Reconfiguration of the National Defense Stockpile Report to Congress

April 2009

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Executive Summary

This report is prepared in response to congressional requests in the House report to accompany H.R. 1815, the National Defense Authorization Act for Fiscal Year 2006, H.R. Rep. No. 109-89, page 476, the House report to accompany H.R. 5122, the National Defense Authorization Act for Fiscal Year 2007, H.R. Rep. No. 109-452, page 444, and the Senate Report to accompany the Department of Defense Appropriations Bill, 2008, S. Rep. No. 110-155, page 189, concerning the National Defense Stockpile (NDS).

This report addresses these requests.

Conclusions

Material management is a complex and rapidly changing field. Increasing global competition for raw materials has added a new depth of complexity, and continued reliance on the strength of U.S. buying power is proving problematic. Ensuring the current and future availability of strategic and critical materials requires a more integrated and responsive approach on the national level.

The NDS has been successful in acquiring and holding strategic material, but has had isolated success in using the material strategically. Transforming the NDS into a Strategic Materials Security Program (SMSP) would enable the Nation to more quickly adapt to current world market conditions and ensure the future availability of materials required for defense and national security needs. The proposed attributes being considered for the SMSP include a broader internal DoD profile albeit a reduced physical footprint, an expanded interface with other federal agencies, greater latitude in entering and exiting markets, and flexibility to develop risk-based value propositions.

The first step is for the reengineered program to be more properly aligned to sense and respond to today's military material needs in scenarios ranging from non conflict to full mobilization. The current NDS is designed to respond to global war scenarios – those requiring national mobilization of all sectors of the economy – whereas today's military must respond to asymmetric national security threats wherever and whenever they occur; frequently on several simultaneous fronts.

Further, the global growth in demand for scarce raw materials and the industrial surges in China, India, Russia, Brazil, and other developing countries require that the U.S. employ a new, integrated and responsive strategy for identifying and ensuring, on a continual basis, an adequate supply of strategic and critical materials required for U.S. security needs. In today's global economy, it is critical to ensure a strong domestic defense industrial base capable of meeting national security needs. Accordingly, the NDS, through the efforts of an Office of the Secretary of Defense-led Working Group, the DoD Strategic and Critical Materials Working Group (WG or Working Group), has developed a plan for a comprehensive Strategic Materials Security Management System (SMSMS) that would identify, on an ongoing basis, those strategic and critical materials required for national security. The system would be founded on an interagency, collaborative approach, and bolstered by the use of experts and timely market research and intelligence. The system would also employ an integrated risk assessment construct, compare demand to supply by analyzing supply sources and risks of supply chain interruption, and identify mitigation strategies to ensure an adequate and timely supply of those materials. This system would be a joint effort by the Office of the Secretary of Defense, the Military Services (MILSVCS), the Defense Contract Management Agency (DCMA), and the Defense Logistics Agency (DLA), with representation and analysis provided by other government agencies such as the Department of Commerce (DOC) and the United States Geological Survey (USGS). The system could also involve other relevant organizations such as Defense research agencies, Federally-Funded Research and Development Centers or industrial associations and private consultants. The reshaped NDS, the SMSP, would continuously monitor global markets, establish supply chain commitments with producers/suppliers; monitor performance to ensure timely availability of materials, and store only limited amounts and types of materials.

The current policy to dispose of materials in the NDS could be modified to reflect the realities of today's global marketplace. Analysis by the Working Group and risk assessment modeling supported the NDS' action to temporarily suspend or limit the sale of 13 selected commodities in the NDS inventory. The analysis also indicated that 39 other materials[1] should be monitored, studied and/or considered candidates for future mitigation strategies to ensure availability. Further, the Working Group concluded that 11 materials used in the largest quantities by DoD be addressed as potential candidates for strategic sourcing. The DoD defines strategic sourcing as "…the collaborative and structured process of analyzing [what] an organization spends and using the information to make business decisions about acquiring commodities and services more effectively and efficiently…" Sales should continue for those materials still deemed in excess to the Nation's defense needs.

If implemented the reconfigured stockpile program would require a stable funding source to make strategic acquisitions, undertake other risk mitigation strategies and operate the stockpile program.

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[1] 40 materials were evaluated but quartz was not included as a material for study as it is a goal material (see Appendix C Table 1, p.C-2):

Potential Changes

Among the initiatives under consideration are the following:

1. Reconfigure the NDS into the SMSP to lead the DoD effort for an integrated, interagency approach to strategic materials management.

2. Grant the SMSP the programmatic flexibility to efficiently and effectively acquire the right materials and to ensure that essential strategic materials are available to respond to current and future needs and threats. This includes the ability to:

- More fully project material needs;
- Leverage the buying power of the DoD and other cooperating federal agencies by aggregating materials requirements and negotiating long-term strategic procurement arrangements;
- Gather, develop, analyze, and disseminate timely information on material demand and supply availability – provide material "Alerts" as necessary;
- Respond to emergent material needs;
- Establish and utilize mitigation tools to ensure the timely availability of materials; and
- Enable planners to take advantage of world market conditions.

3. Modify the current policy to dispose of materials in the NDS to reflect the realities of today's global marketplace. The Nation's new disposal policy should permit the application of a wide variety of risk mitigation strategies to ensure current and future material availability, as well as the sale of materials when determined to be excess to the Nation's needs.

4. Enhance the acquisition authority to employ risk mitigation strategies to avoid potential shortfalls, including constant surveillance of global markets and employing multiple strategies to ensure supplies, including strategic sourcing, partnering with friendly nations and stockpiling when appropriate.

5. Consider the need to augment the Transaction Fund with an annual appropriation. Given today's market conditions, revenue from the sale of the remaining inventory may not be sufficient to cover the costs of operation of the program, and cover environmental liabilities. Accordingly, appropriated funds, and/or some other stable funding source will be required in the next few years.

1.0 Introduction

This report is prepared in response to congressional requests concerning identification and availability of strategic and critical materials important to national defense interests. It provides the background on the establishment of the National Defense Stockpile (NDS) program, the questions posed by Congress regarding the need to reconfigure the NDS, the analysis completed by the Working Group and the conclusions developed as a result of that analysis.

1.1 Background

The NDS program was established under the Strategic and Critical Materials Stock Piling Act of 1939 to maintain and manage strategic and critical materials for use during times of national emergency. Since its inception, stockpiled materials have included ores, base metals, precious metals, minerals and agricultural products. Following the end of the Cold War, the Department of Defense (DoD) determined that virtually the entire Stockpile inventory was excess to DoD needs. Since 1993 Congress has authorized disposal of over 99 percent of the material, earmarking the revenues for various defense programs, primarily military health and retirement benefits.

Responsibility for NDS policy is vested in the Under Secretary of Defense for Acquisition, Technology and Logistics (AT&L) as the NDS Manager. Operation of the NDS program has been delegated to the Defense National Stockpile Center (DNSC), a field activity of the Defense Logistics Agency (DLA).

1.2 Congressional Requests

This report is prepared in response to congressional requests in the House report to accompany H.R. 1815, The National Defense Authorization Act for Fiscal Year 2006, H.R. Rep. No. 109-89, page 476, the House report to accompany H.R. 5122, the National Defense Authorization Act for Fiscal Year 2007, H.R. Rep. No. 109-452, page 444, and the Senate Report to accompany the Department of Defense Appropriations Bill, 2008, S. Rep. No. 110-155, page 189, concerning the National Defense Stockpile (NDS).

Because of the integrated nature of these requests, the reports have been consolidated into a single report.

1.3 Preliminary Report

A preliminary report, submitted to Congress in August 2006, in response to HASC Report 109-89 identified shortfalls in key information needed for in-depth analysis and recommended further independent review. Specifically, the report found a lack of information detailing which materials were forecasted to be required for future weapons systems, domestic production capacity, and alternatives for addressing shortfalls. The report also recommended that the DoD defer preparation of the 2007 Report to Congress on National Defense Stockpile Requirements pending completion of the recommended study.

1.4 NRC Report

DNSC contracted with the National Research Council (NRC) to perform a study to assess the national need for and value of the NDS. The NRC report, Managing Materials for a 21st Century Military[2], presented in October 2007, recommended a new approach to "[identifying the materials needs of the military, understanding the risk of disruptions in the supply chains for those materials, and planning actions to mitigate the impact of surges in requirements and unexpected shortfalls in inputs … ." (p. S-3). The NRC recommendations were designed to make the NDS program a more effective and agile system of management for strategic and critical materials. The report also emphasized an urgent need to improve collection of information, "the geographic locations of secure supplies of critical materials and alternate supplies; the potential for market and geopolitical disruptions as well as logistical and transportation upsets and risks posed by them;" and the use of materials in both defense and non-defense sectors in the U.S. and abroad (p. S-4)

1.5 DoD Working Group on Strategic Materials Availability

Following receipt of the NRC report, AT&L established the DoD Strategic and Critical Materials Working Group to review the NRC findings and address the issues raised by the congressional reports. The Working Group was chaired by the Deputy Undersecretary of Defense for Industrial Policy and included representatives from the office of the Deputy Undersecretary of Defense for Industrial Policy (ODUSD(IP)), the office of the Deputy Undersecretary of Defense for Logistics and Material Readiness (ODUSD(L&MR)), the Defense Logistics Agency (DLA)/ DNSC, the Departments of the Army, Air Force, and the Navy, the Joint Chiefs of Staff J-8 Directorate of Joint Capabilities Integration & Development System (JCIDS), and the Defense Contract Management Agency (DCMA). The Working Group also included representatives from the U.S. Geological Survey (USGS) and the Department of Commerce (DOC), all of which

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[2] Managing Materials for a 21st Century Military; Committee on Assessing the Need for a Defense Stockpile, National Materials Advisory Board, Division of Engineering and Physical Sciences, National Research Council of the National Academies; The National Academies Press, Washington, D.C., 2007. This publication can be obtained from the National Academies Press, 500 Fifth Street NW, Washington, DC 20055.

performed research and analysis on behalf of the group. Their recommendations are incorporated into the discussion below.

As discussed more fully below, the initial response to the congressional request included in SAC Report 110-155 included a decision to suspend or curtail continued sales of selected commodities until this report could be completed and a more detailed analysis of the importance of these commodities for defense needs could be completed. The notification to Congress of this suspension and curtailment of sales was provided as an initial response to the request.

2.0 Analysis

This section provides the specific analysis and Working Group responses to the congressional requests.

2.1 Review the DoD's current policy to dispose of stockpile material

Conclusion: The current policy requires revision.

Rationale: DNSC, the administrator of the NDS, reviewed the remaining inventory to identify those materials for which the U.S. is largely import dependent, for which no viable economic substitute exists, or for which there is concern over the source (for geopolitical reasons) or the supply (for market reasons). That study resulted in the identification of 13 materials as meeting the above criteria. Deliberations by the Working Group supported DNSC's recommendation to temporarily suspend or limit the sale of these 13 commodities and to hold the remaining inventory pending further study. DNSC has earmarked these materials for use by defense contractors on behalf of the Military Services (MILSVCS). As a result, DoD advised Congress that DNSC recommended suspending sales for six commodities for which very little inventory remained in the stockpile and limiting sales of seven other stockpile commodities to defense needs. The revision to DNSC's sales plans was announced August 7, 2008. The commodities for which sales were suspended or restricted are included in Appendix A.

The analysis also indicated that 39 other materials[3] should be monitored, studied and/or considered candidates for future mitigation strategies to ensure availability. As estimated in the report, DoD has a very significant enduring demand for materials to produce weapon systems and ammunition – with DoD's usage of standard materials being approximately three quarters of a million short tons per annum. The Working Group concluded that the 11 materials used in the

[3] 40 materials were evaluated but quartz was not included as a material for study as it is a goal material (see Appendix C Table 1, p.C-2)

largest quantities by DoD be addressed as potential candidates for strategic sourcing. Sales should continue for those materials still considered to be in excess to the Nation's defense needs.

2.2 Determine whether the NDS should be reconfigured to adapt to current world market conditions to ensure future availability of materials required for defense needs

Conclusion: Reconfiguration is necessary to respond fully to evolving conditions in the world market and to rapidly changing requirements for both traditional and new materials. Reconfiguration will address not only NDS materials, but also its interaction with the Nation's key defense material users.

