The General Trend & Raw Material Supply of Global Magnet Industries

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With the development of computer, electronics, communication and modern information industries, NdFeB magnet industry is growing rapidly as a booming business worldwide. Due to the advantages of rare earth, manpower, technical teams and huge domestic market China NdFeB magnet industry made a big jump during the last decade. Its growth rate is the highest one among all other countries. The current situation of NdFeB magnet industry can be concluded as "Five Highs", i.e. "High volume growth", "High grade development", "High expansion of capacity", "High value added product" and "High Variation speed". The connotations of these "Five Highs" and an updated review on Chinese rare earth industry will be given in this paper.

Key words: "reasonable prices" of rare earth, high grade discriminant and price/performance of NdFeB,

1. High Volume Growth

The total global output of NdFeB sintered magnets was 72 tons in 1985, it became 8,000 tons in 1997. The average annual growth rate is +48.1% within the last twelve years. It is really the highest one among all kinds of commercially available magnets. The output of NdFeB magnets is increasing either in developed countries, such as Japan, USA and Europe, or in developing countries, such as China, East Europe and Southeast Asia. The only difference is growth rate. Due to the advantages of raw material abundance, technical teams, manpower and supporting by the huge domestic market, Chinese NdFeB magnet industry made a big jump during the last decade. Its growth rate is the highest one among all other countries. The average annual growth rate of NdFeB in China, Japan, USA and Europe in different periods of time are listed in Table 1.

Table 1. Growth Rates of NdFeB in Each Country

	'85-'97	'85-'89	'89-'97	'85-'91	'91-'94	'94-'97
Japan	42.7%	+74.7%	+27.1%	+72%	+10.3%	+26%
U.S.A.	45.6%	+117%	+19.4%	+71%	+19%	+26%
Europe	47.5%	+76%	+37.4%	+60%	+24.3%	+31%
China	62%	+86%	+50.5%	+80%	+54%	+37%

The growth rate of China keeps the highest one among all others.

The output and producing capacity of sintered NdFeB magnets in China since 1989 is shown in Fig.1.

Fig.1 Growth of Producing Capacity & Output of NdFeB in China Since 1989

As can be seen from Fig.1 that the annual growth rate of output is much higher than +40%, except that of last year. The extremely high expansion of capacity in the initial stage of 1984-1989 reflected the abnormal expansion of Chinese economy at that time. Starting from 1990 the expansion in capacity was much reduced due to the measure taken by Chinese government. During 1990-1994 the average annual growth rate of output and capacity was +62% and +13%, respectively. Consequently, the percentage of actually used capacity increased from 15% (1989) to 77% (1994). Starting from 1994 the growth of capacity is consisting with the growth of output. Now the percentage of actually used capacity is around 80%, which is quite reasonable and it would be kept for long.

The outputs of sintered NdFeB magnets in China, Japan, USA and Europe since 1985 are summarized in Fig.2. The output of China is increasing continuously since 1985. But the situations were not the same for Japan, USA and Europe: their outputs were increased rapidly during 1985-1991. Then they were depressed significantly during 1991-1994. They increased rapidly again after 1995.

The percentage of NdFeB produced in Japan was 63% in 1985, it became 40% in 1997. In the contrast, the percentage of NdFeB produced in China increased from 14% (1985) to 40% (1997). The share of USA and Europe in 1997 is 11% and 9%, respectively. Such share ratio would be remained the same by year 2000.

Fig.2 Output Growth of Sintered NdFeB Magnets In China, Japan, USA & Europe Since 1985

The rise and decline of growth rates in the West Countries is not occasional, they were precisely related to the market demands. According to the statistics of SSMC the market shares of sintered NdFeB magnets in Japan are listed in Table 2. Obviously, **VCM, Motors** and **MRI** are the three major applications of NdFeB magnets in Japan. Especially, VCM is the dominant one whose market share is more than half of the total.

