# RARE EARTH MAGNET INDUSTRY IN THE USA: CURRENT STATUS AND FUTURE TRENDS

S. R. TROUT
Spontaneous Materials
12348 Melrose Circle, Fishers, IN 46038, USA
E-mail: strout@ieee.org

After a brief history of SmCo and NdFeB magnets in the United States, we will review the current situation, both technical and commercial, analyze strengths and weaknesses, and speculate on what the future may hold for these materials and the people who work with them in this country. We will consider optimistic and pessimistic scenarios and comment on what might influence the outcome.

## History

There were at least four important events in the history of samarium cobalt magnets, the precursor of NdFeB. Ironically, none of them directly involved samarium or neodymium. The first was the discovery published in 1935 by Urbaine, et al. [1] that gadolinium, a rare earth, was ferromagnetic. The second was the Manhattan Project during the Second World War. The methods needed to separate uranium for the atomic bomb were first developed using the less hazardous but chemically similar rare earths. This technology lead to the availability of significant volumes of separated rare earths for the first time. The third was the report in 1960 by Hubbard, et al. on the permanent magnet properties of $GdCo_5$. [2] They associated the large coercivity they observed to the large magnetocrystalline anisotropy. Due to the antiferromagnetic coupling of Gd with Co, the other magnetic properties were unremarkable. Hubbard, et al. failed to realize that $GdCo_5$ was a member of a family of $RCo_5$ materials, where R is a rare earth. It wasn't until 1966, when Hoffer and Strnat [3] reported on $YCo_5$, that researchers realized that this was a fertile area of research.

Finally Sm was recognized as the ideal rare earth to use in $RCo_5$ compounds. Some of the groups working on this material in the U.S. were General Electric, Bell Labs, Raytheon, General Motors, Wright Patterson Air Force Base, Fort Monmouth, the University of Dayton and the University of Pittsburgh.

In spite of the excellent magnetic properties, commercialization of $SmCo_5$ was generally slow. One exception was PtCo, once popular in watches and traveling wave tubes. This material was almost immediately rendered obsolete by $SmCo_5$, since $SmCo_5$ was less expensive with higher coercivity. For other applications, a whole new way of thinking was required. For many people, this was the first time they had any experience with a rare earth. Objections over cost and availability needed to be addressed. In nearly every case, a total redesign was required to fully take advantage of the properties of $SmCo_5$, something people were often reluctant to do. (This problem remains with us today.) Common properties were 20 MGOe for $(BH)_{max}$ and 20 kOe for $H_{ci}$.

The main applications were machine tools and computer peripherals, printers and early hard drives. Some of the major U.S. customers were Dataproducts, Digital Equipment and Inland Motors.

A modestly improved material was developed in the late 1970's called 2-17, based on the nominal composition $Sm_2(FeCoCuZr)_{17}$. This alloy is more complicated, both in terms of composition and processing, but it gave us common properties of 26 MGOe for $(BH)_{max}$ with a slightly reduced $H_{ci}$ of 15kOe. And while there was some work on this new material in the U.S. and Europe, the bulk of the research and commercialization activities took place in Japan, notably by TDK and Shin Etsu. By the late 1980's there was clearly less emphasis on research and development of permanent magnets in the U.S. and a subtle shift in applications as well. For example, the Sony Walkman was based on 2-17 magnets, both in the headphones and in the tape drive motor.

If there was a commercial weakness with samarium cobalt magnets, it was the cobalt. The Co content is roughly 66% in $SmCo_5$ and roughly 50% in the 2-17's. Although there were concerns voiced about samarium, they never really materialized. Several disruptions in cobalt supply occurred in the 1970's and 1980's, usually caused by political unrest in Zaire, the major source to the Western world. People wondered if SmCo was capable of being used in large volume applications, such as the automobile. As Jan Herbst from GM said in 1978, "We want a magnet like $SmCo_5$ that has neither samarium nor cobalt." [4]

The Conference on Magnetism and Magnetic Materials (MMM) was held in Pittsburgh, PA in November of 1983. For most of us, this meeting offered the first formal presentations and discussions of NdFeB magnets. We learned that many groups were working in roughly the same area, some by melt spinning and some via powder metallurgy. Regardless of the method, the results were truly extraordinary; the potential seemed incredible. [5-10]

In contrast to $SmCo_5$ and 2-17, commercialization of NdFeB took place at a very rapid pace. Within the next year, several producers were offering magnets with $(BH)_{max}$ of 35 MGOe and $H_{ci}$ of 20 kOe. There are several reasons behind the rush to market. First, the initial companies to commercialize NdFeB used powder metallurgy. With a process similar to what was already in use for SmCo, it was very easy to get started and to make a reasonable product. Second, the marketplace had become comfortable with rare earth magnets from their experiences with SmCo. Third, a very willing group of customers already existed. The disc drive industry was eager to use a stronger magnet that cost less than SmCo.

