Table 1. Temperature rise

Temperature rise	Stator winding		Rotor winding	
	Thermometer method	Resistance method	Thermometer method	Resistance method
No load	19.5 °C	16 °C	15 °C	18 °C
Short circuit	19 °C	36 °C	12 °C	14 °C

CONCLUSION

The above is a brief description of the Kaplan turbine and directly connected generator in Jintsugawa No. 3 power station. This turbine and generator are record products for low head large water quantity Kaplan Turbine, and its latest construction has been drawing attention of all concerned in the electric power industry in Japan. Commercial operations was started in the middle of December, having completed the installation work in such a short time of 80 days.

Introduction of Products

MAGNETIC MATERIALS WITH RECTANGULAR HYSTERESIS LOOP

By

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I. INTRODUCTION

Attention was focused on the magnetic materials with rectangular hysteresis loop after a success by Koppelman of the Siemens Co., in using it for a contact converter in 1941. Since then it has come into use for magnetic amplifiers etc., and the like with considerable expansion of its field of application. After the end of the world war II, inspired by the development in Germany of the application of magnetic materials with rectangular hysteresis loop, researches more undertaken in U.S.A., Great Britain and other countries, resulting in the production of Deltamax, HCR etc. with similar charactristics to Permenor Z 5,000 Z of schmetz Vacuumschmelze A. G.

Research in this field was taken up by many investigators in Japan, too. Our Company made a plan of producing contact converter in 1950 and simultaneously launched research work on magnetic materials with rectangular hysteresis loop. In August 1951 a trial core was completed, for the first time being successful in the industrial production in Japan. Thenceforth our Company has been self-supporting iron cores, to be used for our contact converter and magnetic amplifier and turning out products of superior quality.

Those magnetic materials utilizing the rectangularity of hysteresis loop are, as is well known, oriented 50% iron nickel alloy, Permalloy and Perminver annealed in a magnetic field and oriented silicon steel, but oriented 50% iron nickel alloy is most extensively used because of its good rectangularity and high saturation induction.

Our Company has conducted research on various magnetic materials and put them to practical use, but oriented 50% iron nickel alloy is predominating among them. The following is a brief account for it.

II. MANUFACTURING

Oriented 50% iron nickel alloy is that produced by combining the processes of severe cold rolling and heat treatment at high temperature, and having what is called a "cubic structure" (Fig. 1) in which the [100] direction of each crystal grain is parallel with the rolling direction, and the rolling plane agrees with the plane.

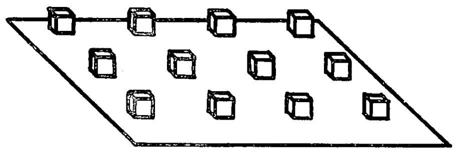


Fig. 1. Cubic structure

The mechanism by which cubic structure is formed has been studied by many investigators, and the following conditions are considered to have effect on the formation in metals with face centered cubic structure.

1. Crystal grain size before rolling.
2. Reduction degree of cold rolling.
3. Temperature and time of heat treatment.
4. Purity of specimen.

These conditions have been studied mainly from the viewpoint of magnetic character.

1) Effect of crystal grain size before cold rolling.

When a 50% iron nickel sheet which has been produced by hot rolling from an ingot is heated at high temperature in hydrogen, not only it is purified but its crystal grain become course. Comparison was made among the magnetic character of various samples which had undergone the same cold rolling and final annealing after their grain sizes had been changed by differring the temperature of heat treatment. The result was, as shown is Fig. 2., that those with large grain size showed poor rectangularity of the hysteresis loop.