Rationale: Under the current statutory framework, the NDS' response mechanism is limited to stockpiling, and only those potential material shortfalls identified through the study and analysis of military conflict scenarios can be stockpiled. The current statute contemplates the mobilization, conflict and replenishment periods experienced in World War II. Absent is the ability to respond to the daily requirements of today's military, regularly deploying within a wide range of scenarios.

Today's military operates in a "come as you are" environment, conducting expeditionary operations against a variety of global threats where they need to be ready to deploy anywhere in the world with very little notice. Military planning is based on a capability-based process and the analysis used to identify supply chain risks needs to be similarly transformed. Stockpiling alone is not the answer. Today's analyses need to focus on risk mitigation strategies required in today's global economic environment to ensure adequate sources of supply. It is imperative that the requirements process include meaningful visibility into future defense needs.

The process must focus on domestic and foreign industrial consumption and production capacity, technological advances, geopolitical issues, and supply chain vulnerabilities, each of which could potentially disrupt material availability.

The global marketplace provides DoD sources of materials and price competition. This presents both an opportunity for and a real threat to assuring an adequate supply of materials critical to national defense and the industrial base. Along with increased global demand for scarce mineral commodities and materials there is a diminished domestic supply and processing capability. Together, that results in increased dependence on foreign sources of supply and greater risk of supply disruptions and/or constricted supplies.

DoD needs a new paradigm in the philosophy for managing the supply of strategic and critical materials to include more direct involvement in the acquisition of raw materials to ensuring adequate supply availability. The NDS should be reconfigured to be the SMSP to allow it to employ the full panoply of supply chain management techniques, including strategic sourcing, partnering with foreign governments, and traditional stockpiling where appropriate. Critical to the success of this effort will be the flexibility to take advantage of favorable market conditions as well as respond to the emergent needs of the MILSVCS.

Key to this system is the input and cooperation of the MILSVCS and research laboratories to ensure that emerging materials are properly identified and studied. Once those materials have been identified, it is critical that the requirements analysis identify the vulnerabilities in the supply chain and take steps to mitigate or eliminate those risks.

One option under consideration is a proposal to revise the Requirements Report process to coincide with the Quadrennial Defense Review (QDR). That would ensure that the planning input takes into account the current defense planning guidance. It would also provide additional time for a more in-depth review process. A second, corollary option could be to grant DoD the ability to implement recommended material changes for acquisition or disposal without need for specific authorizing legislation for each commodity. Under the current process, legislative requests must be submitted following completion of the requirements report, a process tied to the annual DoD legislative authorization process, and consuming at least one year, if not longer. Following receipt of legislative authority, DoD must develop an implementation package, coordinate with the interagency Market Impact Committee (MIC), consult with affected industry and submit the planned Annual Materials Plan (AMP) to Congress in February, with execution delayed until the next fiscal year. In all, the process requires approximately three to four years before DoD can implement the recommendations contained in the Requirements Report. Clearly, that precludes a swift response to emerging needs or the ability to take advantage of changed global circumstances resulting from natural disasters, geopolitical activities, or economic or market conditions.

As part of the enhanced programmatic flexibility, DoD also is evaluating a non-expiring AMP – multiyear execution authority with annual updates and coordination with the interagency MIC. The AMP would continue to be coordinated with the MIC and submitted to Congress on an annual basis; however, it would not expire at the end of the year as it does currently. Changes would be reported via the Annual Operations Report and subsequent AMPs, but carry over would be permitted. Similarly, DoD is considering proposing an enhanced ability to modify the AMP to take advantage of emerging requirements or changing market conditions by eliminating the 45-day waiting period before implementing changes to the current AMP.

Another element in this reconfiguration process could include the expansion of “release” authority. Currently, the only conditions under which material can be released are: (1) a non-delegable release by the President; (2) declaration of national emergency; (3) legislative authority following determination of the material as excess to DoD needs; or (4) special statutory authority where the material has not been determined to be excess. This virtually precludes the use of stockpile material to support ongoing military defense contractor needs or the ability to develop procedures for replenishment.

Working closely with the MILSVCS, OSD, and Interagency Groups and continuously monitoring global developments and volatile commodity markets, the SMSP will be postured to respond quickly to the changing environment. Material projections will be provided through a more robust material identification process; supply chain risk and shortfalls will be determined through a comprehensive analysis process; and a variety of mitigation strategies, beyond traditional stockpiling, will be employed to reduce availability risks.

The SMSP will aggregate materials requirements to move discreetly in and out of markets without causing undue market disruption while ensuring adequate supplies. Based on market intelligence, the strategy employed could include securing materials via strategic sourcing, establishing partnerships with friendly nations, or stockpiling when appropriate. Additional potential benefits to the Nation could be obtained through the release of materials to DoD contractors as Government Furnished Material (GFM) resulting in:

- Shielding programs from surging market prices;
- Reducing production delays and/or production lead-times;
- Minimizing the impact of geopolitical issues that could disrupt the supply of materials; and/or
- Economic benefits derived from bulk purchases.

The SMSP will maintain close relationships with material users throughout the process, readjusting and assisting as necessary to further reduce risks.

Establishing partnership agreements with friendly nations will enhance the Nation's ability to ensure current and future availability of key materials; and the procuring and stockpiling of selected materials deemed truly critical to the Nation's security will provide the necessary insurance policy for the Nation's needs.

A critical component of the entire reconfiguration plan is ensuring a stable source of funding to operate the program.

2.3 Describe the materials critical to the strategic defense interests of the U.S.

Conclusion: As a general statement, materials important to the strategic defense interests of the U.S. are those needed to supply national security interests, and are either lacking in U.S. production or for which there is concern about timely supply availability. Many of the materials required for defense systems rely heavily on foreign sources for the raw material, the processing, or both. Some foreign sources may be subject to political instability, natural disaster, military conflicts, terrorist attacks or even market manipulation or decreased supply. These conditions, at any given time, could potentially place the Nation's material supply chains at significant risk, resulting in the level of risk to individual materials vacillating accordingly.

Rationale: Recognizing the challenges of a continually evolving global marketplace and its potential impact on material availability, the Working Group developed a comprehensive but agile system to identify, on an ongoing basis, those strategic and critical materials required for national security and to regularly monitor the marketplace for reliable availability. This dynamic system is founded on an interagency, collaborative approach, and bolstered by the use of experts and timely market research and intelligence. The system employs an integrated risk assessment construct, compares demand to supply by analyzing supply sources and risks of supply chain interruption, and identifies mitigation strategies to ensure adequate, timely supply of those materials. As needs change, the list of materials critical to the strategic defense interests of the U.S. will change accordingly. Markets will also change as they are affected by such factors as raw material or fabricated product supply, price, quality, and consistency.

The Working Group examined a broad range of materials. The intent was to ensure the study of a robust list – and particularly one that included technologically advanced materials needed by today's national security environment. The Working Group commissioned a series of risk analyses on selected materials to assist in identifying those materials requiring actions or further study. The results of the study are contained in the Institute for Defense Analyses (IDA) Report Executive Summary, Appendix B. Risk assessment tables developed by IDA are contained in Appendix C.

The Working Group assembled an Integrated Materials List (IML) (see Appendix C, Table 3, p. C-5) from various data points (including querying the MILSVCS). The risk analyses IDA conducted of selected materials from that list (Appendix C, Table 1, p. C-2) focus on whether shortages or near-shortages would arise in meeting defense-essential demands for these materials in either of two planning cases: (1) an approved National Security Emergency (NSE) scenario (details are available but are classified as Secret No Foreign (SECRET NOFORN)); or (2) a benchmark peacetime supply disruption scenario (PSD1) that is broadly consistent with OSD-approved Defense Planning Scenarios for "steady-state" contingencies.

When evaluating the selected materials (Appendix C, Table 1, p. C-2) under the 2 planning scenarios described above, IDA determined that 4 materials exhibit shortages under the NSE case (beryllium metal, tungsten, antimony, and quartz) and 30 materials manifest shortages in the PSD1 case.

The issue of the relative dependence on foreign sources of supply is a key risk factor for the majority of the materials analyzed in this report. For illustrative purposes, Appendix D contains a chart from the Mineral Commodity Summaries 2008 produced by USGS. The chart shows the relative import dependence for major minerals and processed materials and considers both primary and secondary (i.e., recovered material) sources of supply. The chart identifies 19 materials/commodities for which the U.S. is 100 percent import dependent. The degree of import reliance increases significantly when secondary sources of supply are omitted, as the grade of material from these sources is not adequate for Defense applications. However, tungsten, antimony, bismuth and nickel (all materials essential to defense systems) move to the 100 percent import reliance category when secondary supply sources are excluded. Additionally, aluminum for defense applications is essentially 100 percent import reliant for its source of raw material (bauxite). Nearly 100 percent of all new aluminum produced in the U.S. is made from alumina which is 90 percent dependent upon bauxite as its raw material source – the U.S. is 100 percent import dependent for its supply of bauxite. Other materials, not studied by USGS, but equally important to defense applications, are also import reliant, for instance gadolinium and natural rubber. However, relative dependence on foreign sources should not be sufficient to recommend stockpiling, especially when the commodities are available for purchase from nations traditionally friendly to the United States, such as Canada, Australia, Mexico, and other long-standing U.S. allies.

Additional recommendations based on the IDA analysis include:

- Holding existing NDS inventory for materials that show anticipated shortages or near-shortages under either the NSE or PSD1 cases while DoD studies these materials again with the most current data available;
- Determining whether to acquire materials or to undertake some other risk mitigation option for materials with no NDS inventory that show anticipated shortages; and
- Monitoring the supply situation for materials that do not presently exhibit anticipated shortages, but not reassessing the material in detail unless its supply seems to be tightening.

Beyond these explicit risk assessments, IDA noted that one or more MILSVC or DoD component respondents to an OSD survey identified 22 (See Appendix C, Table 1, p.C-2) materials from the list of strategic materials as having already caused some kind of significant weapon system production delay for DoD. The same survey respondents identified 19 other materials as having some kind of supply problem. (See Appendix C, Table 2, p. C-4.)

These materials need to be studied to ascertain the severity of the problem. However, it must be noted that materials studies cannot be accomplished without obtaining updated data on the material requirements. Analysis of the supply chain risks associated with these materials requires continued assistance from both the DOC and the USGS, both of which have only limited resources to support the DoD requirements. Even with expanded Memoranda of Understanding with these agencies, and assuming the availability of resources to support the effort, it would still take 9-12 months from the time that a study is initiated before it could be completed.

While the IDA assessment identified many materials that pose some level of risk for DoD and the Nation, refinement can be achieved through the application of a variety of mitigation strategies beyond stockpiling. The SMSP will diligently conduct surveillance of the marketplace to ascertain which mitigation strategy to employ – selecting the most cost-effective alternative among the following: partnering with friendly nations, application of a strategic sourcing option, or stockpiling.

2.4 Describe the domestic suppliers of those materials and their reliance on foreign sources of production

Conclusion: Due to the breadth of this question, it is not possible to discuss the availability of all the materials involved. Each commodity is unique with its own set of concerns and market conditions relating to availability and reliability of foreign sources and domestic production capabilities. Accordingly, DNSC enlisted the assistance of the USGS and the DOC in identifying representative examples. The USGS provided a study on rhenium and manganese and the DOC provided a detailed discussion on tungsten and the impact that producing nations' policies, especially trade policies, have on the global (and by default, U.S.) markets and access to materials. Rhenium has critical aerospace applications and manganese is critical to steelmaking. China controls over 85 percent of the world's reserves of tungsten and is seeking additional supply, thereby making availability of this material almost totally dependent on Chinese export policies. The pervasive conclusion is that the U.S. is highly import dependent and must take steps to minimize the risks of supply chain disruptions to ensure adequate supply availability.

Rationale: Many of the materials required for defense systems rely heavily on foreign sources for the raw material, the processing, or both. The list of strategic and critical materials for which stockpile sales have been suspended or slowed (Appendix A) provides a starting point for a discussion of those materials either lacking in U.S. production or for which there is concern about timely supply availability.

The DOC prepared a detailed analysis of tungsten, for which the U.S. is virtually 100 percent import dependent and for which there is a limited diversity of sources of supply globally. As China is the dominant producer of tungsten, the report outlined the production quotas, export quotas, export licenses, export duties, and other policy mechanisms implemented by the Government of China that constrain global supply and impact prices and availability of tungsten. DOC also provided a list of other materials with market characteristics similar to tungsten. The report revealed an emerging global competition for access to raw materials and concerns regarding the long-term implications for the competitiveness of U.S. manufacturers.

