THE RARE EARTH CRISIS – THE LACK OF AN INTELLECTUAL INFRASTRUCTURE

Karl A. Gschneidner, Jr., Ames Laboratory, Iowa State University, Ames, IA 50011-3020

Background

The rare earth crisis slowly evolved over a ten to fifteen year period beginning in the mid-1980s, when the Chinese began to export mixed rare earth concentrates. With time, they moved up the supply chain and began to export the individual rare earth oxides and metals in the early 1990s. By the late 1990s the Chinese exported higher value products, such as magnets, phosphors, polishing compounds, catalysts, and in the 21st Century they supplied finished products including electric motors, computers, batteries, liquid crystal displays, TVs and monitors, mobile phones, i-pods, compact fluorescent lamp (CFL) light bulbs, etc. As they moved to higher value products, the Chinese slowly drove the various US industrial producers and commercial enterprises in the USA, Europe, Japan, etc. out of business by manipulating the rare earth commodity prices. Because of this, the technically trained engineers and scientists working on rare earths containing products from mining, to separations, to processing, to primary rare earth chemical and metallurgical production, to manufacturing semi-finished and final products were laid-off and moved to other fields or retired.

Considering all of the above, today there is a serious lack of technically trained personnel with the appropriate expertise and experience to bring the entire rare earth industry from mining to original equipment manufacturers (OEM) up to full speed in the next few years. Accompanying this disappearance of technical expertise, innovation and new products utilizing rare earth elements has slowed dramatically, and it may take a decade or more to recapture America's leading role in technological advancements of rare earth containing products. Before the disruption of the US rare earth industry, about 25,000 persons were employed in *all* aspects of the industry from mining to OEM, degreed and non-degreed. Today, only about 1500 persons are employed. The ratio of non-technically trained persons to those with college degrees in the sciences or engineering varies from about 8 to 1 to about 4 to 1 depending on particular area of the industry. Assuming an average of 6 to 1 the number of college degree scientists and engineers decreased from about 4000 to 250 employed today.

The paucity of scientists and engineers with experience and/or training on the various aspects of production and commercialization of the rare earths is a serious limitation to the ability of the United States to satisfy its own needs for materials and technologies, (1) to maintain our military strength and posture, (2) or to assume leadership in critical energy technologies, or (3) to bring new consumer products to the marketplace. The lack of experts is of even greater national importance than the halting in the 1990s and the recent restart of the mining/benification/separation effort in the USA; and governmental intervention and support for at least five to ten years is required to ameliorate this situation. To respond quickly, training programs should be established in conjunction (a) with research center(s) at (an) educational institution(s) with a long tradition in multiple areas of rare earth and other critical element research and technology, as well as close affiliations with other universities, governmental laboratories, and non-profit research organizations having complementary strengths. In addition, single investigators or small teams of rare earthers at other universities should be supported by the standard grants from NSF, DOD, and DOE. These investigators may or may not be affiliated with the Center.

The National Research Center would not only be responsible for training undergraduate, graduate, post-doctoral students, but would also provide short courses for industry personnel and other interested persons, hold an annual meeting highlighting rare earth research being carried out at the Center and affiliated organizations, and provide information about rare earth activities and developments – research, industry, commerce – via a newsletter and other means. The Center would also coordinate its activities with REITA, the Rare Earth Industry and Technology Association.