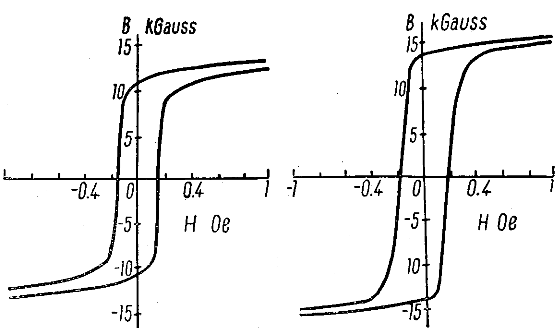


Fig. 2. Relation between grain size before cold rolling and hysteresis loops

2) Effect of reduction degree.

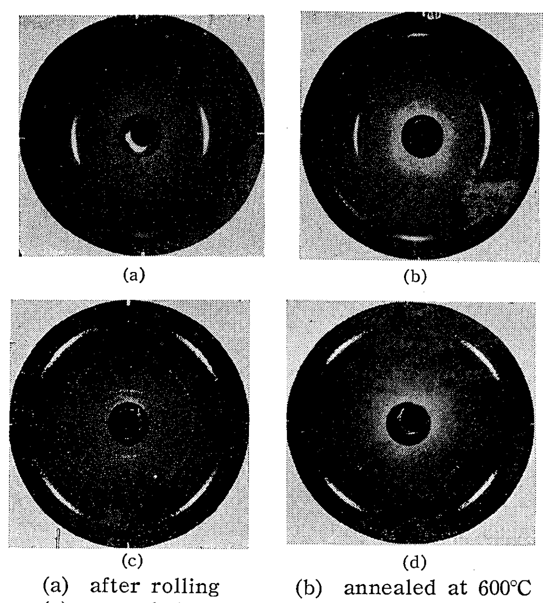
In order to reveal the relation between the reduction degree and magnetic character after recrystallization, six different specimens which had been cold rolled to thickness of 0.1, 0.085, 0.065, 0.05, 0.045 and 0.035 mm without intermediate annealing after hot rolling were compared with the same heat treatment. The result, as shown in Table 1, was that from 0.065 mm remanence increased, and the rectangularity of hysteresis loop improved.

Table 1. Relation between rolling degree and magnetic characteristics

Thickness mm	Coercive force Hc Oe.	Remanence Br Gauss
0.1	0.21	11,600
0.085	0.20	12,200
0.065	0.21	13,200
0.05	0.20	13,500
0.045	0.185	13,200
0.035	0.19	13,200

3) Effect of temperature of final annealing.

In order to find the relation between the temperature of annealing and recrystallization, test piece which had been rolled to a thickness of 0.04 mm and then been made to recrystallize at temperatures of annealing at 100°C interval from 500°C to 1100°C was examined their X ray diffraction. As a result, it is, as shown in Fig. 3, found that from 600°C grain growth and recrystallization start to appear, and as the temperature of annealing is made higher, the cubic structure approaches perfection.



(a) after rolling (b) annealed at 600°C
(c) annealed at 700°C (d) annealed at 1,100°C

Fig. 3. The X-ray diffraction patterns of 50% Ni-Fe alloy

The influence to magnetic characters is as shown in Table 2, which illustrates that as the temperature rises the rectangularity of the hysteresis loop improves, until it reaches a certain temperature where remanence starts to fall.

Table 2. Relation between temperature of annealing magnetic characteristics

Temperature of annealing °C	Coercive force Hc Ö	Remanence Br gauss
950	0.34	13,100
1,020	0.28	13,300
1,070	0.22	13,400
1,120	0.185	13,200

Based on the above experimental results, our aim has been achieved by the following production methods.

Although it is desirable to melt in vaccum, from the economic point of view we use ingots melted in air and good results.

After the ingot is hot rolled, it is given the appropriate cold rolling and annealing to make the crystal grains as small as possible and assure the material become completely uniform, subsquently it is cold rolled without any intermediate annealing to a thickness of 0.06~0.03 mm.

At the Vacuumschmelze A.G. the material is slit into necessary widths when the thickness is still at 0.35 mm on the ground that satisfactory results are not obtainable, because the slitting after final rolling disturbs the recrystallization. Our practice, however, is to slit the strip into 30 mm width at the intermediate thickness for the convenience of the rolling mill capacity. Material to be used at less than 30 mm width is slit in the final thickness. The characteristics shown in Figure 4 are obtained from material slit after final rolling, and almost no effect of the slitting is observed.

