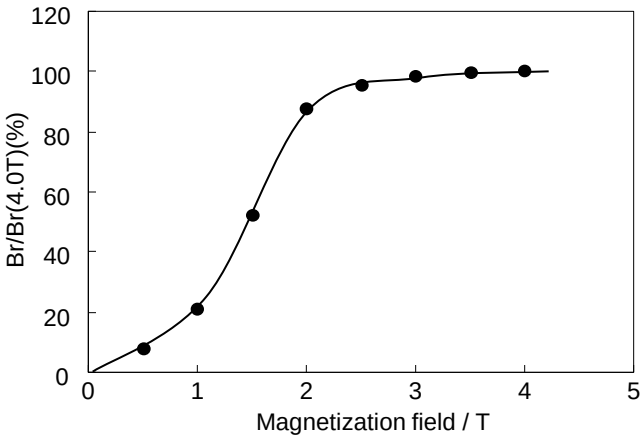
C. Recoil



D. Aging Test



E. Magnetization

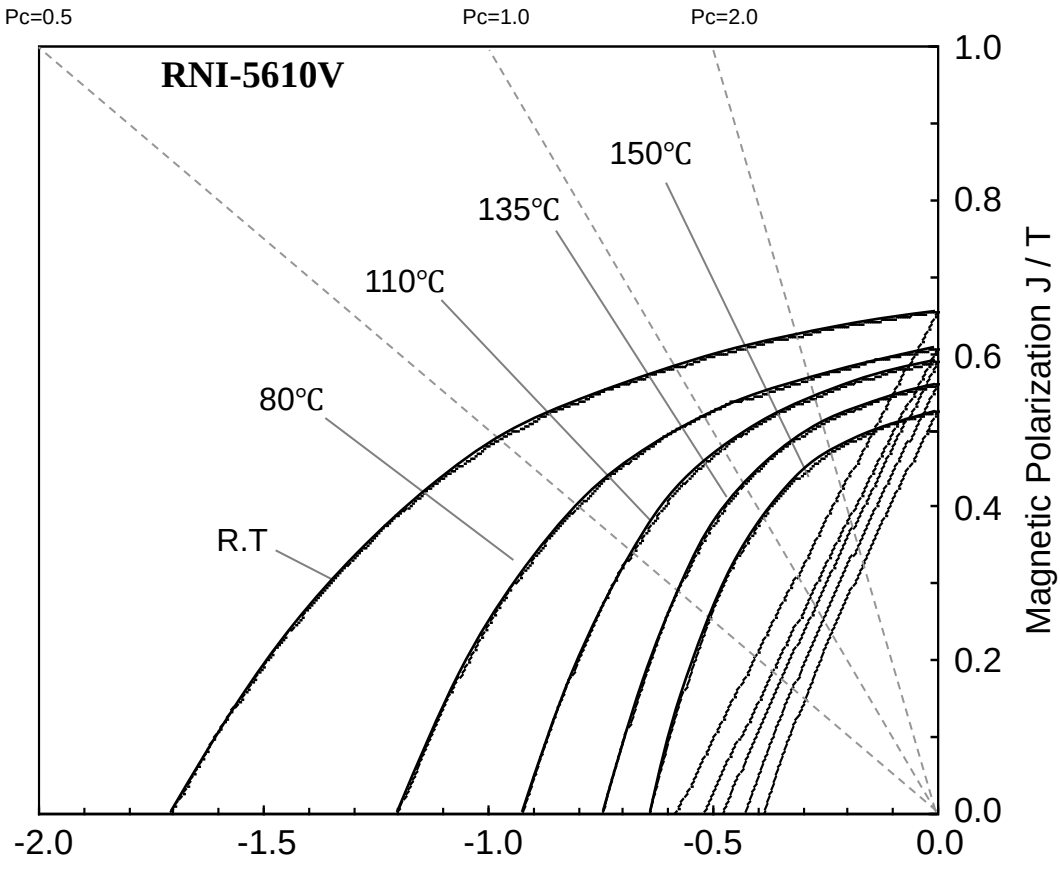


②MF18P base compound

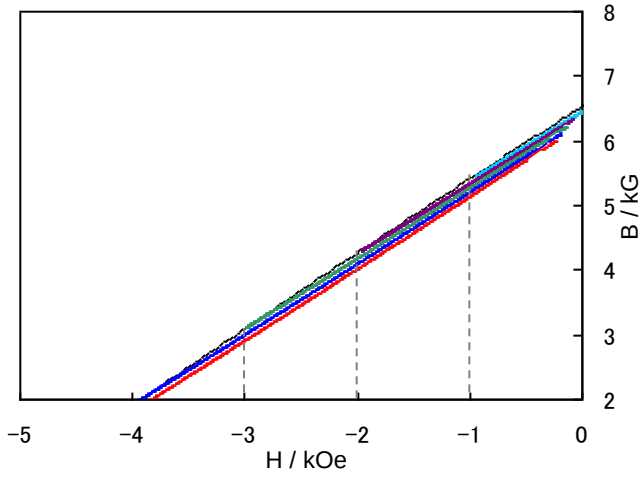
A. Magnetic Properties

	B_r		$_iH_c$		$_bH_c$		$(BH)_{max}$	
	T	kG	kA/m	kOe	kA/m	kOe	kJ/cm^3	MGOe
RNI-5214V (PA12)	0.76-0.81	7.6-8.1	1273-1353	16.0-17.0	501-581	6.3-7.3	111-119	14.0-15.0
RNI-5610V (PPS)	0.64-0.69	6.4-6.9	1273-1353	16.0-17.0	414-493	5.2-6.2	75-83	9.5-10.5