The USGS studies on manganese and rhenium reiterate this concern. The U.S. is 100 percent import dependent for its supply of manganese and significantly dependent on imports of rhenium. Manganese was selected for study due to its close ties to steel production. Rhenium is a byproduct of molybdenum or copper/molybdenum processing. In other words, there must be sufficient copper or molybdenum processing capacity – and rhenium compounds must be captured – in order to have rhenium production. While there is some domestic production of each of these materials, continued and uninterrupted access to the raw materials is essential to produce the downstream products that result from these materials.

The complete reports from the DOC and the USGS are contained in Appendices E, F and G.

2.5 Describe efforts by foreign countries to stockpile critical materials

Conclusion: Unlike the U.S., other countries are not as open with information about the quantity and value of material that they stockpile for strategic defense and economic purposes. Most countries realize that for metals and minerals for which they are import dependent, some type of stockpiling is necessary to maintain a secure supply of these materials. However, they are reluctant to disclose specific information about their plans or capabilities. While Japan, the Republic of Korea (ROK) and China maintain stockpiles for economic and strategic purposes, only the U.S. provides information about the quantities and values of materials in its stockpile.

Rationale: European countries sold off their stockpiles during the 1990s. Recently, however, the European Union has begun to examine its supply vulnerability and has proposed several solutions in conjunction with sustainable development goals (European Technology Platform on Sustainable Mineral Resources, 2007).

Japan and the ROK have the most publicly available information about the materials that are contained in stockpiles, and of these, Japan's information is the most complete. Both Japan's and the ROK's stockpiles function as buffer stocks in support of their industries, rather than for strategic purposes. Japan has stockpiled what it calls "rare metals" since 1983. These metals are chromium, cobalt, manganese, molybdenum, nickel, tungsten, and vanadium. The stockpile, which consists of public and private components, is configured to have a supply of these materials that is equivalent to 60 days of normal consumption. The ROK's Public Procurement Service started stockpiling base metals such as nickel, copper, lead, and zinc in 1967. The ROK appears to use Japan's stockpile model as the model for its stockpile. Recently, the ROK's Ministry of Commerce, Industry and Energy announced plans to expand the list of stockpiled materials to include the following: antimony, chromium, cobalt, ferrochromium, ferromanganese, ferrovanadium, indium, manganese, molybdenum, nickel, niobium, selenium, thallium, titanium, tungsten, and vanadium. The goal will be to have two months of average consumption in reserve. The ROK is budgeting $8.5 billion for material acquisition over the next eight years.

China also maintains a strategic reserve. The State Bureau of Material Reserve, more commonly referred to as the State Reserve Bureau (SRB), operates as part of the National Development and Reform Commission (NDRC), a macroeconomic management agency. According to the NDRC, "The State Bureau of Material Reserve is responsible for managing national strategic material reserve, implementing plans for strategic material reserve, and managing funds, assets, personnel, stockholding facilities and infrastructure construction within the national material reserve system in accordance with authorization by the state regulations and central government agencies" (National Development and Reform Commission, undated). The SRB has generally operated in secret with no information released on the quantity or quality of materials stockpiled.

In 2007, because of its rapidly growing economy and resulting evaluation of its needs for materials, China identified five commodities (cadmium, cobalt, copper, manganese, and petroleum) as strategic reserve minerals for the country. China planned to stockpile about 20 million metric tons of petroleum, 500,000 metric tons each of cadmium and manganese, 200,000 metric tons of copper, and 300 metric tons of cobalt, which represented about 90 to 180 days of net imports of these commodities. The estimated cost to build the stockpile was about $2.7 billion (China Economic News, 2007).

2.6 Describe the steps that are being taken to ensure that strategic and critical materials not produced domestically will be available to support the defense needs of the United States during a protracted conflict

Conclusion: The NDS should be reconfigured to operate as the Nation's Strategic Material Security Program (SMSP) to identify: (1) U.S. strategic and critical materials and requirements, (2) the ability of the U.S. to access those materials not produced domestically from the global market during a protracted conflict, and (3) if required, the appropriate risk mitigating strategy to ensure an adequate supply.

Rationale: When DoD faces shortcomings in the industrial base, it has the necessary authorities, responsibilities, and resources to address these shortcomings and promote innovation and competition if the required strategic or critical materials are available. Specifically, DoD can:

- Directly fund innovation in its science and technology accounts, and encourage industry to do the same via their independent research and development accounts;
- Induce innovation by employing acquisition strategies that encourage competition at all levels of contract performance;
- Use contract provisions to preclude the ability of contractors to favor in-house capabilities or long-term teammate products over more innovative solutions available elsewhere; and/or
- Block exclusive contractor teaming arrangements that effectively reduce the number of suppliers in a given market, especially if the teammates are dominant in a particular market sector.

DoD also can, and does, formally establish restrictions within the Defense Federal Acquisition Regulation Supplement on the use of foreign products for certain defense applications, when necessary, to ensure the survival of domestic suppliers required to sustain military readiness.

DoD has the framework and guidelines in place (via DoD 5000.60-H) for evaluating, on a case-by-case basis, the need for Government action to preserve industrial capabilities vital to national security. Before taking action, DoD must verify the war fighting utility of the industrial capability, that the industrial capability is unique and at risk, that there are no acceptable alternatives, and that the proposed action is the most cost-effective and mission-effective. These criteria deliberately set a high standard for intervention into the industrial base in order to ensure that limited DoD resources are not unnecessarily expended.

DoD's preferred approach to establishing and sustaining the defense technology and industrial base is to leverage its research, development, and acquisition processes and decisions to create a competitive environment that encourages industry to invest in technology development and make sound technology insertion and production capacity/facilitation decisions. When market forces are insufficient, however, DoD can use powerful Defense Production Act tools to focus industry attention on critical technology development, accelerate technology insertion into manufacturing processes, create, or expand critical production facilities, and direct production capacity towards meeting the most urgent war fighter needs. These tools include Title I, Title III, and the DoD Manufacturing Technology (ManTech) program.

Title I of the Defense Production Act (50 U.S.C. App. 2061 *et seq.*) provides the President the authority to require preferential performance on contracts and orders, as necessary, to meet national defense and emergency preparedness program requirements. Executive Order 12919 delegates these authorities to various federal departments and agencies. The Secretary of Commerce has been delegated the authority to manage industrial resources. To implement its authority, the Department of Commerce (DOC) administers the Defense Priorities and Allocations System (DPAS). The DOC has further delegated authority to the Department of Defense under the DPAS to: (1) apply priority ratings to contracts and orders supporting national defense programs; and (2) request the DOC provide Special Priorities Assistance (SPA) to resolve conflicts for industrial resources among both rated and unrated (i.e., non-defense) contracts and orders; and (3) authorize priority ratings for other U.S. federal agency and friendly nation defense-related orders in the U.S. when such authorization furthers U.S. national defense interests. ODUSD(IP) also convenes and chairs the Priority Allocation of Industrial Resources (PAIR) task force. The task force's mission is to ensure industrial resources are allocated to DoD programs in accordance with operational priorities when emergent requirements create competing demands among MILSVCS. The task force works closely with the DOC to ensure effective allocation of materials, or to expedite deliveries of defense items in accordance with PAIR decisions.

Title III of the Defense Production Act (50 U.S.C. App. 2061 *et seq.*) has a program specifically designed to establish, expand, maintain, or modernize industrial capabilities required for national defense. Title III activities strengthen the economic and technological competitiveness of the U.S. defense industrial base and can reduce U.S. dependency on foreign sources of supply for critical materials and technologies.

ManTech is a program that develops and matures key manufacturing processes to accelerate technology improvements in the acquisition and sustainment of DoD weapon systems and components. ManTech investments enable industry to develop and provide defense-essential, affordable, low-risk manufacturing processes that effectively transition technology into new and existing equipment for the war fighter.

DoD can also fund innovative manufacturing technology and industrial base projects under the Industrial Base Innovation Fund Program (IBIF). The purpose of IBIF, as stated in the Conference Report accompanying the Department of Defense Appropriations Act, 2008, H.R. Rep No 110-434, page 346, H.R.3222 (Public Law 110-116) , is to ensure that investments are made to address shortfalls in manufacturing processes and technologies in support of DoD's long-term and short-term needs.

The application of the aforementioned tools has ensured domestic manufacturing production capabilities exist to support DoD needs. DPAS has been used to obtain preferential contract performance and may have provided some short-term relief of supply availability by diverting material to DoD orders moved up in the queue. What is missing is an SMSP to monitor the global marketplace and the authority to take necessary actions to mitigate risk associated with material shortages that would impact DoD's ability to respond to national emergencies. Material shortages could range from full disruption of supply to insufficient supplies to meet defense industry surges in demand.

Although DoD has not experienced significant disruptions in the supply of critical and strategic materials, DoD has experienced periodic supply availability issues in the global marketplace (e.g., titanium sponge/metal) when demand surged (e.g., new weapons system production competed with wartime driven weapon system upgrades/newer models). The ability for the defense industry to surge manufacturing production during wartime is directly impacted by input material availability. Material availability could be further constrained in the future as developing nations, rapidly growing economies, place additional strain on existing supply of these materials. Furthermore, countries, global material sources, are placing restrictions on exports and have developed internal domestic processing of these materials into intermediate/finished products for export. DoD purchases of these products are restricted by statute (e.g., Berry Amendment, Buy American Act and specialty metals provisions). Increasing competition for material supply is occurring concurrently as NDS is depleting its inventories of strategic materials. Thus U.S. ability to insure adequate levels of these materials during national emergencies is severely jeopardized.

In the absence of readily available inventory, DoD will need to maintain vigilance to assess global market conditions to identify events – geopolitical, natural disaster, or economic – that could interrupt or constrict supply chains and take steps to mitigate potential shortfalls. The NDS has been the steward of a stockpile of materials intended to decrease dependence upon foreign sources of supply during national emergency. In light of recent and emerging challenges, the NDS should be reconfigured to be the sentinel of critical and strategic materials tasked with surveying global market conditions and events that could disrupt or constrain the availability of strategic materials and selecting strategies to mitigate potential shortfalls. The NDS should be reconfigured to operate as the Nation's SMSP expanding to interface with other federal agencies, possessing greater latitude in entering and exiting markets, and exhibiting more flexibility in the use of its funding to develop risk-based value propositions. The SMSP must function as the Nation's conduit to acquire and supply users with strategic and critical materials.

3.0 Conclusions

Reconfiguring the NDS would permit it to function as the Federal government's SMSP Manager. The reconfigured program requires a broader internal DoD profile, expanded interface with other federal agencies, greater latitude in entering and exiting markets, and more flexibility in the use of its funding to develop risk-based value propositions. The SMSP could function as the Nation's conduit to acquire and supply users with strategic and critical materials for defense purposes and could assist other Federal agencies carry out their missions.

The first step is for the NDS reconfiguration to be aligned more properly to sense and respond to today's military material needs – from non-conflict to full mobilization scenarios. The global growth in demand for scarce raw materials and the industrial surges in China, India, Russia, Brazil, and other developing countries requires that the U.S. employ a new, integrated and responsive strategy for identifying and ensuring, on a continual basis, an adequate supply of strategic and critical materials required for U.S. national security needs.

Accordingly, DoD is considering a new, comprehensive SMSP to identify, on an ongoing basis, those strategic and critical materials required for national security. The system is founded on an interagency, collaborative approach, and bolstered by use of experts and timely market research and intelligence. The system employs an integrated risk assessment construct, compares demand to supply by analyzing supply sources and risks of supply chain interruption, and identifies mitigation strategies to ensure adequate, timely supply of those materials.

The SMSP would require greater programmatic flexibility to more fully project material needs; gather, develop, analyze and disseminate timely information on material demand and supply availability; provide material "Alerts" as necessary; respond to emergent material needs; establish and utilize mitigation tools to ensure the timely availability of materials, and enable planners to take advantage of world market conditions. An effort using an integrated, interagency approach is best suited to identify strategic materials. Discussing strategies to strengthen the industrial base will help ensure the survival of domestic suppliers required to sustain military readiness.

The SMSP could leverage the potential buying power of DoD, and other cooperating federal agencies, by aggregating materials requirements and negotiating long-term strategic sourcing arrangements.