Over time we learned about corrosion and how NdFeB differs from SmCo in that regard and others. It was a typical process of maturation.

Also by the end of the 1980's General Motors formed Magnequench, solely to make magnets based on melt spinning, at first. Eventually the business plan was changed to allow for the sale of powder. The bonded NdFeB magnet business emerged thereafter.

The growth of the NdFeB market was not steady. It seemed to lunge forward rapidly, then pause, with the variability in the computer market. That still seems to be the case today; although other applications have developed, market growth remains uneven and still heavily dependent on the computer.

Early in the 1990's we saw the rise of Chinese influence in the area of rare earths. The primary driver was the deposit of rare earths in Inner Mongolia near Baotou, the largest in the world, and to a lesser extent the ionic clay ores found elsewhere in China. In 2001 China accounted for over 80% of the world's production of lanthanides. As figure 1 shows, rare earth mine production increased by 33 % between 1994 and 2001. In the same period, the U.S. share of the world market dropped from 32% to 6%, while the Chinese share increased from 47% to 82%.

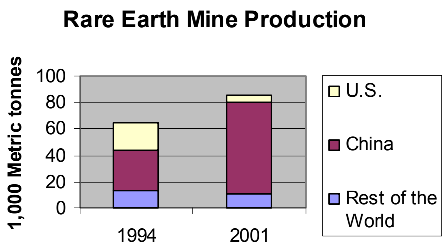


Figure 1. A comparison of rare earth mine production for the U.S., China and the rest of the world. [11]

The influx of supply from China over the last decade or so has caused the prices of all rare earths to drop. For example, neodymium metal that sold for $50/kg in 1990 now sells for less than $10/kg. Magnet prices have fallen over the same time period, but not to the same extent.

Later in the 1990's we have seen an increase in competition from China in the production of magnets. This has affected producers all over the world, not just in the U.S. The powerful combination of locally available rare earths, inexpensive labor and a desire to make value added products leads to a large percentage of rare earth magnets and products containing magnets being exported from China. Figure 2 shows the breakdown of imports into the U.S. of metal magnets over the last ten years. Metal magnets include all permanent magnets except ferrite and bonded magnets. Over the last decade, magnet imports into the U.S. increased by 16%, the Chinese share increased from 7.2% to 34%, and the Japanese share dropped from 44% to 32%.

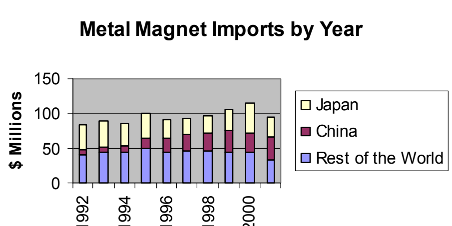


Figure 2. Metal magnet imports into the U.S. by year [12]

## Current status

Inexpensive magnets from China squeeze the profitability for all other producers, not just of rare earth magnets, but of all materials. In fact, the production of ceramic magnets appears headed for extinction in the U.S., again due mainly to lower cost labor in China. This phenomenon is not specific to permanent magnets, but seems to be more part of the general trend toward globalization of the economy, as shown in figure 3. The balance of trade between the U.S. and China has grown by a factor of 6.5 over the last decade.

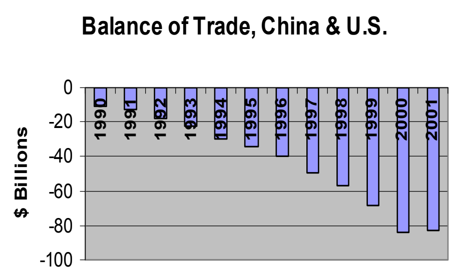


Figure 3. Balance of trade for all products between China and the U.S., 1990 to 2001 [13]

Under current conditions, the trend indicates most magnet production will leave the U.S., within the next decade, in favor of low labor cost regions, predominantly China. I think there is some hope for some of the smaller niche producers. While purchasing agents like to think that buying a magnet is a simple process, selecting the correct magnet for a given application is a fairly engineering-intensive process. The need for technical assistance will help keep the smaller producers afloat. Of course, once the requirements are well-established, finding a low cost magnet elsewhere is not very difficult.