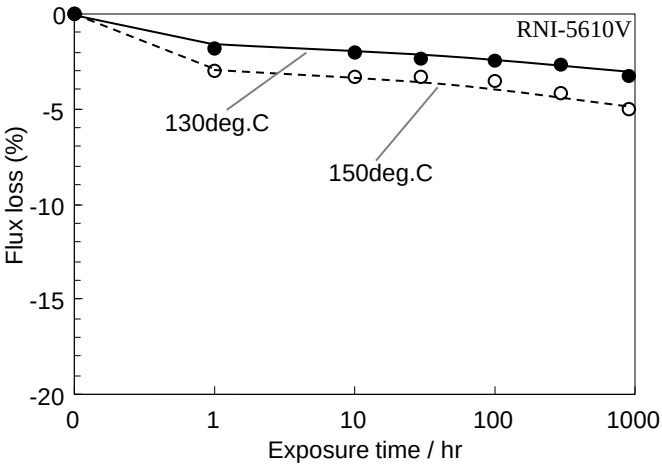
B. Demagnetization Curve



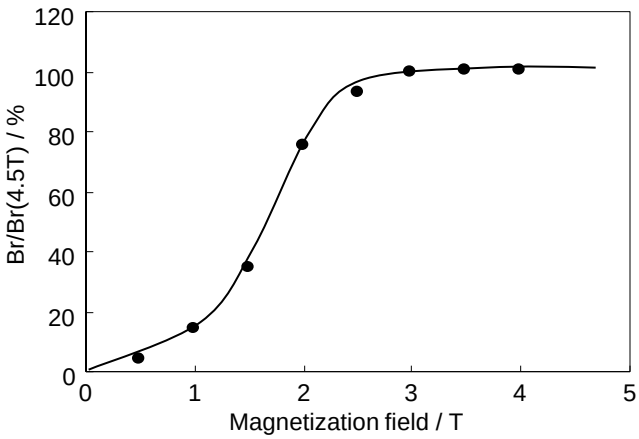
C. Recoil



D. Aging Test



E. Magnetization

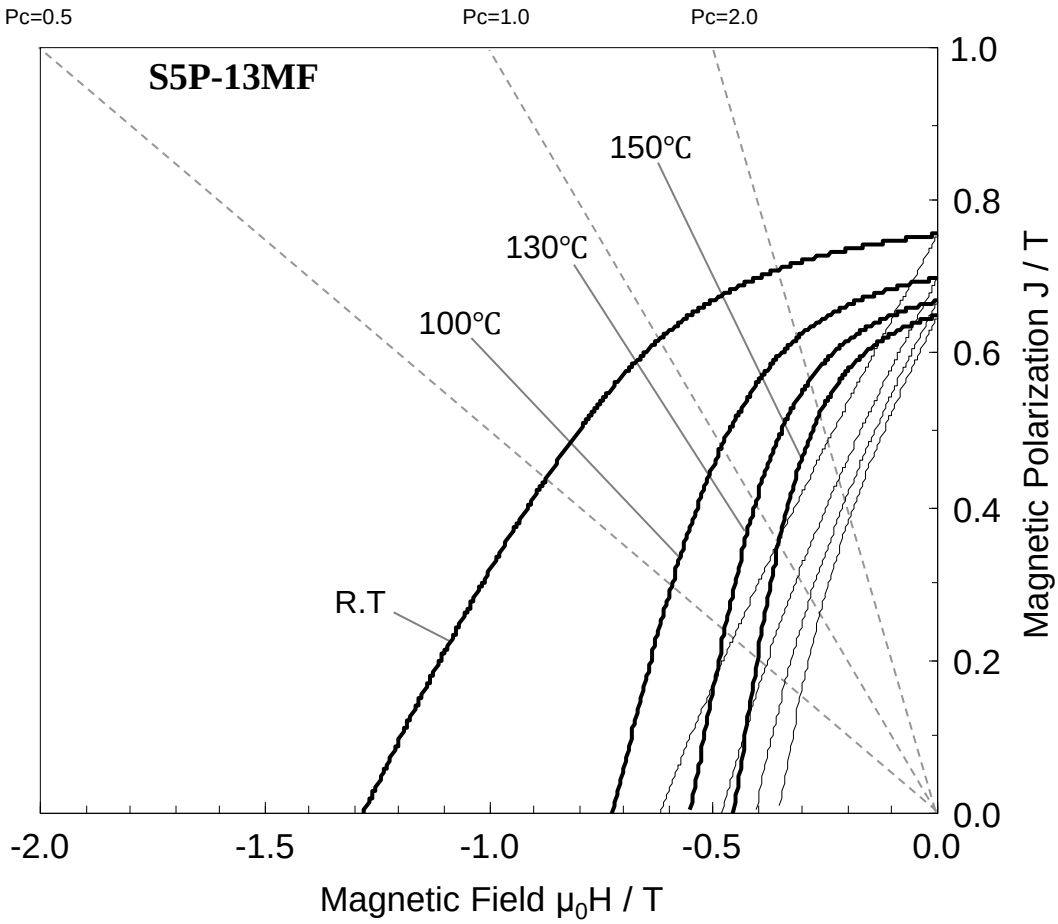


②MF15P+SmFeN base compound

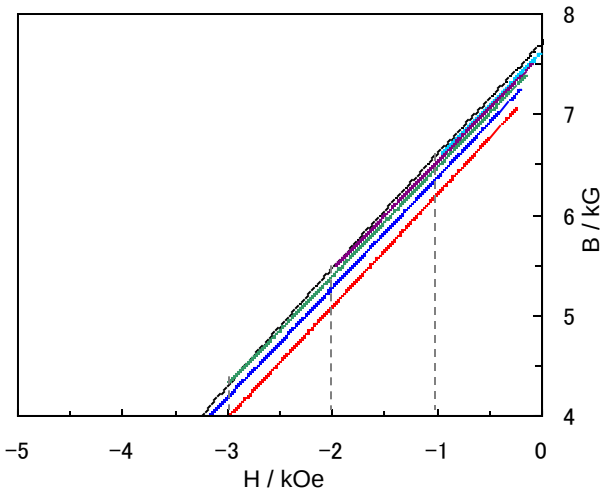
A. Magnetic Properties

	B_r		$_iH_c$		$_bH_c$		$(BH)_{max}$	
	T	kG	kA/m	kOe	kA/m	kOe	kJ/cm³	MGOe
S5B-18MF (PA12)	0.89-0.94	8.9-9.4	955-1035	12.0-13.0	557-637	7.0-8.0	139-147	17.5-18.5
S5P-13MF (PPS)	0.73-0.78	7.3-7.8	995-1074	12.5-13.5	477-557	6.0-7.0	99-107	12.5-13.5