Table 2 Market Shares of Sintered NdFeB in Japan

	1988 ¹⁾	1991 ¹⁾	1995 ²⁾	1996 ³⁾	1997 ⁴⁾
VCM	40%	50%	59%	57%	58%
Motors	14%	18%	15%	16%	15%
MRI	31%	23%	13%	14%	14%
Communication	-	-	5%	5%	6%
Acoustics	1%	6%	3%	3%	3%
Others	14%	3%	5%	5%	4%
Total Output	370t	980t	1160t	2400t	3200t

The significant decline of NdFeB output during 1991- 1992 was caused by the depression of computer industry mainly: due to the excessive inventory and the switching to the new drive type, thus the percentage of magnets used for VCM dropped to the minimum - 50% in 1991. The demand of magnets for VCM was increased sharply after 1992, consequently, the output of NdFeB was increased as well. The percentage of magnets used for VCM reached the peak value of 59% in 1995.

The purchasing of magnets for VCM was slowdown in 1995 due to the switching to the production of new type drive and excessive inventory. Suddenly, NdFeB magnet industry in the West was covered by a gloomy atmosphere, people are afraid of the appearance of the business depression experienced during 1991-1992. Fortunately, the additional demand of motors for air conditioner and automotive use increased, especially the demand of communication use including portable telephone, automotive telephone increased so

significantly that such demand increase even bigger than the loss of demand for computer industry. Thus the possible depression was avoided. Two conclusions can be made from the above mentioned situation:

- 1) First of all, the development of magnet industry could not rely on one application solely, no matter how big it is, otherwise, it would take a big risk.
- 2) To develop new applications is the only reliable way to keep the booming for magnet industry.

The applications of NdFeB in China are quite different from those in the West World. Such situation precisely depends on the industrial level of China, the grades of produced NdFeB and their sales prices. Almost half of the produced NdFeB was used for loud speakers and other acoustics. Various kinds of magnetizer including dewaxer widely used in oil industry are another major application of NdFeB in China. Magnetic force instruments such as magnetic sucker, coupling and separator with NdFeB etc. also widely used in China. The middle and low grades NdFeB made in China just meet the needs of such applications. The market shares of NdFeB for various applications in China are listed in Table 3.

Table 3 Market shares of Sintered NdFeB in China

	1985	1988	1991	1994	1997
Acoustics	55%	50%	36%	33%	30%
Magnetizer	25%	22%	21%	21%	21%
Motor/Sensor	-	8%	20%	24%	28%
Coupling/Separator	16%	12%	13%	15%	12%
VCM/Meter	-	-	<1%	2%	4%
Others	4%	8%	10%	5%	5%
Output, tons	10t	75t	340t	1,230t	3,150t

Looking forward to the 21 century we are fully confident of further rapid growth of global magnet industry. The reason is obvious: the sales of PC in the West World will keep annual growth rate of 20%, the growth rate in the developing countries, such as China, India would be even higher. Moreover, the large computer systems worldwide need to be converted to new generation. The total estimated cost to just the U.S. will exceed \$300 billion, for the World \$600 billion. A portion of the cost would be spent for hardware including NdFeB magnets.

The new applications of magnets in electric vehicle (EV) and automated highway system (AHS) would open a "New World" for NdFeB magnet industries worldwide.

2. High Grade Development

The computer, communication and informative industries are the major users of NdFeB magnets. With development of these modern industries, more and

more strict requests are rising for magnets. For example, the most popularized notebook computer, for which only the 2.5 inch disk drive can be used, its VCM needs NdFeB with energy products >40MGOe. As for the magnets for automotive use, especially for EV, its working temperature should be as high as 200 °C or more. The corrosion resistance of the magnets used for AHS should be very high. All magnet producers did their best to develop new high grades to meet all above mentioned requests.

The NEOMAX with 50 MGOe is available now ⁶⁾. Hitachi Metals now produces high Br, high Hc grades in mass scale steadily ⁷⁾. Magnets with 48 MGOe was made by VAC (Vacuumschmelze) and magnets with even higher energy products will be available in 1998 ⁸⁾. Magnets with 45 MGOe are made by Shin-Etsu, and 48-50 MGOe by TDK, respectively. The similar grades with energy products of 45-50 MGOe are made by YBM's plants in Hungary and USA (Crumax) as well.

Except grades with high (BH), the grade with extreme high iHc has been developed. For example, EH grades with iHc=30-34 kOe were introduced by SSMC. Such magnets can be used at temperature as high as 240 °C, which is designed for EV use. The similar grades of VACODYM411 and HS-36EH used at 210 °C have been introduced by VAC ⁸⁾ and Hitachi, respectively. The new grades of NdFeB introduced by SSMC, Hitachi and VAC are listed in Table 4.