Initially a total of about 170 trained persons having Ph.D., Masters and B.S. degrees are required per year for the first four years to quickly catch up to fill in the present void of technically trained and skilled personnel over the whole spectrum of rare earth commerce from the mine(s) to OEMs. After this, about 50 students per year with a solid background in the fundamentals of chemistry, materials science, and various engineering disciplines, and *some* knowledge in the rare earth science and technology are needed to maintain the normal growth of the field. The number of graduating students required at the beginning of the value added chain (i.e. geology, mining, benefication) to satisfy the industry requirements is small because currently there is only one operating mine in the USA, but several more will become operational in the USA and Canada in about five years. As one moves up the chain, significantly more students are needed. In the separation and the processing fields (the latter includes metal preparation, magnet scrap recovery, recycling and ceramics) about two to three times more students will be in demand. In the next higher step up the ladder of the value chain another increase of about twice as many highly educated persons are needed. These include physical, inorganic, and organic chemists; chemical and metallurgical engineers; physical metallurgists; condensed matter physicists; and electrical, mechanical and industrial engineers. These persons would be involved with magnetic and electronic materials, phosphors, lighting, optical displays, catalysis, batteries, oxidation and corrosion, and recycling. As the rare earth related industries expand in the United States significant job creation in supporting areas such as logistics, manufacturing technology, and business administration is to be expected. In addition, blue collar jobs, such as production workers, tradesmen, technicians, support and administrative staff, will result from this expansion of the rare earth intellectual infrastructure.

Personnel Needs from the Mine to OEM

The number of students required per year is given in parenthesis.

1. Exploration and evaluation of ore sources: basnesite, monazite (1-2)
2. Mining and benification of an ore body: mixed rare earth concentrate (2-4)
3. Separation processing: individual rare earth oxides or carbonates, halides (4-6)
4. Production of metals and starting chemical compounds for magnets, batteries, catalysts, phosphors, pigments, electronic materials, glasses and ceramics, polishing compounds, metal alloys (10-15)

5. Manufacturing of semi-finished products for OEMs: neodymium metal for magnets; lanthanum for nickel metal hydride batteries; vanadates for phosphors; garnets for lasers; etc. (15-25)
6. Original equipment manufacturer (OEM): magnets for electric motors, computers, wind turbines, i-pods; batteries for hybrid and electrical automobiles; color TVs and monitors; 3-way catalytic converters; laser containing devices, etc. (25-50)

The number of B.S., M.S. and Ph.D. scientists and engineers to be trained per year for the above six categories increases as one moves down the list from category 1 to category 6. A total of about 60 to about 100 students need to be graduated each year to maintain the scientific and engineering person-power requirements of the entire rare earth industry from mining to OEM. These numbers include most engineering disciplines (primarily mining, chemical, materials, electrical, mechanical) and the hard sciences – chemistry, materials science, and physics.

Scholarships

One of the problems in the USA at the present time is that the number of US trained science and engineering undergraduate students going on for advanced degrees (M.S. and Ph.D.) is quite small, and there is an insufficient number to fill all of the available teaching and research positions at universities. This lack of students is filled by hiring well trained foreign undergraduate students from third world countries such as China, India, etc. In order to encourage US students to become involved, a Rare-earth Graduate Scholarship (RGS) Program should also be initiated. It would provide $10,000 per year *over and above the normal stipend* a student receives from a university for two years for a M.S. student or, for four years for a Ph.D. student, assuming the student is making reasonable progress toward his/her degree. When a student completes his/her studies and graduates with the M.S. or Ph.D. they would receive an additional bonus of $5,000 for the M.S. and $10,000 for the Ph.D. ($5,000 if he or she obtained a M.S. degree first and received the $5,000 M.S. degree bonus). There should be 20 such scholarships per year. The cost would be 200 K$ for the first year, 400 K$ and 600 K$ for the second and third years, respectively, and 1,000 K$ for the fourth (because of the bonuses) and succeeding years. The scholarships would be limited to students who are US citizens or a foreign student holding a green card. The scholarships will be administered by the National Research Center, but would be available to any bona fide student carrying out research on a topic involving rare earths at a US university, i.e. the RGSs would not be limited to students affiliated with the Center.

Alternate Route to Replace the Intellectual Infrastructure

If the USA does not undertake the task of educating US students in rare earth science, engineering and technology, then industry could turn to China, since they train hundreds of students with an emphases on rare earths, and recruit the Chinese scientists and engineers to work in the US. If we would hire too many Chinese, China might also put an embargo on exporting scientists and engineers. **However, we believe this is an unacceptable solution and the USA has no choice but to educate our own students.**