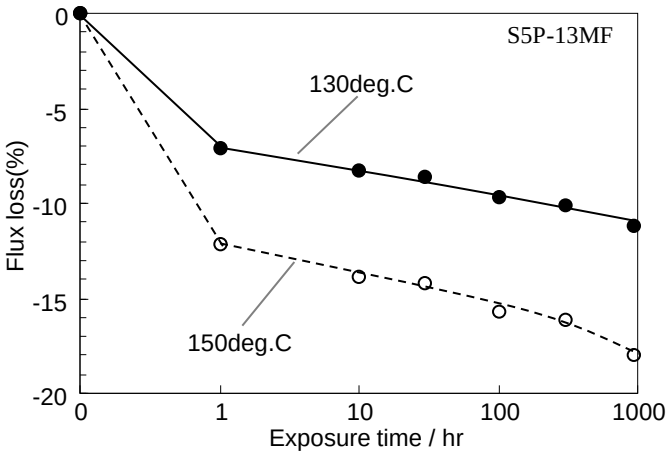
B. Demagnetization Curve



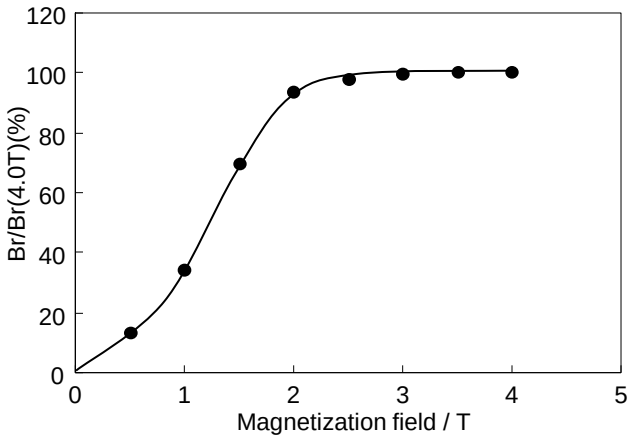
C. Recoil



D. Aging Test



E. Magnetization

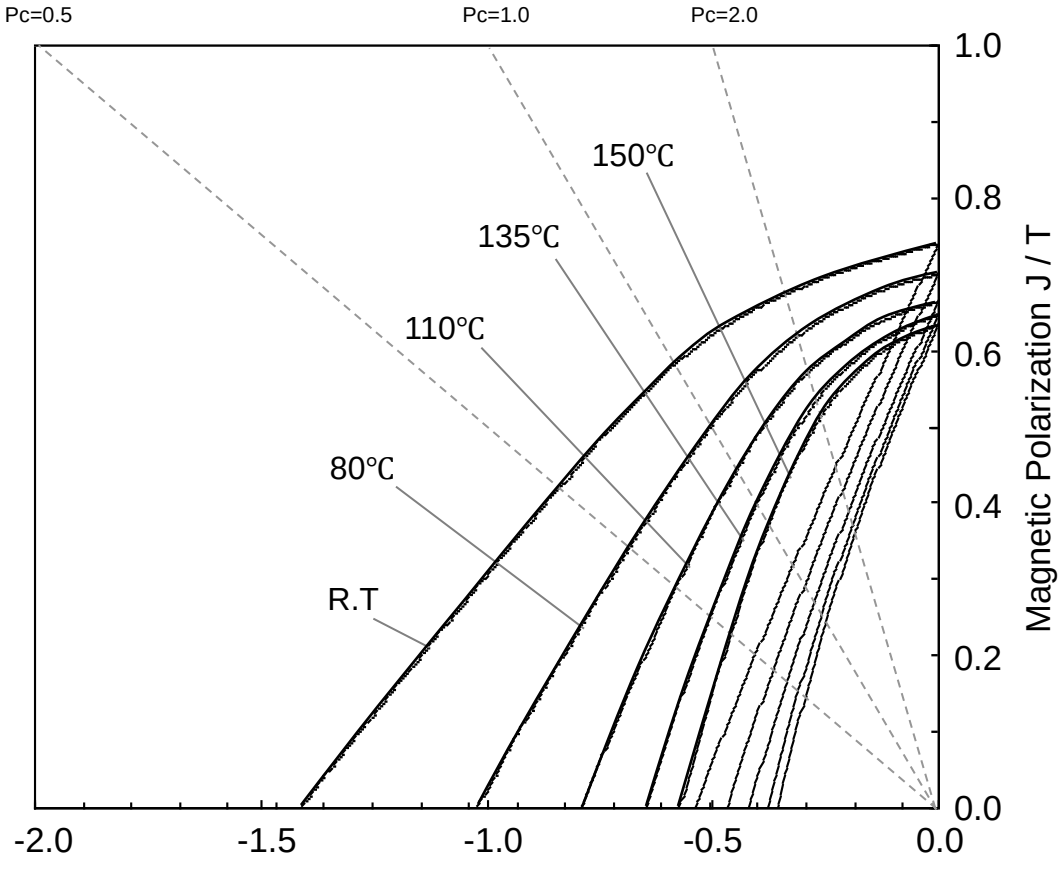


②MF18P+SmFeN base compound

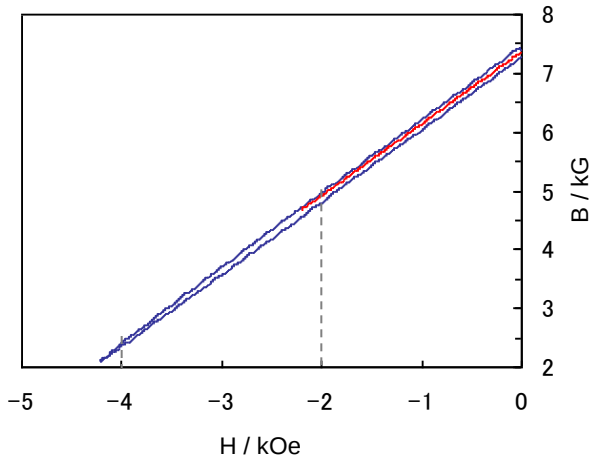
A. Magnetic Properties

	B_r		$_iH_c$		$_bH_c$		$(BH)_{max}$	
	T	kG	kA/m	kOe	kA/m	kOe	kJ/cm³	MGOe
S5B-17ME (PA12)	0.89-0.94	8.9-9.4	955-1035	12.0-13.0	557-637	7.0-8.0	139-147	17.5-18.5
S5P-12ME (PPS)	0.73-0.78	7.3-7.8	995-1074	12.5-13.5	477-557	6.0-7.0	99-107	12.5-13.5