Table 4 NdFeB Magnets with High Br & iHc

Grade	Br, kG	Ihc, kOe	(BH)max , MGOe	Tw, °C
NEOMAX-50	13.9-14.5	11—14	47-51	80 °C
HS-48-50	13.7-14	11	48-51	80 °C
VACODYM510	13.6-14	13.5-14	50+1	80 °C
NEOMAX 32EH	11.1-11.9	30-34	30-34	240 °C
NEOMAX 35EH	11.6-12.3	26-30	32-36	240 °C
HS-36EH	11.9	28	34	210 °C
VACODYM411	10	41	25	210 °C

Note: Tw - working temperature

As can be seen from Table 4 that the *Discriminant of High Grade Sintered NdFeB Magnets* should be expressed as follows:

$$(BH)max(MGOe) + iHc(kOe) = 60$$

Five years ago the *Discriminant* was :

$$(BH)max(MGOe) + iHc(kOe) = 50$$

The speed of grade development of NdFeB is the highest one in the history of magnet development.

Moreover, in order to improve the corrosion resistance of NdFeB several more effective coating

technologies have been developed, such as new BP coating process ⁹⁾, TiN coating by PVD sputtering and vapor composed polyimide film ¹⁰⁾.

3. High Speed Expansion of Capacity

In order to meet the fast growing market demand of NdFeB, all NdFeB producers did their best to expand producing capacity. The average growth rate of NdFeB output in China is around 50%. Expansion rate of capacity of major Chinese producers is more than 50% annually. The major NdFeB producers in the West World are in the similar situation:

SSMC, the number one NdFeB producer in the world, made its capacity of 100 tons/month in 1995, its capacity became 120 tons/month in 1996. It will be 200 tons/month by the end of 1997 and reach 250-300 tons/month by the end of 1998, i.e. the expansion rate is 50% annually.

Hitachi Metals planned to invest 68 million USD to expand the capacity from 35 tons/month to 100 tons/month by the end of 1998.

TDK was planned to expand its capacity from 50-60 tons/month to 200 tons/month by 1999.

Another major sintered NdFeB producer, Shin-Etsu Magnetics Inc., was believed to have the similar expansion plan.

YBM is planning to expand its facility in Hungary from 200 tons/year to 500 tons/year within two years. The producing capacity of Crumax (former Crucible Magnetics, which was acquired by YBM in August, 1997) will be doubled by 1999.

Based on the facts mentioned above, it can be sure that the growth rate of NdFeB would be around 35-40% by year 2000.

4. High Value Added Products

As is well known, the higher grade, the higher sales price, consequently, the higher profit would be obtained. This is the driving force for product improvement. Due to the keen competition all NdFeB makers recognized that the "quality" is more important than "quantity".

The sales prices of different NdFeB grades in international and Chinese market are listed in Table 5. The price changes of different grades both in Chinese market and global market are summarized in Fig. 3. The price in China market is related to the block magnets, the prices in the international market are related to the final products of magnets. The curve A and B shows the changing trends of price/performance in Chinese market and global market, respectively. The shadowed area in the figure indicates the price range of magnet devices. As can be seen from Fig. 3:

1) The sales prices in Chinese and global market are quite different, which are evidenced by the two distinct curves A and B.

Table 5 Price/Performance of NdFeB in Chinese & Global Markets

Grade	Magnetic Performances		Average Market Prices		Note
	(BH) max, MGOe	I _{hc} , kOe	¥/kg	\$/kg	
N30	30±1MGOe	>11	200	25	Sales Price in China
N35	35±1MGOe	>11	250	31	
N40	40±1MGOe	>11	450	56	
Magnet Device			970	120	Market
N45	45±2MGOe	>12	\$130-150/kg		Sales Price in Global Market
N48	48±2MGOe	>11	\$150-180/kg		
N50	50±2MGOe	>10	\$200-220/kg		
Magnet Device			\$300-340/kg		

Note: (RMB) ¥8.2=\$1USD

Fig. 3 Changing Trend of Price/Performance of NdFeB in China(A) & Global Markets(B)

2) The changing trend of both curves A and B is the same: Price increases with the rising of grades exponentially, the differences between them are the number of exponent solely.