The current policy to dispose of materials in the NDS should be reconsidered to reflect the realities of today's global marketplace. The Nation's new disposal policy should permit the application of a wide variety of risk mitigation strategies to ensure current and future material availability, as well as the sale of materials when determined to be excess to the Nation's needs. Some mitigation strategies include strategic sourcing; partnering with friendly nations; and stockpiling.

Potential Changes

Based on the coordinated analysis completed by the Working Group and the risk assessments and studies, the following options are under consideration:

Reconfigure the NDS to be the Strategic Materials Security Program.

Re-define the NDS as the SMSP to encompass the full range of responsibilities to develop an integrated, interagency approach to strategic materials management.

Modify the Strategic and Critical Materials Stock Piling Act to grant the SMSP programmatic flexibility to efficiently and effectively acquire the right materials and to ensure that essential strategic materials are available to respond to current and future needs and threats.

Develop a legislative proposal to address the need for enhanced programmatic flexibility to enable the Department to identify and respond to emerging requirements and potential supply chain shortfalls.

Enhanced programmatic flexibility could include: (1) broadening the scope of the Requirements Report by leveraging ongoing materials input from the MILSVCS, (2) civilian and industrial requirements in the Requirements Report, (3) issuing the Requirements Report on a quadrennial basis, to coincide with the QDR, with annual updates (4) and include multi-year execution authority.

A restructured SMSP would create the ability to leverage the buying power of DOD and other cooperating federal agencies, by aggregating materials requirements and negotiating long-term strategic sourcing arrangements; enabling planners to capitalize on favorable world market conditions. The SMSP will continue to gather, develop, analyze and disseminate timely information on material demand and supply availability, utilizing mitigation tools and providing material "Alerts" as necessary.

A stable source of funding ***to support the broadened mission of the SMSP*** will be critical to the success of these efforts.

The reconfigured NDS model would include providing strategic sourcing contractual support and virtual managed inventory operations. Funding stream projections are based on the new requirements of the NDS mission as identified in this report. Failure to procure a stable source of funding could limit the ability to provide risk mitigation for strategic materials to the defense needs of the U.S.

4.0 Appendices

A – NDS Materials with Sales Suspended or Restricted

B – IDA Analysis Executive Summary

C – IDA Supplementary Risk Assessments (Contains tables 1- 3)

D – USGS Mineral Commodity Summaries Table: 2007 US Net Import Reliance for Selected Nonfuel Mineral Materials

E – Department of Commerce Analysis of Tungsten

F – USGS Study of Manganese

G – USGS Study of Rhenium

Appendix A

NDS Materials with Sales Suspended or Restricted

COMMODITY	DEFENSE USE	COUNTRIES OF ORIGIN	REMAINING INVENTORY	% IMPORT DEPENDENCE
Zinc	Galvanizing agent for steel	Canada, Peru, Mexico, Australia	8,264 Short Tons	58
Tin	Anti-corrosive, alloying agent	Peru, Bolivia, China, Indonesia	3,863 Metric Tons	79
Iridium	Hardening agent in platinum alloys	South Africa, United Kingdom, Germany, Canada	567 Troy Ounces	94
Platinum	Catalyst; heavy-duty electrical contacts	South Africa, United Kingdom, Germany, Canada	8,380 Troy Ounces	94
Germanium	Semiconductors and transistors, fiber optics, medical industry	Belgium, Canada, Germany, China	17,871 Kilograms	100
FerroChrome (High Carbon and Low Carbon)	Stainless steel	China, Africa, Kazakhstan	314,847 Short Tons	62*****
Tungsten Metal Powder and Tungsten Ores and Concentrate (O & C)	Steel hardening and toughening	China, Canada, Germany, Portugal	Powder - 585,619 Pounds; O&C – 46 million Pounds	70*****
Tantalum Carbide	Hard refractory ceramic	Australia, Brazil, China, Germany	3,801 Pounds	100
Niobium/Columbium	Nuclear industry, superconductor	Brazil, Canada, Estonia, Germany	22,156 Pounds	100
Cobalt	Magnetic properties, corrosion and wear resistant	Norway, Russia, Finland, China	2.26 million Pounds	78*****
Ferromanganese	Used in steel production and steel deoxidizer	South Africa, Belgium, Ukraine	526,000 Short Tons	100
Beryllium	Aerospace systems and nuclear weapons	Kazakhstan, Germany, United Kingdom	215 Short Tons	100
Chromium Metal	Aerospace systems and high grade stainless steel	South Africa, Kazakhstan, Russia, Zimbabwe	5,390 Short Tons	62*****
*** Indicates where secondary material sources are included—not all such material is suited for defense purposes. Import dependency is therefore much higher for these materials.**				

Appendix B

Executive Summary

KEY MATERIALS FOR HIGH-PRIORITY WEAPON SYSTEMS, AND ASSESSING RISKS TO THEIR SUPPLY

A Report for the U.S. Defense National Stockpile Center

31 July 2008

THE INSTITUTE FOR DEFENSE ANALYSES

Executive Summary

The Institute for Defense Analyses (IDA) was tasked by the U.S. Defense National Stockpile Center (DNSC) to prepare an assessment of materials needed by the Department of Defense (DoD), especially for a set of priority weapon systems, and to develop and illustrate an approach that the DoD could use to assess the risks to the continuous supply of a test set of these materials. This paper describes IDA's findings and recommendations.

The principal tasks IDA has undertaken in this project are as follows:

(1) Select a set of 20-25 high-priority DoD weapon systems for materials assessments;

(2) Assess the "standard" and "special" materials used to produce these selected weapon systems;

(3) Conduct a set of risk evaluations upon a test set of materials—drawing on a specific set of risk filter criteria requested by the sponsor; and

(4) Summarize key findings and provide recommendations to the sponsor regarding next steps in developing an ongoing risk assessment process for materials of importance to the DoD.

KEY FINDINGS

As estimated in this report, the DoD has a very significant enduring demand for materials in order to produce weapon systems and munitions. These materials range from aluminum and platinum group metals to high performance fibers and advanced composites, ceramics, polymers, a wide range of metal alloys, and many others. For what are called "standard" materials in this report (those having systematic demand-estimation data and techniques called Material Consumption Ratios), the DoD uses on the order of *three quarters of a million short tons* of them per year. [1] This report contains the most comprehensive compilation of the DoD's demands for such materials that has ever been prepared, both for priority weapons systems and overall.

Table ES-1 offers a representative profile of the DoD's ongoing, year-by-year demands for standard materials, developed using the best method available for assessing total defense demands for them. As Table ES-1 shows, some of these materials are used in vastly larger quantities than others. On a tonnage basis, the table shows the DoD's regular "top 11" standard materials to be as follows: (1) aluminum metal; (2) copper; (3) lead; (4) fluorspar acid grade; (5) zinc; (6) rubber; (7) manganese ore – chemical / metal grade; (8) nickel; (9) ferrochromium; (10) chromite ore (all grades); and (11) titanium

[1] A Material Consumption Ratio (MCR) is an estimated quantity of a material needed by a specific U.S. industrial sector to produce a dollar of that sector's (industrial) output.

sponge. Chapter 2 of the IDA report (available on request) contains a discussion of the strengths and limits of the model and data used by IDA.

Table ES-1 – The DoD's Approximate Annual Usage of Standard Materials

Standard Material	Regular DoD Demand in STONS/yr	Rank-Order for DoD/yr (STONS)
Aluminum Metal	275,219.8	1
Aluminum Oxide Fused Crude	6,002.8	
Antimony	4,693.8	
Bauxite Refractory	7,700.5	
Bismuth	171.5	
Cadmium	75.0	
Chromite Ore (all grades)	9,630.5	10
Chromium Ferro (Ferrochromium)	9,667.8	9
Chromium Metal	913.8	
Cobalt	4,242.8	
Columbium	484.8	
Copper	105,625.8	2
Fluorspar acid grade	56,544.5	4
Fluorspar metallurgical grade	2487.5	
Iridium (Platinum Group)	0.3	
Lead	88,464.8	3
Manganese Dioxide Battery Grade Natural	63.5	
Manganese Dioxide Battery Grade Synthetic	4,158.5	
Manganese Ferro (C and Si)	7,897.0	
Manganese Metal--Electrolytic	1,368.8	
Manganese Ore Chem/Metal Grade	25,041.8	7
Mercury	35.5	
Molybdenum	3,049.0	
Nickel	17,311.75	8
Palladium (Platinum Group)	2.3	
Platinum (Platinum Group)	0.8	
Rubber (natural)	29,490.3	6
Silicon Carbide	8861	
Silver	349.5	
Tantalum	141.0	
Tin	2,867.5	
Titanium (sponge)	8,788.5	11
Tungsten	895.0	
Vanadium	134.8	
Zinc	51,085.5	5
Total	733,468.05	

The estimates in Table ES-1 draw upon the best data available to IDA. They should be treated as initial findings, however. More research is needed, using such DoD sources as Bills of Materials for major weapon systems, in order to confirm -- or properly revise -- the initial estimates presented here. Future rounds of the "repeatable" materials assessment process that the DoD is now building should enable progress along these lines.

For several reasons, it would be useful for the DoD to undertake these future assessments on a sustained basis. For one thing, it is difficult for the DoD to identify material supply vulnerabilities that it has or may have unless it has a strong evidence base and process in place for determining the full range of materials it uses and needs. Secondly, an increasingly detailed understanding of the DoD's materials demands should help the Department, indeed the federal government as a whole, buy smarter and with more bargaining power. On this second point more specifically, such information should help the DoD determine whether and for which materials it can take significant advantage of its collective buying power to achieve economies of scale (better prices for materials) in the markets by buying larger lots of them -- relative to its current practice of leaving its components and contractors largely on their own to buy these items separately. As the largest buyer of such materials within the federal government, it seems appropriate to IDA for the DoD to lead by positive example in this regard for the United States Government. To help move such an initiative along, IDA recommends that the 11 standard materials that the DoD is estimated in this report to buy the most of—as shown in Table ES-1-- could serve as leading nominees for strategic buying efforts by the DoD in the next several years.

From the evidence provided in this report, the DoD appears to be heavily reliant upon foreign sources for many of the materials it uses today. In some instances, these foreign sources may be subject to political instability, natural disaster, military conflicts, terrorist attacks or even market manipulation schemes or decreased supply due to political decisions. These conditions could potentially place the DoD's supply chains for some of these materials at significant risk.

Accordingly, the DoD would be well advised to strengthen its management mechanisms and assessments to understand the risks it now faces and may face from such supply chain problems, and to develop a set of risk mitigation strategies for its most serious material problems. This report offers some initial assessments suggestive of the potential severity of the material shortages that the DoD could encounter in the future if it were faced with any of a spectrum of supply disruption scenarios.

A recommended next step for the DoD would be to update the initial demand-supply comparisons and risk assessments in this report with the most current data available to the Department. An important related step would be for the DoD to convene one or several senior panels to review the most current assessments and to make policy recommendations as to which supply scenario(s) the DoD should use as benchmarks to determine how much risk it is prepared to accept with respect to materials sources in the years ahead.

Along these lines, note that the current NDS materials requirements process prepares estimates of the material shortages that the DoD could encounter in seeking to meet its demands for materials in the context of a postulated Base Case national security emergency (NSE) scenario. If material shortages are identified in that process, they become candidates for risk mitigation efforts by the U.S. Government.

For risk management of potential Peacetime Supply Disruption (PSD) problems, the DoD may also want to consider using a complementary, significantly adapted version of the national emergency requirements process. Such a PSD management approach would employ a markedly different type of Base Case supply scenario from the current "Section 14" NSE Base Case, one focused far more on peacetime (rather than mobilization) production conditions, and featuring relatively robust U.S. civilian demands. Such a PSD scenario would highlight the possibility that the DoD is potentially vulnerable to a variety of significant supply disruptions in politically unreliable countries in the emerging future that the DoD faces. Using a systematic approach of this sort could help the DoD identify materials that are sensible candidates for risk mitigation efforts, efforts that could include but would hardly be limited to stockpiling. Such an approach could even work in parallel with the national security emergency materials requirements approach the Department uses today. The two processes together could provide the DoD systematic assessments for materials problems under both national security emergency conditions as well as other important supply scenarios and conditions. The Department might even consider using the two approaches together by taking the shortages estimated in both the NSE and PSD Base Cases and using the maximum shortage estimate across the two cases as the planning target for risk mitigation initiatives, either by stockpiling or by any other more promising approaches.