One popular strategy is to form some sort of business relationship with a Chinese partner.

This gives the U.S. partner better access to low cost magnets from China and gives the Chinese partner better access to the U.S. market. Some of these arrangements are informal; others have well-defined legal structure, including financial investments. This approach makes sense as a way to stay in business for the short to medium term. However, in the long term, magnets will be made where labor is inexpensive, i.e. China.

One trend of interest is the recent decline of the U.S. dollar to most of the world's major currencies. The euro has gained roughly 10% against the dollar in the first half of 2002. The Japanese yen and South Korean won have gained about 8% in the same time period. Ordinarily, a weaker dollar is helpful for domestic manufacturers, making their products a bit less expensive to export while making foreign goods more expensive. A weak dollar has been promoted by one magnet company as a strategy to battle Chinese competition. [14] But since 1998, the Chinese yuan has been unofficially tied to the dollar, at a rate of 8.28 yuan to one dollar. Should the Chinese maintain this policy, it has the effect of making Chinese products less expensive in the above mentioned currencies and maintains the status quo with respect to the dollar. This is no help to U.S. manufacturers trying to sell against Chinese competition. [15]

**Future Trends**

Certain events could either slow down or stop the move of magnet production to China.

- Trade war, tariffs
- Military or defense requirements
- Economic or political collapse in China
- A new breakthrough material
- Production consolidation in the U.S.

A strong commercial reason like a trade war or increased tariffs could remove the incentive to buy from overseas, stopping or reducing trade by making it too expensive. While always a possibility, these are unlikely.

Trade could also be reduced or interrupted by military or defense concerns. Magnets are used in some important defense related equipment. The U.S. might take steps to stockpile magnets or require that magnets be made domestically. However, most military applications use SmCo, so it may not have much effect on NdFeB.

While I don't think that political or economic collapse of China is likely. It is a distinct possibility, based mainly on the growth rate of the economy and its size. There is certainly some chaos associated with business in China today and a small chance that something could trigger a collapse.

A development more specific to the magnet industry, would be the discovery of a new material that surpasses NdFeB. This would certainly change the landscape, although how it would change depends on many unknown factors, the magnetic properties, the cost, the ease or difficulty of manufacture, where the new material is invented, to name but a few.

The rationale for this scenario is that the theoretical $(BH)_{max}$ of NdFeB is about 64 MGOe and the theoretical $(BH)_{max}$ of Fe is 115 MGOe, assuming we could give Fe coercivity without losing much moment. It therefore is reasonable to speculate that there may be a material with better magnetic properties than NdFeB. [16] While this is a distinct possibility, I question if this material will be as dominating as NdFeB, if it is found. I think it is very likely to be more expensive or have some other weakness, preventing it from overtaking NdFeB entirely, the way NdFeB took over from SmCo.

Of course that all remains to be seen, but we have a target.

Consolidations are a painful subject, mainly because they are a threat to people's livelihoods. However, there have been several in the U.S. permanent magnet industry over the last few years. The hard ferrite segment of the market has been particularly hard hit. But the pressure to exit unprofitable business or consolidate is found in all segments of the business. If we wait to the bitter end, Adam Smith's "invisible hand" will force many companies out of business, or we may end up with just one or two magnet manufacturers in the U.S through consolidation. But will they be healthy?

I think there is good reason not to wait. Our business may end up healthier if we act over the next few years to voluntarily contract and consolidate our manufacturing base. This may be less disruptive, save the remaining technical talent and leave us with a good business that can survive long into the future. This is not an easy scenario to imagine. The permanent magnet industry in the U.S. is notoriously secretive and reluctant to change. But this may be the only way to remain healthy and really viable.

There are certainly reasons to be concerned about the future of the rare earth magnet business in the U.S. But perhaps it is useful to remember the saying about the weather in New England, "If you don't like the weather, just wait five minutes. It will be different."

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