3) The gap between curves A and B reduces with the rising of grades. It means that in order to keep the higher sales price and to get ride off the impact of Chinese magnets, the producers in the West have to do their best to develop the highest grades. Chinese producers have to do the same, in order to obtain higher sales price and better economic efficiency.

4) The sales prices for magnet devices are much higher than the price of magnet itself. One Chinese magnet manufacturer assembles their magnets into Hi-Fi acoustic system and brush-less motors, rather than the sales of magnet directly. In this way the average sales price per unit weight is \$120/kg, in contrast, the sales price of magnet block in domestic market is \$30-50/kg only. Similarly, one magnet manufacturer in the West mainly sells devices and magnets with peculiar shape and size, the average sales price per unit magnet weight is as high as \$300-340/kg.

One can conclude that *to sell both of the high grade magnets and high value added products, rather than the sales of conventional grade magnets is the only way to keep booming of magnet business.*

5. High Speed Change of Magnet Manufacturer's Structure

The huge capacity and solid foundation of technology and capital are needed for magnet manufacturer, who faces the market with so many unpredictable fluctuations and keen competitions. In other words, to establish a dynamic management systems and operating mechanism, rather than being a division of certain big company, whose core business is different from magnets, is absolutely necessary in doing magnet business, i. e. **to concentrate all human, material and financial resources in magnet business.** Only in this way the fleeting opportunity in the market can be caught and the company will be in an impregnable position in the very dangerous market.

Conform to the trend of the times a storm of joint venture, consolidation and acquisition engulfed in the magnet industries all over the world. Many well known and established for long companies disappeared, some new ever known one appeared in front of us.

Let us take some samples from the West: The magnet division of Krupp Widia Co. (Germany), Ovonics (USA) and the Outokumpu Magnets (Finland) disappeared in early 90s. Then the most famous leading magnet company in USA, Magnequench, was sold out by GM in 1995. The ownership of well known magnet producer-Stackpole Magnetic System was changed in 1996. Now it became Kane Magnetics International, Inc. The most recent acquisition is that Crucible

Magnetics (USA) and Philips Components (England), both of them were acquired by YBM in August, 1997 and in March, 1998, respectively. The acquisition of Philips hard ferrite plant by Ugimag is a most significant one recently. Thyssen Magnet Technik Co. left its parent company and becomes an independent company recently. The joint venture between SSMC and Ugimag for making hard ferrite. The acquisition activities of Arnold Engineering... all of these are only a few announced deals, the iceberg, the unannounced one would be much more.

Due to the lower labor cost, abundant raw materials and the potential huge market in China and South East Asian countries become the ideal place, where the new magnet producing line will be built up. The joint venture between Lucky Metals (Korea) and China for making sintered NdFeB magnets has been built up in 1990. A plant owned by Seiko Epson has been built in Shanghai to produce bonded magnets. These businesses were so successful there that they are under expansion now. AMR already owns two rare earth facilities in China, which produce rare earth oxides and master alloy. Rhone Poulenc also set up joint venture in Baotou to produce alloy. It is expected that more magnet producers from West may follow these samples as well.

A plant with capacity of 300 tons/year for producing rapidly quenched magnetic powder is under construction in Thailand by AMM. It will be put into operation in early 1998.

6. Supply of Rare Earth

Considering the rapidly expansion of global RE magnet industries and worrying about the shortage of rare earth supply appeared in 1993-1994 people asked the same question frequently: "How about the rare earth supply in future"? To answer this question, a brief review on Chinese rare earth industry is given below.

6.1 Rare Earth Industry In China

The proven RE reserves are 48 million tons REO in China, the prospective reserves are more than 120 million tons. Most of them are primary minerals deposited in north China, almost 80% of them concentrates in Baotou, Inner Mongolia, where rare earth deposit coexists with iron deposit. The iron mining in Baotou is around 7-10 million tons per year, which contains 0.4-0.6 million tons REO. Last year (1997) 35,000 tons REO was produced in Baotou. It means that only 7% of the total extracted REO was used. The rest 93% extracted REO has to store as

tailings. Such tailing as the best RE concentrates can be used whenever, while it is needed. Such stored tailings is big enough to satisfy the global needs of rare earth for hundreds years. Obviously, there is no any problem of RE supply in the visible future, from the point of view of RE reserves. The output of Chinese rare earth mineral products is listed in Table 6. The data in brackets are percentages for each type of products.