For what may be called a Peacetime Supply Disruption planning Scenario, several possible Base Case Supply assumptions for the DoD to consider are as follows:

- The Department would need to meet its regular materials demands relying only on (a) current U.S. domestic production;

- The Department would need to meet its regular materials needs relying only on a combination of (a) current U.S. domestic production plus (b) current U.S. imports from foreign suppliers judged to be highly reliable;

- The Department would need to meet its regular needs by relying only on (a) current U.S. domestic production plus (b) current imports from foreign sources, but excluding (c) any of those foreign sources that are "global market dominators" and also less-than-fully reliable;

- The Department would need to meet its regular needs by relying only on (a) its current fraction of U.S. domestic production plus (b) some extra share of domestic production that it may plausibly obtain within a prudent interval (say within 3-6 months), plus (c) highly reliable current foreign suppliers minus (d) all less-than-fully-reliable market dominators.

The assessments of a test set of 17 materials in Chapter 5 of the present study indicate significant potential material problems for the DoD even in conditions short of a major war. For example, in a PSD(#1) in which DoD is assumed to need to rely upon its regular share of domestic production plus its regular share of sales from our fully reliable foreign suppliers in order to meet its regular peacetime demands, three quarters of the test materials (13) manifest shortages (9) or near-shortages (4) in a year-long PSD. In PSD#1, the estimated shortages for the test materials alone amount to half a billion dollars (in 2008 prices). In PSD (#6), in which DoD is assumed –potentially quite optimistically—to be able to obtain twice its regular shares of both domestic production and of fully reliable imports, more than half (9) of the test materials still show shortages (3) or near-shortages (6) in such a PSD. Since DoD officials have indicated that the DoD needs to have *assured access* to key materials to produce weapon systems and munitions, such cases may be well worth the DoD's considering as benchmarks for a PSD planning case. IDA believes that the DoD should give serious consideration to a PSD#1 type of scenario as a place to start such a process. Variants of PSD1 have also been structured that include essential civilian demands, and they are available for DNSC/DOD's use as appropriate.

If the DoD can make initial decisions about Base Case Supply assumptions for a PSD Scenario, then the Department can determine, with analytic tools available to it already, which materials are likely to be subject to shortages according to the selected Base Case. After that, the DoD can develop risk mitigation options for each particular problem material, implementing the most sensible of them as circumstances suggest. Overall, a PSD case could be used in parallel with and as a complement to a national security emergency planning case in the new repeatable process that DoD is considering.

Chapter Six presents a set of recommendations to the DoD for next steps in addressing the materials issues that the Department and the Nation face in the emerging security environment. These are as follows:

Recommendation 1: The Department should consider identifying *complementary* Peacetime Supply Disruption (PSD) and National Security Emergency (NSE) Base Cases in a new, expanded materials security program, to focus the DoD's attention on materials warranting close monitoring and risk mitigation efforts.

Recommendation 2: The Department should consider commissioning a next set of assessments for the highest priority non-standard materials (e.g., have the Department of Commerce develop systematic demand-side estimates for such materials; invest in supply-side analyses by the United States Geological Survey for these materials). Non-standard materials (those not having MCRs today) that the Services have identified as problematic in their responses to a recent OSD survey could be a strong candidate set (see Appendix 6), as well as polymer matrix composites/high performance fibers (Appendix 5).

Recommendation 3: The Department should consider continuing to compile data from the Services on materials used to produce key weapon systems, both more-in-depth compilations for the weapon systems examined in this report as well as studies of a next set of 20-24 weapon systems.

Recommendation 4: For materials shortages estimated under postulated PSD or NSE scenarios, the DoD should consider conducting special studies to assess the costs and effectiveness of various options for mitigating such risks, e.g., a DoD stockpile, industry stockpiles, contingency production contracts (with U.S. firms, highly reliable foreign firms), identifying substitute materials, and DPAS (DX) ratings.

Recommendation 5: The Department should consider assessing the net benefits to the DoD of having a strategic buyer/agent such as DNSC for selected materials, potentially starting with the "top 11" standard materials identified in this report (see table ES-1) plus other promising special material candidates.

Recommendation 6: Overall, the DoD should consider reconfiguring the NDS as a Materials Security Program. Such a program could consist of a structured, interrelated set of initiatives along the following lines:

- **Establish a Smart-Strategic Buyer Program** (evaluate the "top 11" standard materials for suitability as a way to start)
- **Regularly Assess Potential Material Shortages in**
  - Peacetime Supply Disruption (PSD) Scenarios
  - National Security Emergency (NSE) Scenarios
- **Identify Ways to Mitigate Risks to Material Supplies** through
  - Stockpiling
  - Contingency contracts (in U.S., other)
  - Investments in capacity
  - Other
- **Mitigate Risks Based on Analysis** of the merits of options
- **Regularly Assess Impacts of Existing and Potential Material Shortages** on COCOM equipment needs and unit readiness.

A proactive position by the DoD on these matters would include moving ahead aggressively to prepare evidence and recommendations for the next administration, evidence and recommendations that would then be available when DoD is asked for them in the course of the forthcoming Quadrennial Defense Review. To wait until the QDR is issued (in early 2010) in order to move out smartly upon this materials security program seems likely to be a needless and potentially costly delay for the national security of the United States.

ORGANIZATION OF THIS REPORT

This paper presents IDA's study results and recommendations in six chapters. Chapter 1 addresses the first task listed above. Chapters 2 and 3 provide initial assessments of standard materials and special materials, respectively. Chapter 4 describes a set of supply risk criteria and initial evaluations using them, focusing upon a test set of materials. Chapter 5 draws together key criteria from Chapter 4 into a set of integrated, illustrative assessments across a "risk tolerance" spectrum. Chapter 6 offers a set of recommendations for next steps that the DNSC and the DoD may wish to pursue in this area.[2]

[2] IDA contributors to this study are: Dr. Jim Thomason (Project Lead), Dr. Jim Bell, Eleanor Schwartz, Dr. Bob Atwell, Dr. Dick Van Atta, Nicholas Karvonides, Zack Rabold and Tiki Mitchell. Additional IDA contributors: Paul Collopy, Jeff Hendrix, Dr. William Hong, Christopher Martin, Gene Porter, Dr. Michael Rigdon, David Sparrow, Mark Taylor, Lisa Veitch, Chris Wait, and Dr. Jim Woolsey.

Appendix C

Supplementary Risk Assessments

A Report for the U.S. Defense National Stockpile Center

3 September 2008

THE INSTITUTE FOR DEFENSE ANALYSES

Supplementary Risk Assessments

DNSC commissioned IDA to assess risks to the continuous supply of a broad set of strategic materials. These include 13 materials that DoD asked Congress in early 2008 to suspend sales of temporarily, pending a risk review.

IDA has now completed an initial risk review of the strategic materials shown in Table 1.[3] Results for the group of 13 are listed first.[4] The risk analyses IDA conducted focus on whether shortages or near-shortages would arise in meeting defense-essential demands for these materials in either of two planning cases: (1) an approved National Security Emergency (NSE) scenario (details are available but are SECRET/NOFORN); (2) a benchmark Peacetime Supply Disruption scenario (PSD1) that is broadly consistent with OSD-approved Defense Planning Scenarios for "steady-state" contingencies. Shortages are defined as a projected supply-to-demand ratio of 1.0 or less, *exclusive* of any NDS inventory. Materials with shortages in the NSE and/or PSD1 scenarios are indicated in the second and third columns of Table 1. Materials with near-shortages in the PSD1 case (a projected supply-to-demand ratio greater than 1.0 but less than or equal to 2.0) are indicated in the fourth column.

In the NSE case, 4 materials exhibit shortages (column 2). In the PSD1 case, 30 materials manifest shortages (column 3); an additional 13 materials show near-shortages (column 4). Thus 43 materials have supply-to-demand ratios of 2.0 or less in the PSD1 case, and 9 materials have larger ratios. (Quartz has not been assessed in the PSD1 case.)

For materials with NDS inventory that show shortages or near-shortages in the NSE or PSD1 cases, IDA recommends that DoD ask Congress to continue to hold remaining inventory while DoD studies these materials again with the freshest possible data. For other materials with shortages, that is, those with no NDS inventory, IDA recommends that DoD determine promptly whether to acquire some NDS inventory or to undertake some other risk mitigation option. For materials with near-shortages in PSD1 but no current NDS inventory, IDA recommends that DoD reassess them with fresh data as soon as possible. If a material fails to exhibit even a near-shortage, IDA generally recommends that DoD monitor its supply situation but not reassess the material in detail unless its supply seems to be tightening.[5] Material-by-material recommendations are shown in the final (sixth) column of Table 1.

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[3] IDA assessed 52 of these 53 materials using systematic modeling techniques and the best available data. Quartz was assessed separately by DNSC for the NSE case.

[4] The top group (of 13) includes 12 that OSD had originally requested a suspension of inventory sales on in January 2008, plus chromium metal, which OSD added to the list of 12 soon afterwards.

[5] In the case of columbium (niobium), IDA recommends that DoD hold remaining inventory pending a fresh foreign reliability assessment (underway).

Table 1. Risk Review of Selected Strategic Materials

	NSE Shortage*	PSD1 Shortage**	PSD1 Near-Shortage***	OSD Survey 2008 Identified a Problem	Recommen-dation****
Materials DoD Recommended for Reserve					
Beryllium Metal	X	X		X	Hold/Goal Material
Chromium Metal		X		X	Hold/Study
Cobalt		X		X	Hold/Study
Columbium (Niobium)				X	Hold/Study
Ferro Chromium			X		Hold/Study
Ferro Manganese			X		Hold/Study
Germanium			X	X	Hold/Study
Iridium			X		Hold/Study
Platinum			X	X	Hold/Study
Tantalum		X			Hold/Study
Tin		X		X	Hold/Study
Tungsten	X	X		X	Hold/Study
Zinc		X		X	Hold/Study
# of materials in group with shortage, near shortage, or problem (of 13)	2	7	5	9	
Other Systematically Analyzed Materials					
Aluminum Metal		X		X	Study/PB
Aluminum Oxide Fused Crude		X			Study/PB
Antimony	X	X			Study/PB
Bauxite Refractory		X			Study/PB
Beryl Ore		X			Study/PB
Beryllium Master Copper Alloy			X	X	Study
Bismuth		X			Study/PB
Boron					Monitor
Boron Composite Filaments			X		Study
Boron Nitride		X			Study/PB
Cadmium				X	Study
Chromite Ore (all grades)					Monitor
Copper		X		X	Study/PB
Fluorspar Acid Grade		X			Study/PB
Fluorspar Metallurgical Grade					Monitor
Gallium		X		X	Study/PB
Hafnium			X	X	Study
Indium		X		X	Study/PB
Lead		X			Study/PB

Table 1. Risk Review of Selected Strategic Materials (continued)

	NSE Shortage*	PSD1 Shortage**	PSD1 Near-Shortage***	OSD Survey 2008 Identified a Problem	Recommen-dation****
Manganese Dioxide Battery Grade--Natural					Monitor
Manganese Dioxide Battery Grade--Synthetic		X			Study/PB
Manganese Metal--Electrolytic		X			Study/PB
Manganese Ore Chem/Metal Grade					Monitor
Mercury		X			Hold/Study
Molybdenum			X	X	Study/PB
Nickel		X		X	Study/PB
Palladium (Platinum Group)		X			Study/PB
Quartz	X	TBD	TBD		Goal Material
Rhenium		X			Study/PB
Rhodium			X		Study
Rubber (natural)		X			Study/PB
Ruthenium			X		Study
Silicon Carbide		X			Study/PB
Silver		X			Study/PB
Tellurium			X	X	Study
Titanium (sponge)		X		X	Study/PB
Vanadium				X	Study
Yttrium		X		X	Study/PB
Zirconium Metal			X		Study
Zirconium Ores and Concentrates					Monitor
# of materials in group with shortage, near shortage, or problem (of 40)	2	23	8	13	
Total # of materials with shortage, near shortage, or problem (of 53)	4	30	13	22	

*Based on National Security Emergency Planning Scenario
**Peacetime Supply Disruption Case 1-- Based on OSD Defense Planning Scenarios (supply/demand ratio of 1.0 or less)
***Peacetime Supply Disruption Case 1-- Based on OSD Defense Planning Scenarios (supply/demand ratio between 1.0 and 2.0)
****Hold--Hold Most/All Inventory, Amount TBD; PB--Potential Buy or Other Risk Mitigation Initiative; Study; Monitor

Beyond these explicit risk assessments, IDA notes that a significant number of these materials (22 of 53) were also recently identified—by one or more Service or DoD component respondents to an OSD survey—as having *already* caused some kind of significant weapon system production delay for DoD.[6] The fifth column of Table 1

[6] Results are based on a survey of DoD components that OSD (AT&L/Industrial Policy) conducted in June through August of 2008. The purpose of the survey was to identify strategic (non-fuel) materials with

indicates these materials. IDA recommends that all of these materials be studied intensively and promptly to determine the severity of such delays, whether the problem has been resolved or persists, and what prudent options exist for DoD to mitigate such difficulties now and in the future.