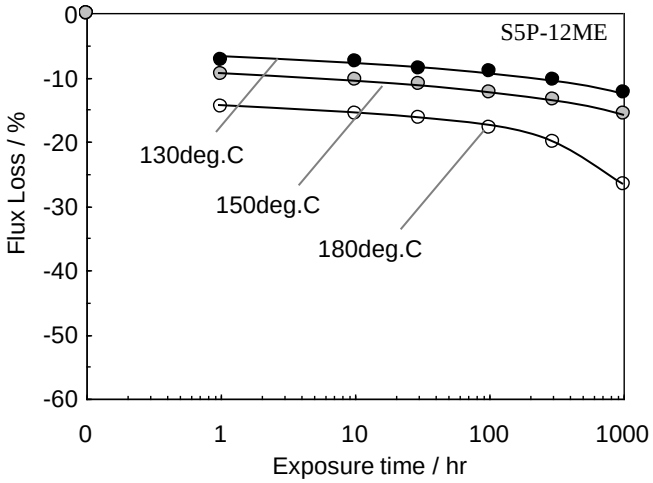
B. Demagnetization Curve



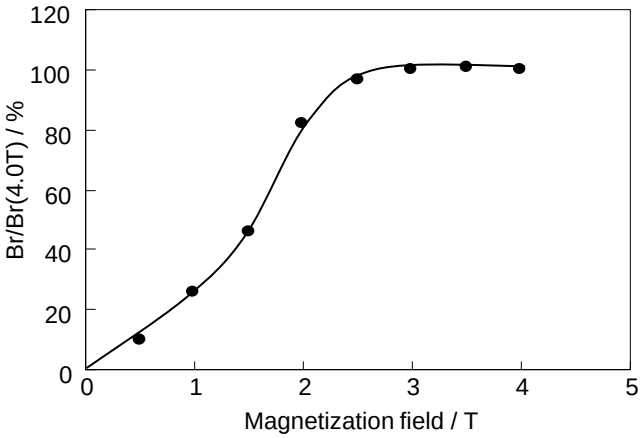
C. Recoil



D. Aging Test



E. Magnetization



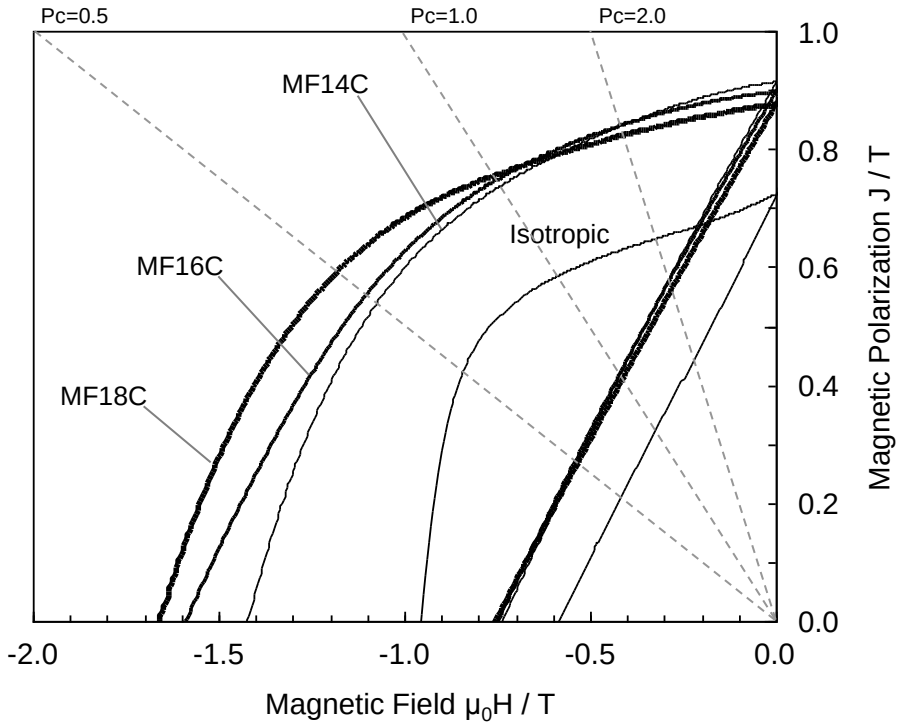
4-1. Compression Magnet Characteristics

A. Specifications

Product name		MF14C		MF16C		MF18C		Isotropic
		Block	Ring	Block	Ring	Block	Ring	
B_r [kG]		9.0 – 10.7	8.5 – 10.1	8.5 – 10.5	8.0 – 10.0	8.5 – 10.5	8.0 – 10.0	7.3
$_iH_c$ [kOe]		13.0 – 14.5	13.0 – 14.5	15.0 – 17.0	15.0 – 17.0	16.5 – 18.0	16.5 – 18.0	9.5
$_bH_c$ [kOe]		7.0 – 8.5	6.7 – 8.2	7.0 – 8.5	6.7 – 8.2	7.5 – 9.0	7.2 – 8.7	5.9
$(BH)_{max}$ [MGOe]		19.0 – 23.0	17.0 – 21.0	18.0 – 22.0	16.5 – 20.0	17.5 – 21.5	16.0 – 19.5	10.0
Temperature coefficient of B_r [%/deg.C]		-0.11 (RT-120 deg.C)		-0.11 (RT-150 deg.C)		-0.11 (RT-150 deg.C)		-0.12 (RT-120 deg.C)
Temperature coefficient of $_iH_c$ [%/deg.C]		-0.56 (RT-120 deg.C)		-0.47 (RT-150 deg.C)		-0.46 (RT-150 deg.C)		-0.35 (RT-120 deg.C)
Recoil permeability [%]		1.10-1.20		1.10-1.20		1.10-1.20		1.2
Density [g/cm^3]		6.1 - 6.3	5.9 – 6.2	6.1 - 6.3	5.9 – 6.2	6.1 - 6.3	5.9 – 6.2	6.0
Coefficient of thermal expansion [deg.C^{-1}] (JIS K7197)	Parallel to alignment direction	9.6×10^{-6}						–
	Perpendicular to alignment direction	4.3×10^{-6}						–
Modulus of elasticity [GPa]		R.T 32, 150℃ 21						–
Compression strength [MPa]		100 ー 200						–
Electronic resistivity [μΩm]		500 ー 700						–

※Typical magnet shape
- Block magnet: 7mm x 7mm x 7mm
- Ring magnet: O.D 26mm-Thickness 1.0mm-Length 16mm