The rolled material is wound to give a shape into coil form as for use and is given heat treatment in an electrical furnace of unique design. The condition of heat treatment is determined for each ingot after test annealing has been conducted.

For materials with a perfect rectangular hysteresis loop, or in cases where material will small coercive force is required even at the cost of some degree of rectangularity, special heat treatment, such as magnetic annealing is carried out.

III. CHARACTERISTICS AND SHAPE OF PRODUCTS

In Table 3 and Fig. 5 are given hysteresis loops of our company's cores with rectangular hysteresis loop produced according to the foregoing process.

Table 3. Typical Characteristics

Shape of hysteresis loop	Coercive Force Hc Ö	Remanence Br gauss
General rectangular hysteresis loop	0.15—0.2	14,000—14,500
Perfect rectangular hysteresis loop	0.08—0.12	14,500—15,000
Low coercive force	0.04	12,500—13,000

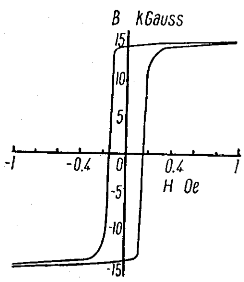
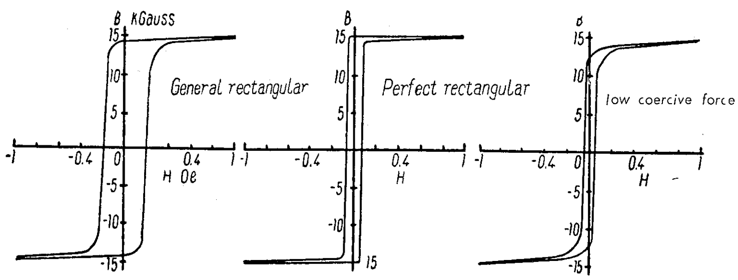


Fig. 4.
Hysteresis loop of a 50% Ni-Fe core slitted to 4mm after the final rolling



(a) (b) (c)

Fig. 5.
Typical hysteresis loops of cores made in our company

The shape of these products made by our Company are all a toridal core, the width of which ranges from 4 to 30 mm, with a outer diameter of from 15 to 460 mm. The weight varies from 0.5 gr to 25 kg. Those samples are shown in Fig. 6.

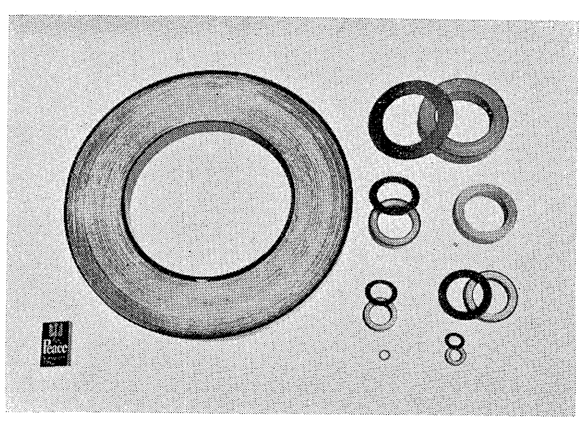


Fig. 6. Photogragh of our products of various sizes as compared with a cigarette

IV. EXPERIMENT

As the magnetic materials described here are used in A.C. circuits, it is necessary to learn their dynamic character when magnetized by an alternating current.