In the same OSD survey, DoD respondents identified 19 additional materials that have also already caused some kind of production delay. These materials are shown in Table 2. IDA believes that DoD should examine these materials as soon as feasible, in comparable fashion to the 22 marked in Table 1. (Table 3 lists the materials in Tables 1 and 2, plus materials that respondents to the OSD survey identified as *potentially* problematic.)

Table 2. OSD Survey 2008: Other Materials Causing Production Delays (19 Materials)

Material	Recommendation
Aluminum-Lithium (AL - 2.8 Cu - 1.5 Li)	Study
Carbon Fiber	Study
Ceramic/Al Nitride/Copper	Study
Cerium	Study
Deuterium	Study
Europium	Study
Gadolinium	Study
Helium	Study
Image Intensification Tubes	Study
Kevlar	Study
Lanthanum	Study
Lithium	Study
Nomex	Study
PWA 1484	Study
Rene N5	Study
Selenium	Study
Steel (Specialty)	Study
Tritium	Study
Xenon	Study

Finally, IDA recommends that all materials manifesting shortages in the NSE or PSD1 cases that do not now have regular demand ratio data (material consumption ratios) be top priority candidates for future data development efforts.[7] Next in priority for such data development would be those materials exhibiting near-shortages in the PSD1 case.

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which the components have already had significant supply problems, as well as any materials they expect such problems with in the future.

[7] Material Consumption Ratios (MCRs) give the amounts of material required for an industrial sector to produce a given dollar amount of output. They are helpful in determining material demand. They are developed based on material usage data from the Department of Commerce. A separate MCR is computed for each combination of material and industrial sector. Of the 53 materials in Table 1, 35 have MCRs. Of the 13 materials in the initial group, 11 have MCRs (the exceptions are beryllium and germanium).

Table 3. Materials Identified/Assessed by DoD in 2008 Study
(Integrated Materials List; 128 materials)

Materials DoD Recommended for Reserve (13)	
Beryllium Metal	
Chromium Metal	
Cobalt	
Columbium (Niobium)	
Ferro Chromium	
Ferro Manganese	
Germanium	
Iridium	
Platinum	
Tantalum	
Tin	
Tungsten	
Zinc	
Other Systematically Analyzed Materials (40)	
Aluminum Metal	Quartz
Aluminum Oxide Fused Crude	Rhenium
Antimony	Rhodium
Bauxite Refractory	Rubber (natural)
Beryl Ore	Ruthenium
Beryllium Master Copper Alloy	Silicon Carbide
Bismuth	Silver
Boron	Tellurium
Boron Comp Filaments	Titanium (sponge)
Boron Nitride	Vanadium
Cadmium	Yttrium
Chromite Ore (all grades)	Zirconium Metal
Copper	Zirconium Ores and Concentrates
Fluorspar acid grade	
Fluorspar metallurgical grade	
Gallium	
Hafnium	
Indium	
Lead	
Manganese Dioxide Battery Grade--Natural	
Manganese Dioxide Battery Grade--Synthetic	
Manganese Metal--Electrolytic	
Manganese Ore Chem/Metal Grade	
Mercury	
Molybdenum	
Nickel	
Palladium (Platinum Group)	

Table 3. Materials Identified/Assessed by DoD in 2008 Study
(Integrated Materials List; 128 materials)
(continued)

Other Materials Identified by DoD Respondents (75)	
A 286	Osmium
Aluminum-Lithium (AL - 2.8 Cu - 1.5 Li)	Petroleum
Ammonium Perchlorate	Petroleum Based Structure Adhesive Epoxy
AMS 5536	Polycarbonate Film
Barium Titanate	PTFE Ceramics and Glass Fiber
C 1023	PWA 1447
Carbon Fiber	PWA 1480
Ceramic/Al Nitride/Copper	PWA 1484
Cerium	PWA 509
Covar Ceramic	PWA 655
Deuterium	Raw Sapphire
Di-Beta-Naphthyl-P-Phenylene	Rene 125
Dibutyl Tin Dilavrate (DBTDL)	Rene 142
E-Glass	Rene 41
Europium	Rene 77
Ferro Magnetic Materials	Rene 80
Fiber Glass S-2	Rene 88
Gadolinium	Rene 95
Gold	Rene N4
Hast-S	Rene N5
Hast-X	Rene N6
Helium	Scandium
Highly Intrinsic Silicon Boule	Selenium
HS 188	Silicon Wafers
HS 25	Steel
HS 31	Ti- 6-2-4-2
Image Intensification Tubes	Ti- 6-4
Inco 625	Ti- 8-1-1
Inco 718	Ti-17
Inco 901	Tritium
Inconel (nickel & chromium)	Vel. Therm
Kevlar	Waspaloy
L605	X 40
Lanthanum	X 750
Lithium	Xenon
Lithium-ion	
Magnesium and Magnesium Oxide	
Mar M 509	
Metal Alloys (Super Alloys)	
Nomex	

Appendix D

USGS Mineral Commodity Summaries Table

2007 US Net Import Reliance for Selected Nonfuel Mineral Materials

2007 U.S. NET IMPORT RELIANCE FOR SELECTED NONFUEL MINERAL MATERIALS

Commodity	Percent	Major Import Sources (2003-06)[1]
ARSENIC (trioxide)	100	**China**, Morocco, Hong Kong, Chile
ASBESTOS	100	Canada
BAUXITE and ALUMINA ✹	100	Guinea, Jamaica, Australia, **Brazil**
CESIUM ✹	100	Canada
FLUORSPAR ✹	100	**China**, Mexico, **South Africa**, Mongolia
GRAPHITE (natural)	100	**China**, Mexico, Canada, **Brazil**
*I*NDIUM ✹	100	**China**, Japan, Canada, Belgium
MANGANESE ✹	100	**South Africa**, Gabon, Australia, **China**
MICA, sheet (natural)	100	**India**, Belgium, **China**, **Brazil**
NIOBIUM (columbium) ✹	100	**Brazil**, Canada, Estonia, Germany
QUARTZ CRYSTAL (industrial)	100	**Brazil**, Germany, Madagascar, Canada
RARE EARTHS ✹	100	**China**, France, Japan, **Russia**
RUBIDIUM ✹	100	Canada
STRONTIUM ✹	100	Mexico, Germany
TANTALUM ✹	100	Australia, **Brazil**, **China**, Germany
THALLIUM	100	**Russia**, Netherlands, Belgium
THORIUM	100	United Kingdom, France
VANADIUM ✹	100	**Czech Republic**, Swaziland, Canada, Austria
YTTRIUM ✹	100	**China**, Japan, France, Austria
GALLIUM ✹	99	**China**, Ukraine, Japan, Hungary
GEMSTONES	99	Israel, **India**, Belgium, **South Africa**
BISMUTH ✹	95	Belgium, Mexico, **China**, United Kingdom
PLATINUM ✹	94	**South Africa**, United Kingdom, Germany, Canada
STONE (dimension)	90	Italy, Turkey, **China**, Mexico
DIAMOND (natural industrial stone)	88	Botswana, Ireland, Namibia, **South Africa**
ANTIMONY ✹	86	**China**, Mexico, Belgium
RHENIUM ✹	86	Chile, Germany
BARITE	83	**China**, **India**
TITANIUM MINERAL CONCENTRATES ✹	82	**South Africa**, Australia, Canada, Ukraine
POTASH	81	Canada, Belarus, **Russia**, Germany
TIN ✹	79	Peru, Bolivia, **China**, Indonesia
COBALT ✹	78	Norway, **Russia**, Finland, **China**
PALLADIUM ✹	73	**Russia**, **South Africa,** United Kingdom, Norway
TUNGSTEN ✹	70	**China**, Canada, Germany, Portugal
TITANIUM (sponge) ✹	64	**Kazakhstan**, Japan, **Russia**, Ukraine
CHROMIUM ✹	62	**South Africa**, **Kazakhstan**, **Russia**, Zimbabwe
PEAT	60	Canada
ZINC ✹	58	Canada, Peru, Mexico, Australia
MAGNESIUM COMPOUNDS	57	**China**, Canada, Austria, Australia
GARNET (industrial)	56	Australia**, India**, **China**, Canada
SILICON (ferrosilicon) ✹	56	**China**, Venezuela, **Russia**, Norway
SILVER ✹	55	Mexico, Canada, Peru, Chile
MAGNESIUM METAL	54	Canada, **Russia**, Israel, **China**
DIAMOND (dust, grit and powder)	52	**China**, Ireland, **Russia**, Ukraine
NITROGEN (fixed), AMMONIA	44	Trinidad and Tobago, Canada, **Russia**, Ukraine
VERMICULITE	40	**South Africa**, **China**
COPPER ✹	37	Chile, Canada, Peru, Mexico
MICA, scrap and flake (natural)	32	Canada, **China**, **India**, Finland
PERLITE	30	Greece
ALUMINUM ✹	26	Canada, **Russia**, **Brazil**, Venezuela
GYPSUM	26	Canada, Mexico, Spain, Dominican Republic
SULFUR	24	Canada, Mexico, Venezuela
PUMICE	20	Greece, Italy, Turkey
SALT	18	Canada, Chile, The Bahamas, Mexico
CEMENT	17	Canada, **China**, Thailand, Republic of Korea
NICKEL ✹	17	Canada, **Russia**, Norway, Australia
PHOSPHATE ROCK	14	Morocco
BROMINE	13	Israel, United Kingdom
IRON and STEEL	12	Canada, European Union, Mexico, **Brazil**
IRON and STEEL SLAG	7	Canada, Italy, France, Japan
LIME	1	Canada, Mexico

Those marked by an ✹ are materials identified as important to defense systems.

[1]In descending order of import share

Those appearing in **bold** share an increased risk of supply disruption related to economic and/or geopolitical concerns.

Appendix E

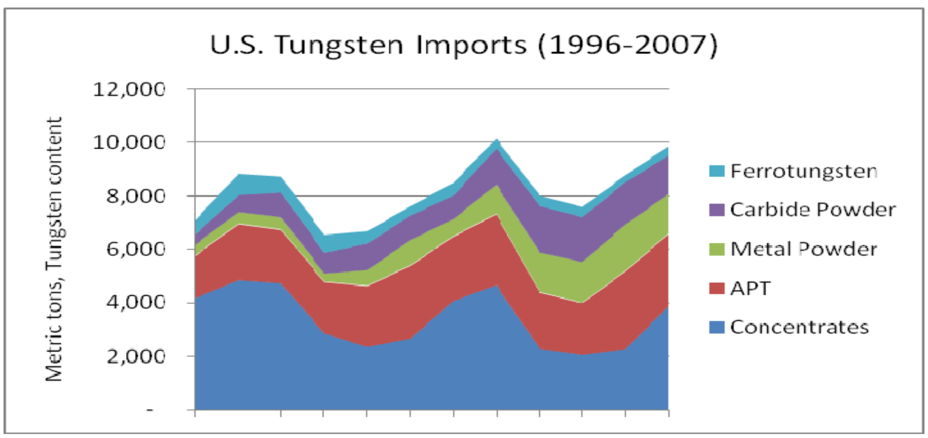
Department of Commerce Analysis of Tungsten

Task Order 1

Report on Domestic Suppliers of Tungsten and their Reliance on Foreign Sources of Production

There has been no mining of tungsten in the United States since 1995, when the single operating mine suspended production due to depressed tungsten prices. These conditions were due largely to high levels of production and exports by China, which resulted in a four-year Orderly Marketing Agreement with the United States beginning in 1987 covering ammonium paratungstate (APT) and tungstic acid, and the imposition of antidumping duties on ores and concentrate of 151 percent between 1991 and 2000. Remaining domestic reserves of tungsten are estimated at 140,000 tons, around 5 percent of the world total. Raw materials are currently obtained from concentrate imports and tungsten-bearing scrap, as well as the drawdown of industrial and National Defense Stockpile stocks of concentrate and powder. Annual imports of tungsten ore and concentrate have ranged between 2,100 and 4,900 tons (tungsten content) during the period 1996 to 2007 (see Table 1). Bolivia and Portugal have been consistently significant sources during this period, with Peru, Rwanda, and Thailand participating at times. Russia and Kazakhstan were major suppliers until 2000, and Canada has been since 2002. Concentrate was imported from China only between 2000 and 2003.