B. Demagnetization Curve



4-2. Magnetic Properties

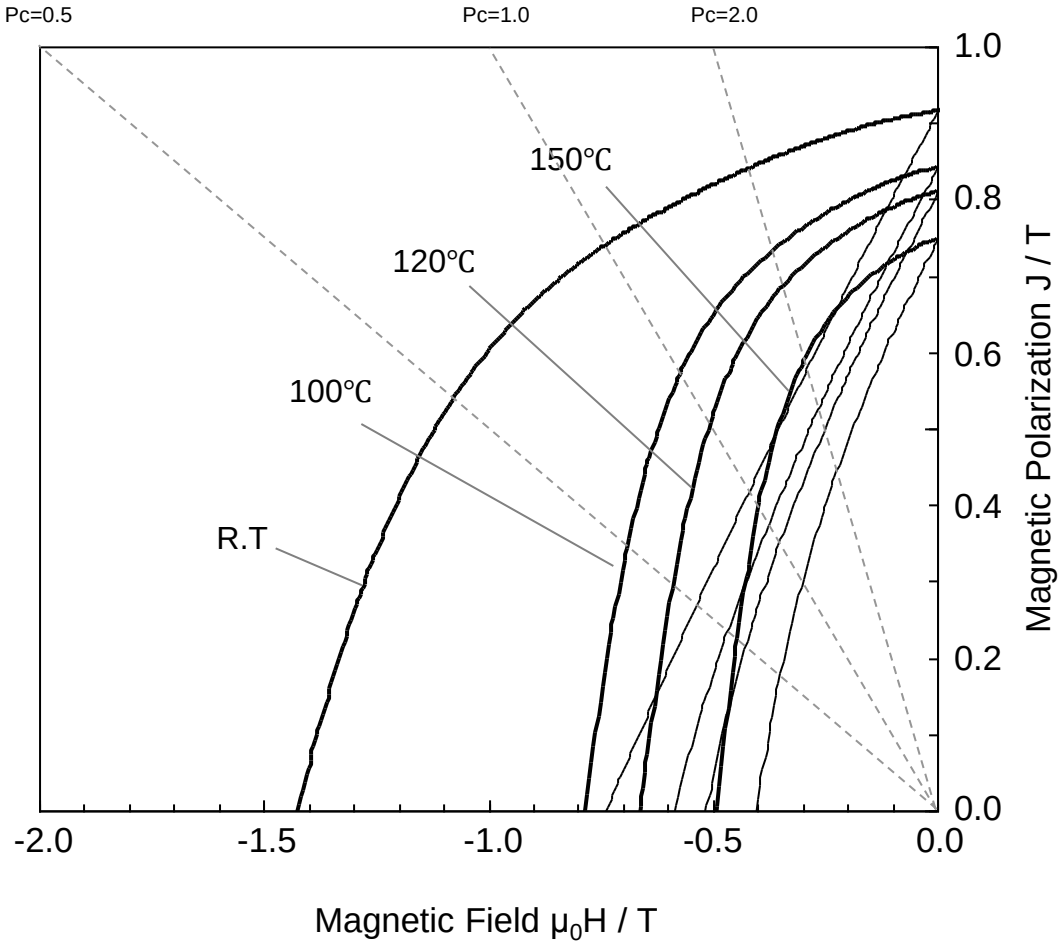
① MF14C

A. Magnetic Properties

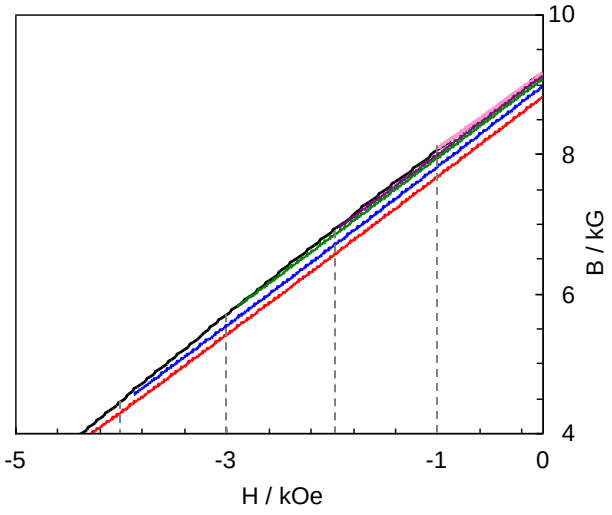
	B_r		$_iH_c$		$_bH_c$		$(BH)_{max}$	
	T	kG	kA/m	kOe	kA/m	kOe	kJ/cm^3	MGOe
Block magnet	0.90-1.07	9.0-10.7	1034-1154	13.0-14.5	557-677	7.0-8.5	151-183	19.0-23.0
Ring magnet	0.85-1.01	8.5-10.1	1034-1154	13.0-14.5	533-653	6.7-8.2	135-167	17.0-21.0

※Typical magnet shape
- Block magnet:7mm x 7mm x 7mm
- Ring magnet: O.D 26mm-Thickness 1.0mm-Length 16mm