Table 6 Structure of Chinese RE Mineral Products (REO, tons)

	1994	1995	1996	1997
Baotou(B)	15,743 (50.8%)	26,905 (56%)	34,559 (62.1%)	35,000 (65.7%)
Sichun(B)	7,502 (24.2%)	8,500 (17.7%)	12,500 (22.6%)	11,000 (20.7%)
Shangdong(B)	960 (3.1%)	963 (2%)	951 (1.7%)	1,200 (2.2%)
Ionic Ore	5,854 (18.9%)	9,770 (20.4%)	7,473 (13.5%)	6,000 (11.3%)
Monazite	930 (3%)	1,864 (3.9%)	90 (0.2%)	50 (0.1%)
Total	30989t	48002t	55373t	53250t

As can be seen from Table 6 that almost 90% of Chinese RE products made from bastnaesite, among them more than 65% comes from Baotou, 20% from Sichun and 2% from Shangdong. The ionic ore is only 10% of the total. As for the monazite, it is stopped in producing in fact. Such structure of RE products will be remained the same in near future.

Now China rare earth industry occupies number one place in the world not only because of her abundant RE reserves, but also because of her annual output and exported RE products. China is the only country, which is able to satisfy all market demands of rare earth worldwide.

6.2 Market Supply of Rare Earth

The shortage of RE supply in 1992-1994 is due to the extremely low sales prices of RE since 1990-1992. There should be a "*reasonable price*", which is acceptable for both manufacturers and customers. The

price fluctuation of Nd_2O_3 and Nd metal in Chinese market since 1990 is summarized in Fig.4. Due to the

Fig.4 Price Fluctuation of Nd_2O_3 & Nd Metal in Chinese Market

sharply increase of market demand for Nd_2O_3 and Nd metal in late 80s, the market prices of both products reached peak value of \$30/kg and \$60/kg, respectively.

Under the stimulation of high prices, all manufacturers expanded their producing capacity so quickly that instead of shortage the overproduction appeared. This is the reason of price decline since 1989 to 1992. Many manufacturers have to slow down or stop their producing activities completely, while the market prices became lower than the limit of survival since 1991. But the market demand is increasing still. Then the shortage of supply appeared in the end of 1992, consequently the prices increased again. With the increase of price the production of RE is recovered. The recovery was so quick that since 1995 the supply became more than the demand, the price decreased again. Take lesson from the previous period The Association of Chinese Rare Earth Producers suggested its members to reduce their products in late 1996. Thus a possible serious price fluctuation was avoided. If the market prices can be kept within the frame of "reasonable price", then even if price fluctuation happened, it would not be as significant as before. In

one word, if we take care of the balance between demand and supply, then both shortage and overproduction can be avoided.

The outputs of oxides and metals of Pr, Nd, Sm, Dy in China since 1995 are listed in Table 7.

Table 10 Output of Oxides & Metals of Pr, Nd, Sm, Dy in China

	1995	1996	1997
Nd_2O_3 , tons	2,036t	3,090t	5,356t
Δ , %	-	+51.8%	+70%
Nd metal, tons	293t	368t	1,200t
Δ , %	-	+25.6%	+226%
Pr_6O_{11} , tons	580t	400t	570t
Dy_2O_3 , tons	212t	255t	262t
Dy metal, tons	19t	24t	37t
Sm_2O_3 , tons	208t	252t	165t
Sm metal, tons	21t	6t	7t

Note: Δ - annual growth rate (%)

7. Closing Remarks

Within the last five years the structure of global magnet industries has been greatly changed due to the storm of consolidation, acquisition and joint venture mentioned above. This is the trend of the times. Facing the opportunity and challenge of 21st century, each magnet manufacturer has to consider on this seriously and to adapt to circumstances, and to occupy the more favorable position.

There are enough rare earth reserve and producing capacity to meet the increasing demand of rare earth worldwide. The only reason caused shortage of supply is the market price, which should be kept in the frame of "reasonable price".

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