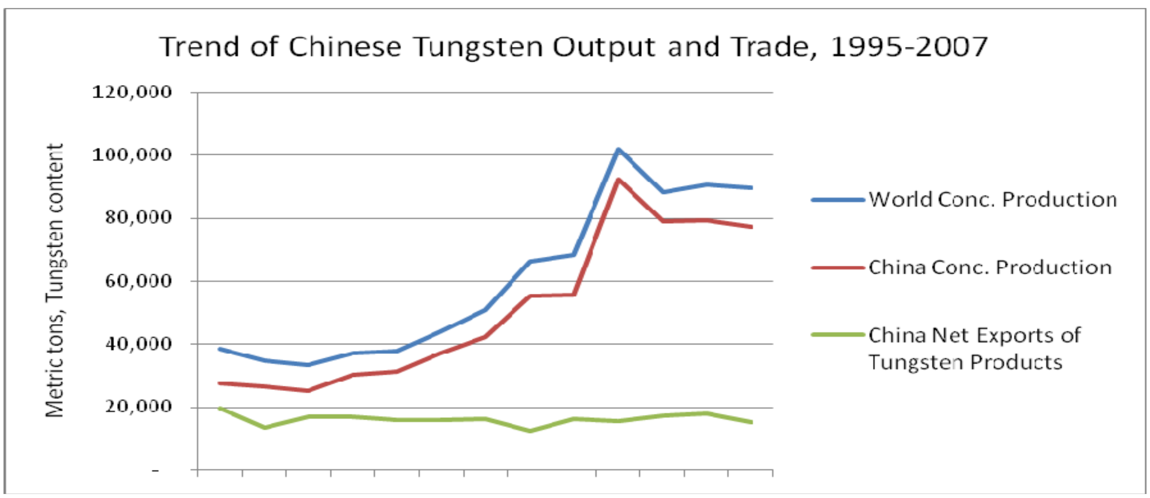
Tungstates, principally APT, are produced from concentrate and undergo additional chemical processing to yield metallic tungsten products. In 2007, net imports, almost entirely from China, provided about 2,000 of the 12,000 tons of APT consumed by U.S. tungsten processors. Both imports and exports of APT have been rising somewhat since 1996, and the net imports have fluctuated between 1,100 and 2,500 tons per year, supplying 12 to 27 percent of U.S. consumption (Table 1). China has consistently been the source of almost all APT imports.



In 2007, the U.S. had net production of tungsten metal powder of 3,890 tons, and 4,530 tons of tungsten carbide powder (Table 1). Metal powder imports of 1,480 tons, from Germany, Israel, and China, only slightly outweighed 1,050 tons of exports. U.S. foreign trade in tungsten powder has steadily grown since 1996; in 2007 both imports and exports were more than triple their 1996 levels. Net imports of powder had been running at only a few percent of consumption, with a positive export balance in some years. In 2004 imports' share of the market rose substantially when domestic production dipped, but by 2007 imports represented about 10 percent of consumption. Imports of tungsten carbide powder exceeded exports in 2007, at 1,454 and 1,276 tons, respectively. These imports have risen steadily in recent years, from about 400 tons in 1996 to over 1,700 in 2004, while exports have remained generally within a range of 1,000 to 1,700 tons per year. Net imports as a share of consumption are normally only a few percent, and an export surplus has been realized in half of the years since 1996. In 2007 China was the largest source of carbide imports (735 tons), followed by Canada and Israel. Consumption of tungsten ferroalloys, estimated at 236 tons in 2007, has declined by half since 1996, and is supplied almost completely by imports, mostly from China.

China

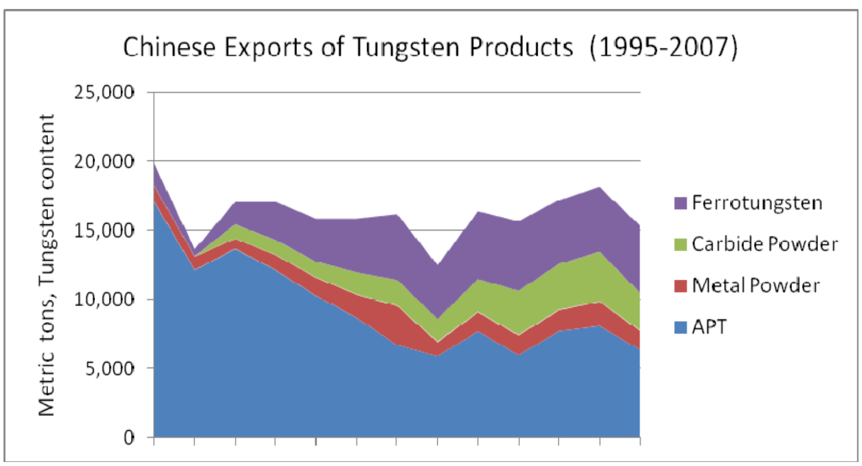
China has long been a major global player in tungsten, possessing about two-thirds of the world's tungsten reserves. Its production has greatly increased over the past decade, roughly tripling since the mid 1990's (Table 2). Output of ore and concentrate in the rest of the world during this time has fluctuated, but experienced little net growth. Thus, China is responsible for essentially all the approximately 130 percent increase in world output since 1995, increasing its share of global tungsten concentrate production from about 75 percent in 1995 to 85 percent in 2007.



Tungsten production has been controlled by the Chinese government through both ownership and regulation. In the mid 1990's about 40 percent of production occurred at state-owned mines, the remainder at operations owned by local government units or private entities. Mining operations at that time were under pressure from relatively low tungsten prices. Declining quality of ore and financial problems at some state mines, which were in many cases required to bear various social costs for the benefit of the local community led to the closure of some facilities. In 1998 the China National Nonferrous Metals Corp. was abolished, and by 2000 the tungsten assets it had owned had been turned over to local governments. A new agency, the State Bureau of the Nonferrous Metals Industry, under the State Economic and Trade Commission, was created in 1998 to oversee the industry through planning and regulation rather than outright management.

The U.S. Geological Survey reports that the mining of tungsten is also regulated by the Ministry of Land and Natural Resources through the issuance of permits for mining operations and quotas on the output of concentrate. The granting of permits and quotas has resulted in the closure of some smaller uneconomic mines, as well as those operating illegally or in environmentally destructive ways. The concentrate production quota for 2002 was set at 43,730 tons, slightly more than estimated mine output during the previous year. Actual production apparently overshot the quota level in 2002, and has continued to do so, despite the annual quota being raised 35 percent over the next four years, to 59,060 tons for 2006. China supplements its domestic output of concentrate with a consistent flow of net imports, principally from Canada, Russia, North Korea, and Congo. At times these have been quite large in relation to concentrate output available in the rest of the world, particularly in the last few years as China has tightened enforcement of its concentrate production quotas.

While China remains the world's largest exporter of primary tungsten products (Imports of all primary tungsten products, and exports of concentrate, are relatively insignificant), its overall volume of exports has not greatly changed over this period, as domestic consumption has absorbed most of the rapid increase in output. The composition of this trade, however, has shifted toward higher value added products. In 1995, tungstates accounted for the bulk of exports. Since then the tungstate shipments have declined by more than 60 percent, and now constitute only about 40 percent of processed tungsten products trade. Tungstate exports in 2006 contained around 6,400 of tungsten, compared to that year's APT production of 45,600 tons, as estimated by the China Nonferrous Metals Industrial Association (CNIA).



Production of tungsten and tungsten carbide powders was estimated at 20,200 tons in 2006. Net exports of both powder types totaled about 4,000 tons, 20 percent of output. Exports of tungsten carbide powder have risen steadily since the late 1990's, although they did suffer a decline in 2007, and now are twice the volume of tungsten metal powder exports, which have not shown a noticeable pattern of growth. The CNIA estimated 2006 output of tungsten ferroalloys at 11,500 tons. That year's exports of 4,600 tons were triple the level of 1995.

Both imports and exports of other tungsten products, wrought and unwrought, including scrap, have risen rapidly over the past decade. Exports rose from 144 tons in 1995 to over 2,100 tons (gross weight) in 2007. Imports have grown also, but China has consistently had a surplus in trade in these items.

Export Policies

The aforementioned shift in China's exports towards downstream, value-added products may be the result of policies implemented by the Government of China. China's trade in tungsten has been managed by a combination of export licenses, quotas, and taxes. The full details of these controls are not entirely available, but the Ministry of Foreign Trade and Economic Cooperation (MOFTEC) determines annual export quotas. Except for a small increase in 2005, the quotas have slowly but steadily contracted from 17,400 tons (tungsten content) in 2000 to 15,400 tons for 2007, with a further reduction to 14,900 announced for 2008. Aspiring exporters must obtain an export license before qualifying to be awarded part of the quota. There are also export duties levied on most categories of tungsten exports. At the start of 2008, these ranged from 5 percent, on metal and carbide powders and other unwrought items, to 10 percent on tungstates, 15 percent on scrap, and 20 percent on ferrotungsten, according to various press reports. The current rates on tungstates and ferrotungsten represent an increased from the previous year.

With only limited alternative sources of material available, China's exports have a major influence on the world supply of tungsten products. As a result, by restraining, and even reducing, its exports of tungsten products even while its output of raw material increases substantially, China's export policies may create a competitive advantage for its tungsten product manufacturers. Furthermore, as China's general industrial development continues this advantage may spread downstream to more manufactured goods containing tungsten components.

Import Reliance and Access to Materials

Heavy reliance on imported material makes consuming industries vulnerable to fluctuations in the world price and availability of such inputs. China, for example, is a major producer of many of the materials for which the United States is heavily import reliant (Table 3). In addition to tungsten, China produces at least half of the world output of antimony, arsenic, bismuth, fluorspar, indium, and rare earths, for all of which the United States is totally reliant on imports. In some cases China also maintains a great share of total global reserves, and typically exercises various controls over its exports of these commodities. At the WTO Council for Trade in Goods, in November, 2007, the United States posed questions to China about the justification for maintaining these controls on a dozen materials, including antimony, coke, fluorspar, indium, magnesium carbonate, molybdenum, rare earths, silicon, talc, tin, tungsten, and zinc.

With the increases in world demand for many materials, such policies, if widely adopted, could result in severe distortions of global markets and a difficulty for U.S. manufacturers to obtain raw material inputs in a timely and cost competitive manner.

Appendix F

Manganese

A Report on Domestic Suppliers of Selected Materials and their Reliance on Foreign Sources of Production

Manganese Strategic Considerations

The United States is 100% import reliant to meet the demand for manganese. Manganese is particularly essential to steel production, as all steels contain manganese. There are no substitutes for manganese in steel (nor in many other of its applications), so continued supply of manganese is absolutely vital to any defense effort as well as the maintenance and growth of an industrial economy.

Concerns about manganese supply for defense needs led the U.S. Government to establish a significant manganese stockpile following World War II. Manganese materials included in the stockpile were chemical-, metallurgical-, and natural-grade manganese ores; high-carbon ferromanganese; electrolytic manganese metal; and synthetic manganese dioxide. In the early 1990s, manganese supply concerns lessened because of the dissolution of the Former Soviet Union and the United States' reliance on diverse foreign sources to meet a different mix of materials. As a consequence, the stockpile goal for manganese ore was reduced to zero, and the Government embarked upon a program of disposing of existing inventories. By Fiscal Year 1999, the stockpile goals for all manganese materials except high-carbon ferromanganese were zero, and by FY 2001 that of high-carbon ferromanganese was also reduced to zero (U.S. Department of Defense, 2000, 2002).

As of December 30, 2007, the National Defense Stockpile (NDS) contained about 484,000 metric tons (t) of manganese materials (gross weight) excluding electrolytic manganese metal (table 6). This represented a 76% and 49% decrease from that of 2001 and 2006, respectively. On the basis of manganese content, the total remaining inventory at the end of 2007 was about 34% of the national apparent consumption in 2006.