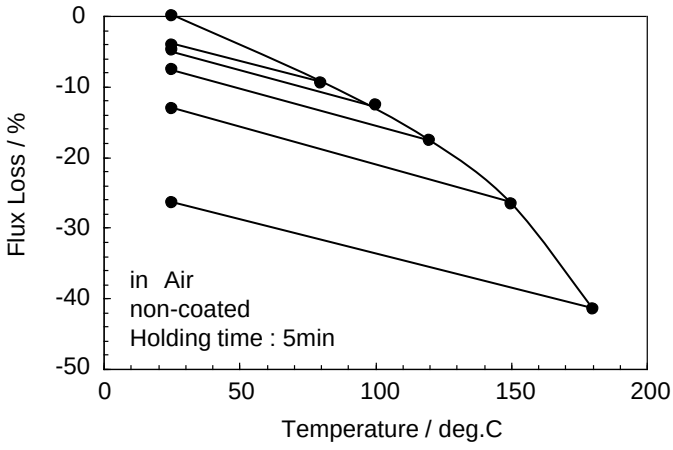
B. Demagnetization Curve



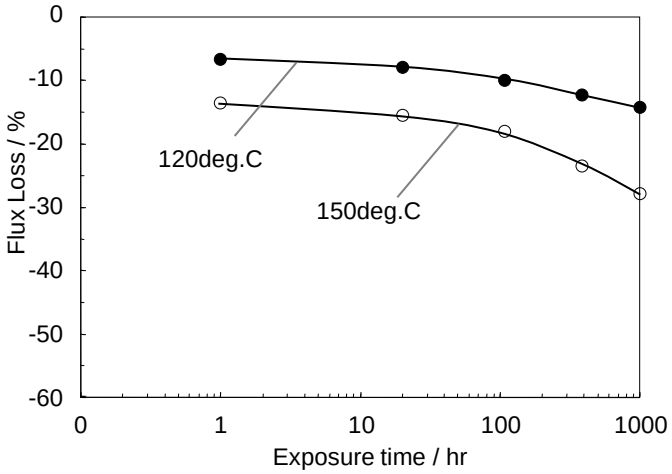
C. Recoil



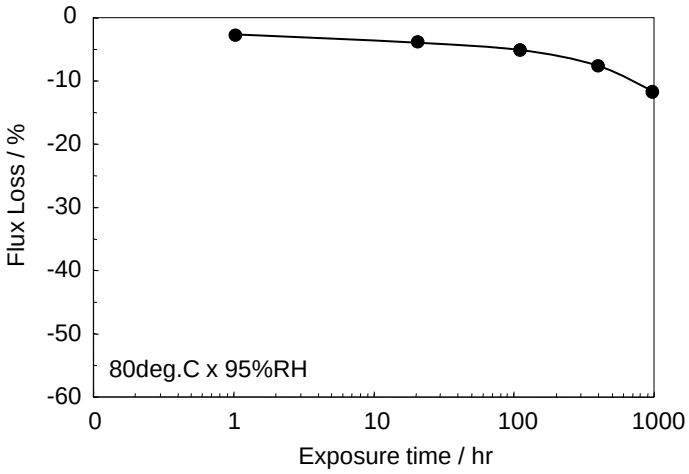
D. Irreversible Loss



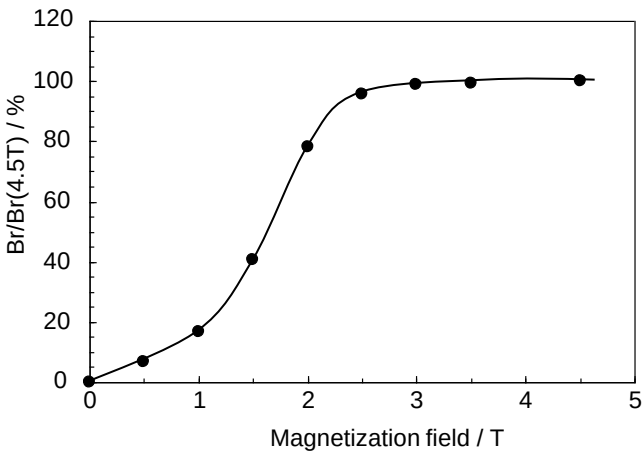
E. Aging Test



F. Humidity Test



G. Magnetization



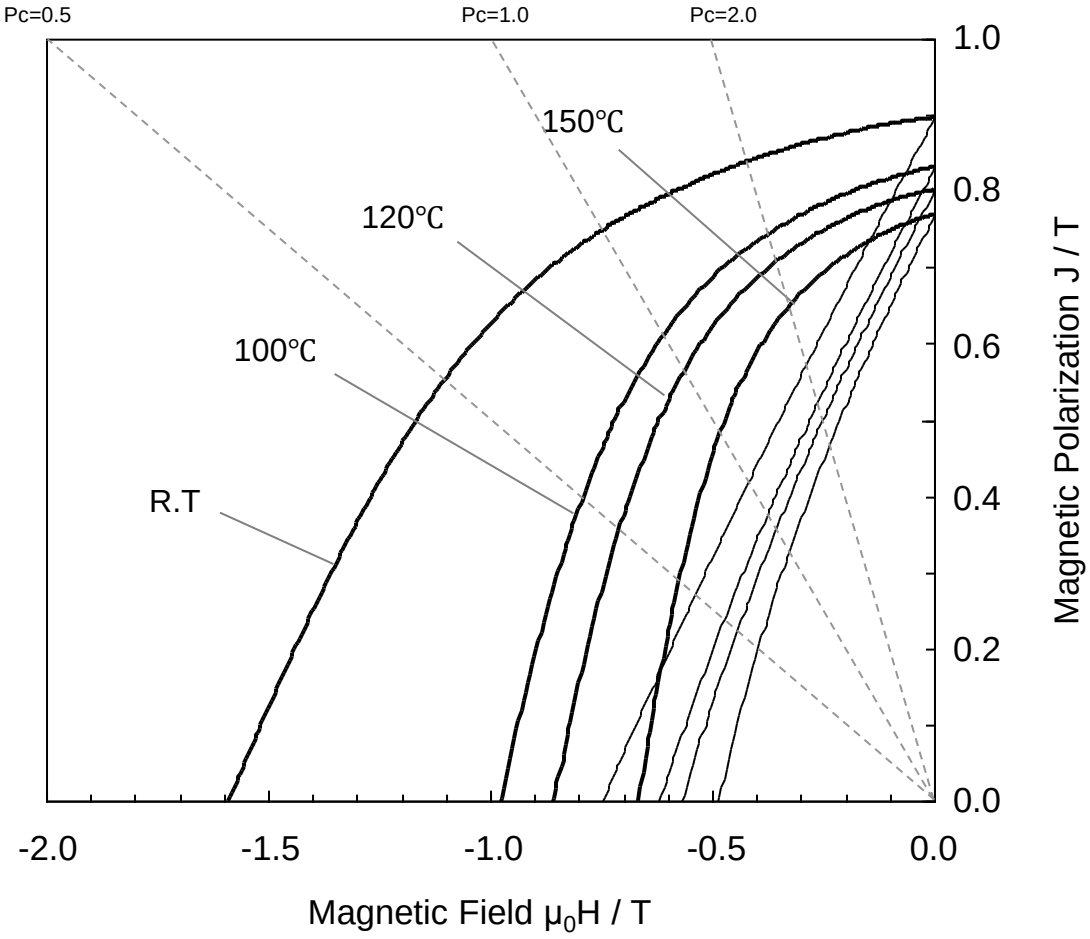
② MF16C

A. Magnetic Properties

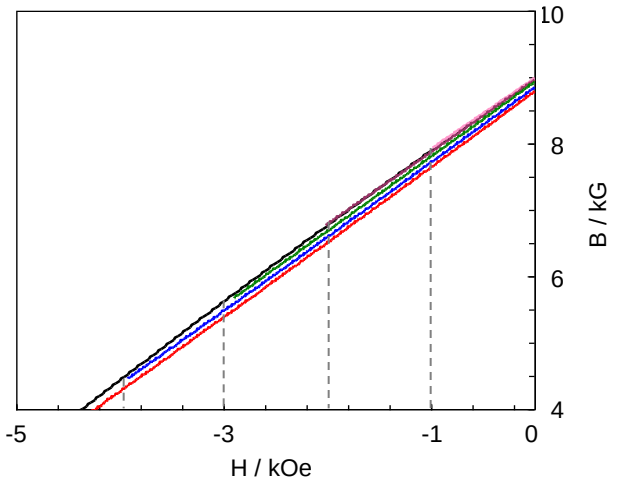
	B_r		$_iH_c$		$_bH_c$		$(BH)_{max}$	
	T	kG	kA/m	kOe	kA/m	kOe	kJ/cm³	MGOe
Block magnet	0.85-1.05	8.5-10.5	1194-1353	15.0-17.0	557-677	7.0-8.5	143-175	18.0-22.0
Ring magnet	0.80-1.00	8.0-10.0	1194-1353	15.0-17.0	533-653	6.7-8.2	131-159	16.5-20.0

※Typical magnet shape
- Block magnet: 7mm x 7mm x 7mm
- Ring magnet: O.D 26mm-Thickness 1.0mm-Length 16mm