The major difference between static and dynamic character is that in the dynamic character permeability decreases and coercive force increases. It is consideced that the cause for this lies in the fact that when it is magnetized by an alternating current, an eddy current is produced because the velocity of magnetization change dB/dt is finite. Further investigation reveals that this is related to the movement velocity of the domain boundary. This movement velocity is known to have a relation of

$$v = A\,(H - Ho)$$

for many experiments. Here v is the movement velocity of the domain boundary, H the external field, A and Ho the constant related to the specimen character. If the movement velocity of the domain boundary is determined solely by the eddy current, it should become quite large in Ferrite (semi-conductor), but experimental results show that it is much smaller than the valve expected according to the eddy current. It may be attributed to that the movement of the domain boundary is accompanied by a resistance similar to internal friction.

As there is a relation $dB/dt \propto v$ between the velocity of magnetization change and velocity of domain boundary movement, when dB/dt becomes greater, the external magnetic field naturally becomes larger.

An example of a result obtained by our investigating about the relation between coercive force and dB/dt in oriented 50% nickel alloy is shown in Fig. 7. The dynamic character differs according to the circuit conditions, so in this experiment it was magnetized at 50 cycle; it is made to have a flat step for the current during time Δt and the measurment was made with varied Δt increasing voltage. For the measurment of Δt an average voltage during the Δt was obtained approximately from the voltage wave form induced in core and calculated by the following formula,

$$\Delta t = \frac{\Delta BNA}{\bar{E}}$$

where ΔB is the flux change of the reverse magnetization range and is in the neighbourhood of 26,000 gausses. N is the number of primary winding, and A the sectional area of specimen, Furthermore, in the graph conversion to frequency was made by $f = \frac{1}{2\Delta t}$ for convenience and used for the abscissa.

It may be stated from these results that if the increase in coercive force was due only to the microscopic eddy current it is to change in proportion to the square of the thichness. However as such a marked change is not noticed in thickness, it is clear that for the material of a thickness to this extent the eddy current difference due to thickness does not play a major roll in the increase of coercive force.

It is of course necessary to reduce thickness to prevent the increase of coercive force in dynamic character and the decrease of permeability, but as considerable change may result from the dimensions and manner of interlayer insulation, the careful attention must be paid to these also.

The magnetic character of high permeability magnetic materials are greatly affected by external stress, and in order to keep them free from external stress they are used after being enclosed in a protective box,

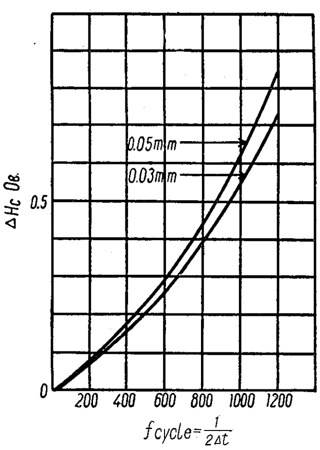


Fig. 7. Increase of coercive force by magnetizing with alternating field

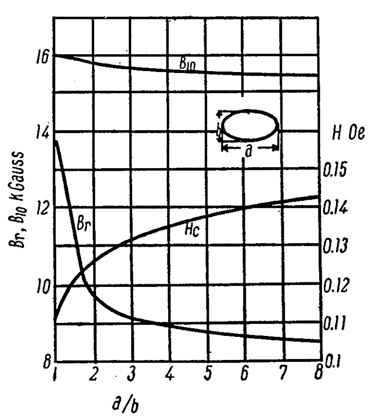


Fig. 8. Effect of stress on magnetic characteristics of the core compressed in the direction of diameter

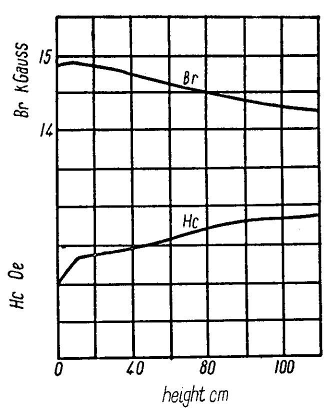


Fig. 9. Change of magnetic characteristics by the falling down shock

The results obtained by ourselves in investigating the effect of stress on oriented 50% iron-nickel core are shown in Fig. 8 and 9.