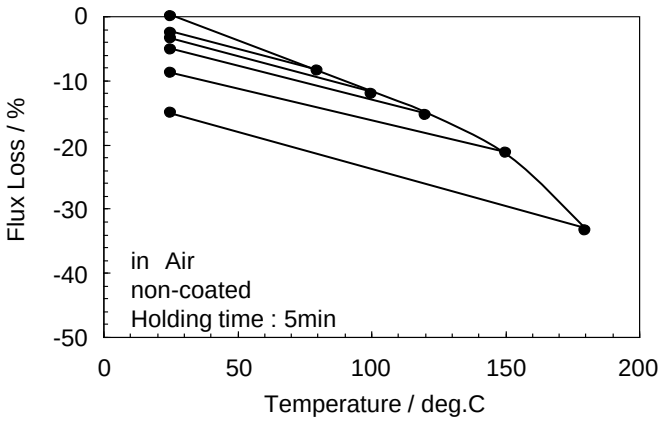
B. Demagnetization Curve



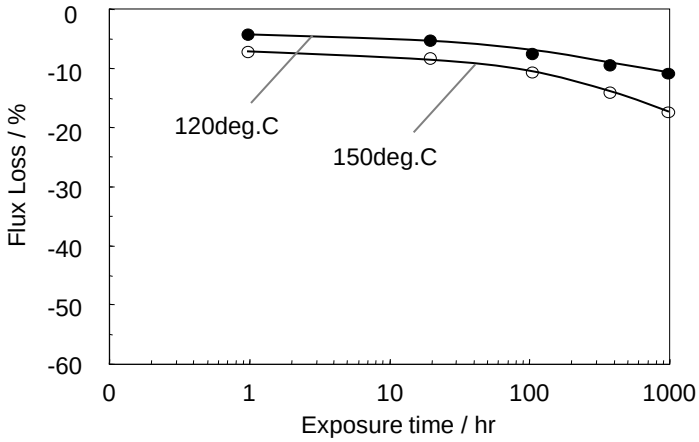
C. Recoil



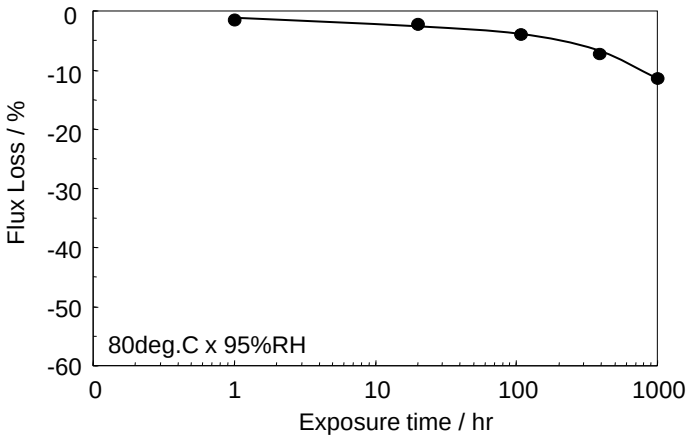
D. Irreversible Loss



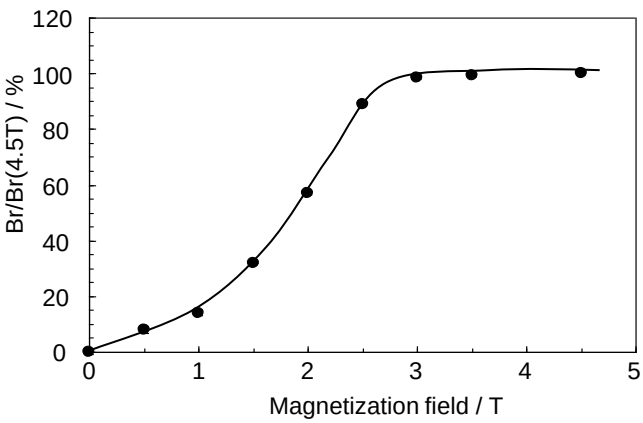
E. Aging Test



F. Humidity Test



G. Magnetization



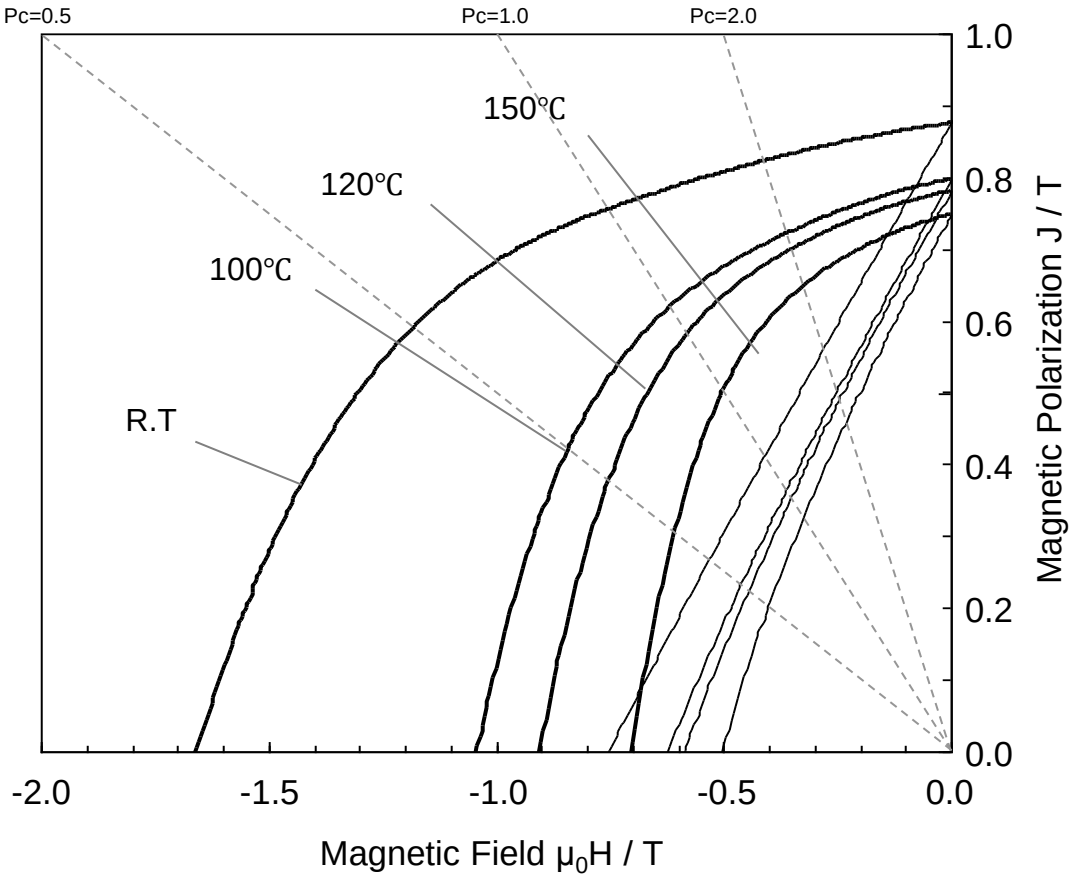
③ MF18C

A. Magnetic Properties

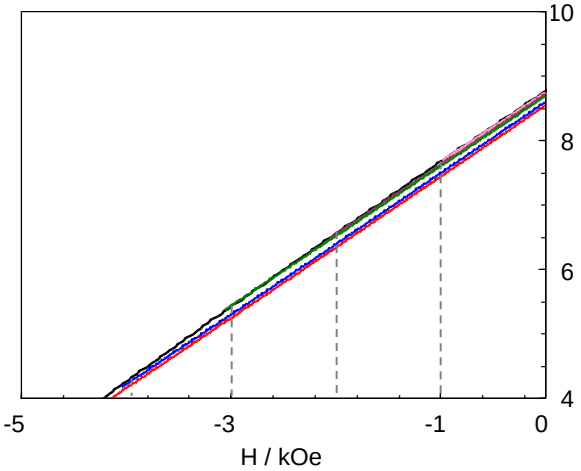
	B_r		$_iH_c$		$_bH_c$		$(BH)_{max}$	
	T	kG	kA/m	kOe	kA/m	kOe	kJ/cm^3	MGOe
Block magnet	0.85-1.05	8.5-10.5	1313-1432	16.5-18.0	597-717	7.5-9.0	139-171	17.5-21.5
Ring magnet	0.80-1.00	8.0-10.0	1313-1432	16.5-18.0	573-693	7.2-8.7	127-155	16.0-19.5

※Typical magnet shape
- Block magnet: 7mm x 7mm x 7mm
- Ring magnet: O.D 26mm-Thickness 1.0mm-Length 16mm

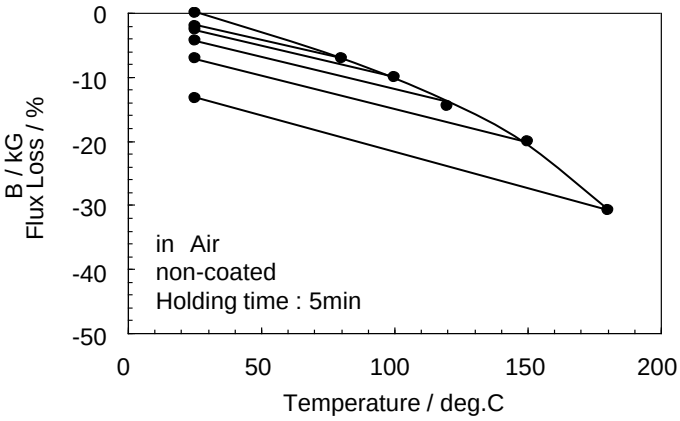
B. Demagnetization Curve



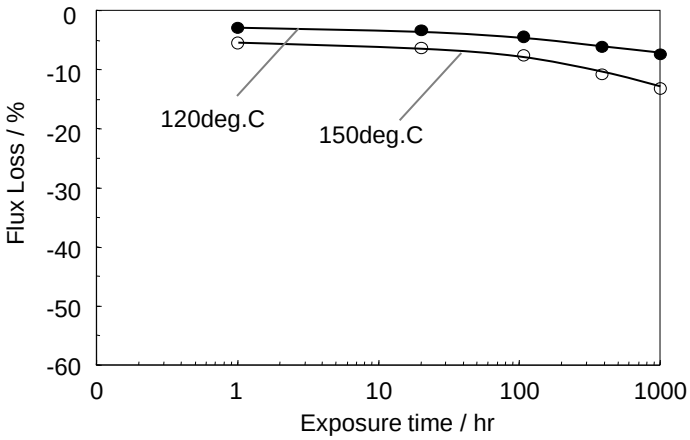
C. Recoil



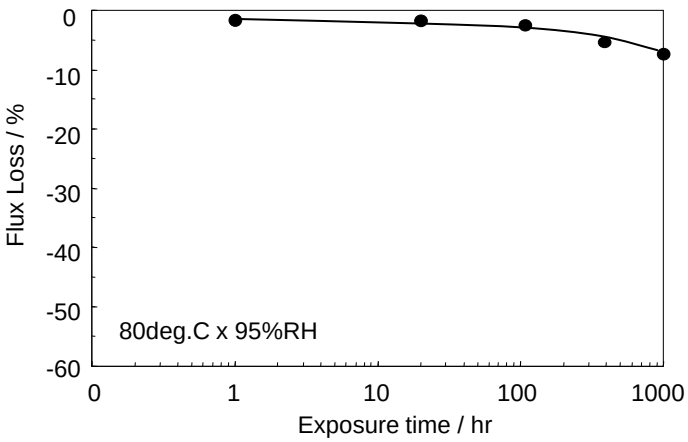
D. Irreversible Loss



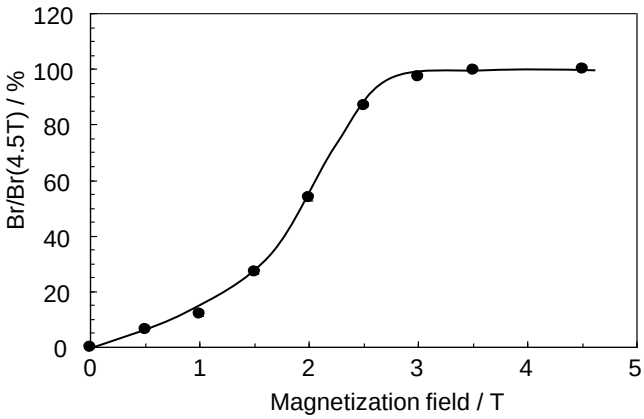
E. Aging Test



F. Humidity Test



G. Magnetization



5. Mechanical / Physical Properties

Type		Compression molding
Binder resin		Epoxy
Tensile strength	MPa	12*
Modulus of elasticity	GPa	21*
Poisson's ratio	-	0.33
Tensile strain at breaking	%	0.1
Compressive strength	MPa	100*
Compression strain at breaking	%	1.1*
Hoop stress	MPa	(27)
Radial crushing strength	MPa	20
Coefficient of thermal expansion	% /℃	9.6×10^{-6}**
Molded density	g/cm^3	6.0

*Measurement temperature: 150℃
**Measurement temperature: -40 ℃ ~ 150 ℃

6. Coolant resistance of Injection molding

Customer	Magnet shape	Material	Coolant (Solvent)	Testing condition	Judgement	Note
A company	Φ10-L7mm (Injection)	18P+SmFeN+PPS	Unknown(HFC＋Oil)	150℃、1,000hr、Pressure vessel (Pressure : unknown)	Applicable	including H2O Review needed
B company	Φ10-L7mm (Injection)	18P+SmFeN+PPS	Freol-8G / R134a	150℃、14days、Pressure vessel (Pressure : unknown)	Applicable	
			55MT / R600a	150℃、14days、Pressure vessel (Pressure : unknown)	Applicable	
			FVC68D / R410A	150℃、14days、Pressure vessel (Pressure : unknown)	Applicable	
			RB32G / R410A	150℃、14days、Pressure vessel (Pressure : unknown)	Applicable	
			NM56 / R410A	150℃、14days、Pressure vessel (Pressure : unknown)	Applicable	
			RB68A / R410A	150℃、14days、Pressure vessel (Pressure : unknown)	Applicable	
			POE46 / R134a	150℃、14days、Pressure vessel (Pressure : unknown)	Applicable	
B company	Roter shape	18P+SmFeN+PPS	FVC68D / R410A	150℃、14days、Pressure vessel (Pressure : unknown)	Applicable	
			RB32G / R410A	150℃、14days、Pressure vessel (Pressure : unknown)	Applicable	
			RB68A / R410A	150℃、14days、Pressure vessel (Pressure : unknown)	Applicable	
	Roter shape	18P+SmFeN+PPS	FVC68D / R410A	170℃、21days、Pressure vessel (Pressure : unknown)	Applicable	Including H2O Testing shape : Motor
			RB32G / R410A	170℃、21days、Pressure vessel (Pressure : unknown)	Applicable	
			RB68A / R410A	170℃、21days、Pressure vessel (Pressure : unknown)	Applicable	

2018.01.15 Technical Data

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