Fig. 8 shows the result about a specimen of the dimensions of 30×50ϕ×60ϕ (mm) compressed in the direction of the diameter. Fig. 9 is the result about a similar sized specimen being repeatedly dropped on the floor, each time the height being increased.

V. APPLICATION

The products manufactured by our Company using the cores with rectangular hysteresis loop are given below, while more new varieties of application are being planned for the future.

(1) Contact converters
(2) Magnetic amplifiers
(3) D-C current (voltage) transformers
(4) Voltage stabilizers

In these reports are described the case of oriented 50% iron-nickel alloy, but also research work on orient silicon steel and alloys, of the Permalloy system is carried out obtaining materials with excellent charactristics to be used in the above instruments.

(5) Acknowledgement

The writers wish to extend their gratitude of Dr. K. Mihara of his guidance in the reseach and production of special magnetic materials such as oriented 50% iron-nickel alloy and other materials.

HEAVY CURRENT SELENIUM RECTIFIER FOR WATER ELECTROLYSIS
CAPACITY 180 kW 90 V 2,000 A

Supplied to the Fukiai Factory of the Kawasaki Seitetsu K. K.

Selenium rectifiers are one of those that have greatly extended its sphere of application in recent days. Their maintenance is simple and operation easy, with advantage of high efficiency at any load. Production of superior selenium rectifier element has resulted in long life and extensive use in various fields. As a typical the selenium rectifier for water electrolysis recently supplied to Fukiai Factory of the Kawasaki Seitetsu K.K. is accounted for herein.

This equipment is composed of a system which recieves as shown in the connection diagram of the main circuit in Fig. 1, 3 phase power at 2,200 V 60 c and is adjusted to the required voltage by an induction voltage regulator, after which it is supplied to a selenium rectifier through a transformer and is converted to a D.C. power of 90 V-50 V 2000 A.

Details of each instrument are as follows:

(1) Selenium Rectifier 1 set

Type :	Indoor use oil circulating water cooled
Rated Output	180 kW Continuous
Rated Voltage	90 V
Rated Current	2,000 A
Rectifying system	3 phase full wave bridge connection
Accessaries	Water cooled oil cooling device, oil conservator, oil circulation pump, etc.

(2) Rectifier Transformer 1 set

Type :	Indoor use oil immersed self cooled
Capacity	230 kVA continuous
Number of Phase	3 phase
Primary voltage	2,830 V
Secondary voltage	80 V (Equivalent to 90 V D.C.)

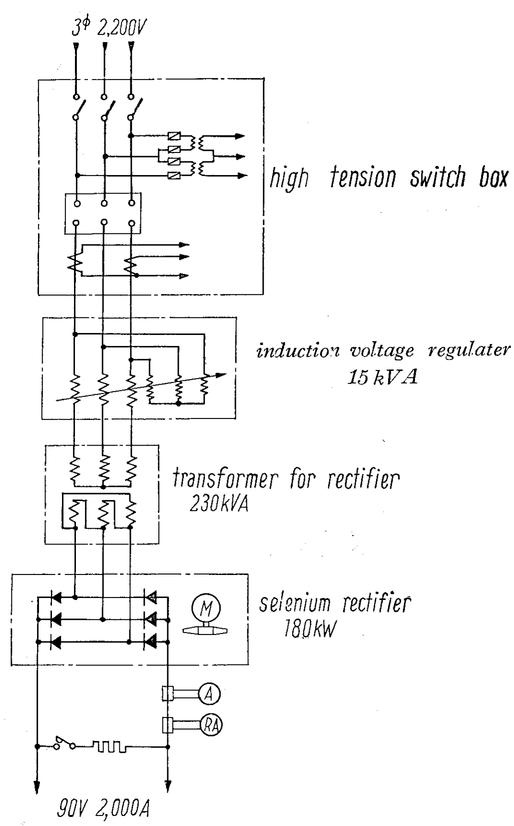


Fig. 1. Connection diagram of main circuit