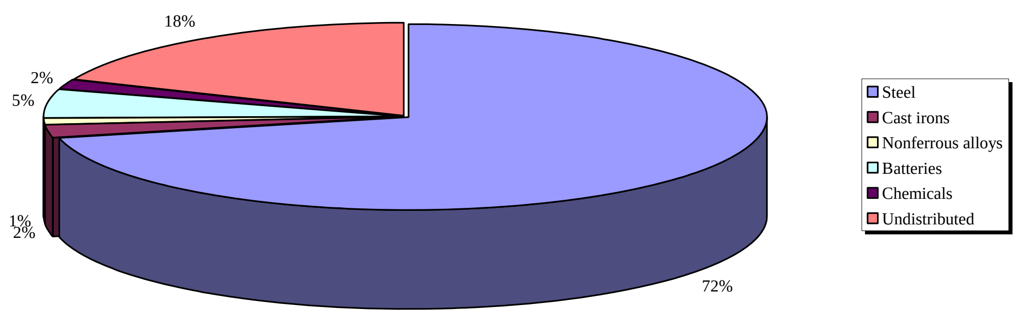
Every 2 years the USGS Minerals Information Team prepares metal commodity analyses for the Institute for Defense Analyses on materials that have been held in the NDS or that are of strategic importance. Manganese is one of the metals analyzed.

Uses

Manganese is one of the most important ferrous metals and one of the few for which the United States is 100% import reliant. It is predominantly used in metallurgical applications as an alloying addition, particularly in steel and cast iron production. The importance of manganese arises from its desulfurizing, deoxidizing, and/or alloying properties, as well as its chemical properties. Steel and cast iron together provide the largest market for manganese (historically 85% to 90%), but it is also used as an alloy with nonferrous metals such as aluminum and copper (figure 1). Nonmetallurgical applications of manganese include: battery cathodes (manganese dioxide), soft ferrites (manganese-zinc ferrites) used in electronics, micronutrients found in fertilizers and animal feed (manganese sulfate and manganous oxide), water treatment chemicals (potassium permanganate and manganese dioxide), and other chemicals (manganese dioxide) such as those used as a colorant for automobile undercoat paints, bricks, frits, glass, textiles, and tiles. The product “manganese violet” is used for the coloration of plastics, powder coatings, artists glazes, and cosmetics.

There are no substitutes for manganese in its major applications—the manufacture of steel, steel alloys, non-steel alloys, batteries, and fertilizers and animal feed.

Figure 1. U.S. Consumption by End Use of Manganese Dioxide, Ferroalloys and Metal in 2006[1]
(Based on an Estimated Apparent Consumption of 1.05 Million Metric Tons Contained Manganese)



[1]Historic data show that 85% to 90% of domestic manganese consumption has been for steelmaking. Manganese consumption in 2006 was believed to be closer to those levels than what is shown here, especially considering the significant portion of the "undistributed" end use. The undistributed end use is the difference between the amount of manganese materials apparently and reportedly consumed. Because of the incompleteness of reporting to the U.S. Geological Survey voluntary consumption survey, the information in this figure represents relative rather than absolute quantities.

More About Steel—The Largest Market for Manganese:

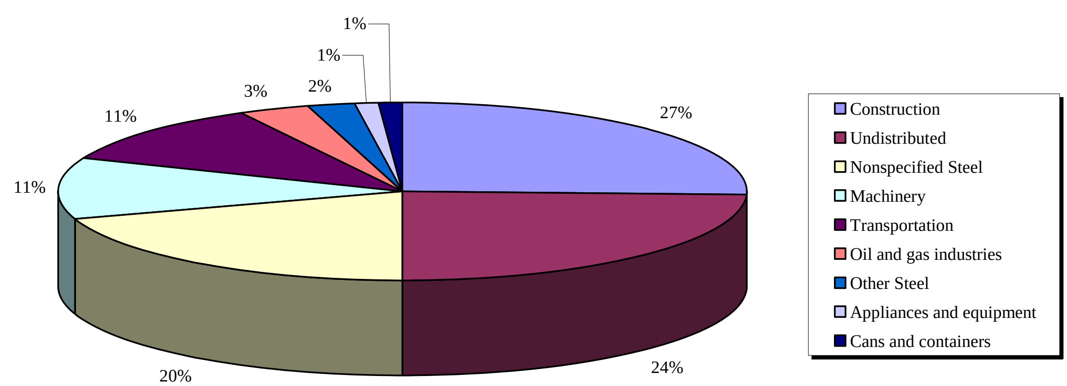
As already shown, steel production is by far the greatest application for manganese. The distribution of manganese in steel mill products is shown in figure 2. Steel-related demand was apportioned among end uses on the basis of American Iron and Steel Institute (AISI) data on shipments by market classification; assumptions as to average manganese content of steels for the respective markets; and manganese consumption data reported to the USGS voluntary consumption survey.

Net shipments of steel mill products in the United States were 99.3 million metric tons (Mt) in 2006. Shipments by market classification were: service centers (27.5%); construction (19.1%); nonclassfied (15.3%); automotive (14.2%); converting (7.7%); all other (4.1%); containers (2.8%); exports reported by companies (2.8%); oil and gas industuries (2.5%); machinery and electric (2.4%); and appliances (1.6%) (American Iron and Steel Institute, 2006, p. 28). The dominant steel grade of these products shipped was carbon (93%), followed by alloy (5%) and stainless steels (2%) (American Iron and Steel Institute, 2006, p. 22-23).

Carbon steels are determined by the amount of carbon present and are the most widely used throughout all market classifications. Manganese content of carbon steels ranges from 0.05% to 1.65%. Alloy steels are those finished steels other than those classed as carbon and stainless steels, and have a manganese content ranging from 0.05% to 2.1%. Alloy steels may be divided into full-alloy steels, high-strength low-alloy steels, and tool steels. Stainless steels are those steels that contain a minimum of approximately 11% chromium and are resistant to corrosion. Stainless steels are used in the following applications: food processing; chemical and petrochemical; transportation (aerospace, automotive, marine, and railway); tubes and pipes; construction; and other (pharmaceutical and medical applications, and electronic and electrical applications). The manganese content of stainless steels range from 0% to 19% (Davis, 1988, p. 205, p. 206, p. 347-348, and p. 364-367).

Figure 2. Manganese Consumption by Steel Market Classification in 2006[1, 2, 3]

(Based on an Estimated Apparent Consumption of 1.05 Million Metric Tons Contained Manganese)



[1]Manganese in the "undistributed" end use of figure 1 is assumed to be consumed in the manufacture of steel mill products. This is reflected by the "undistributed" steel category.

[2]"Nonspecified steel" includes steel for converting & processing, nonclassified shipments, and some steel shipped by steel service centers and distributors.

[3]"Other steel" includes forgings not elsewhere classified, industrial fasteners, and ordnance and other military products.

Manganese content of steel, averaged over all grades, is about 0.7%, and many steels have manganese contents within plus or minus 50% of this average value. Hadfield steels—those steels that contain between 10% to 14% manganese and 1% to 1.4% carbon—are produced in comparatively small tonnages. Hadfield steels are typically used in wear-resistant applications such as railroad tracks, and mining and crushing equipment. These manganese steels have the special characteristic of increasing in hardness upon impact in service while retaining toughness and ductility. The function of manganese in cast iron and cast steel production is similar to that in wrought steel. Manganese contents of ferrous castings are also similar to those of ordinary wrought steel.

Usually manganese is added as a ferroalloy to the steelmaking process. However, sometimes ore is charged directly to the steelmaking process in place of ferromanganese (FeMn), as in Japan. Low-grade ore may be used to add manganese to the burden of blast furnaces for making pig iron. Significant quantities of slag in which manganese is a minor constituent are used in construction, road building, and for other purposes.

Decisions as to which manganese ferroalloys to use in a steelmaking operation are based on a number of factors, including the relative price of manganese units contained, the composition of the steel being produced, and the steelmaking practice being employed. FeMn, particularly high-carbon ferromanganese, has tended to be the main manganese ferroalloy used by integrated steel producers, whereas scrap-based electric furnace mills (so-called “minimills”) have tended to use mainly silicomanganese (SiMn).

Principal Forms

Because most manganese materials in the United States are used in metallurgical processes and battery manufacturing, this study focuses on the principal forms of manganese—manganese ore, manganese ferroalloys, manganese metal, and manganese dioxide.

Manganese Ore:

Manganese ore is the primary source of manganese used in the manufacture of manganese ferroalloys, metal, and dioxide. Virtually all manganese ores are subjected to some form of beneficiation to achieve a concentrated product having greater manganese content and fewer undesirable impurities. Manganese content of the more commonly used and traded ores, concentrates, nodules, and sinter for metallurgical purposes is in the approximate range of 38% to 55%. A manganese content of 48% is considered standard as a pricing basis. The composition of ores used for chemical purposes and in batteries may be approximately the same as that of metallurgical ores although particle size tends to be smaller. For battery-grade dioxide ores the manganese content may be expressed in terms of the active ingredient, MnO2, which contains 63% manganese. Dioxide ores typically contain from 70% to 85% MnO2 (44% to 54% manganese), but can be less as in local ore consumed in uranium extraction operations in South Africa.

Manganese Ferroalloys:

The key manganese ferroalloys are FeMn, which is subdivided into standard (high-carbon), medium-carbon, and low-carbon grades and SiMn. High-carbon FeMn is smelted directly in either a blast furnace or an electric submerged-arc furnace (SAF) and SiMn in a SAF; the latter is predominantly used throughout the world including the United States. SiMn is smelted in a similar manner as that of high-carbon FeMn, except a more siliceous charge, usually in the form of quartz, quartzite or an ore having high silica content, is used. When SAFs are used, high-carbon FeMn and SiMn can be produced interchangeably. Production of refined grades of manganese ferroalloys, such as medium- and low-carbon FeMn, involves two additional stages using equipment such as a converter or a direct arc furnace.

Exxaro Resources Limited (formerly Kumba Resources Limited) successfully demonstrated its new AlloyStream™ technology to produce ferromanganese directly from fine manganese ore at its Pretoria, South Africa, pilot plant. The use of such ores was previously limited by existing smelting technologies (Kumba Resources Limited, 2006). The AlloyStream technology reportedly lowers the cost of ferromanganese production by 30% to 50% by using cheaper reductant and less electric power than conventional technology (Metals Place, 2006).

Manganese Metal:

Manganese metal with a purity of not much greater than 96% can be produced electrothermically by smelting in electric arc furnaces, as is the case in Ukraine. Most production of metal is by an electrolytic process, and for most grades industry specifications call for a total manganese content of at least 99.5%, of which a minimum of 99.9% is metallic. Processing for electrolytic manganese metal (EMM) typically yields material in the form of a flake, which may be ground into a powder. Its relatively high price limits EMM use to the production of some stainless steel, aluminum, and copper alloys. In addition to EMM, master alloys and briquettes are used for alloying manganese with aluminum and copper. In the United States, manganese is added to aluminum melts principally in the form of briquettes that are made by compacting manganese and aluminum powders.

Manganese Dioxide:

Manganese dioxide for battery applications is available in both mineral and synthetic forms. These include natural manganese dioxide ore and two forms of synthetic dioxide—electrolytic manganese dioxide (EMD) and chemical manganese dioxide (CMD), which are produced electrolytically and chemically, respectively. The manganese dioxide content of EMD ranges from 90% to 92% with a corresponding manganese content range of 57% to 58%. The manganese dioxide content of CMD is generally around 90%, with a corresponding manganese content of 57%.

Sources

Manganese Ore:

The United States possesses no reserves of manganese ore containing 35% or more manganese or from which concentrates of such grade could be commercially produced. As a result, manganese ore is not mined in the United States, except for ultra low-grade manganese schists that contain less than 5% manganese at 2 mines in South Carolina—the Grover and Martin Mines. Manganese recovered from these mines is used as a brick colorant. Estimated manganese content of world manganese ore reserves in 2007 totaled 460 Mt. World manganese ore production, on a contained weight basis, was 11.9 Mt in 2006 (figure 3), led by South Africa, Australia, China, Brazil, Gabon, Ukraine, and India in order of production (figure 4).

Nearly all manganese-bearing ores and iron ores contain both manganese and iron. Most such ore is consumed in the production of manganese ferroalloys or pig iron, in which manganese and iron are simultaneously recovered. Otherwise, manganese coproduction with other metals and, conversely, manganese byproduct recovery are insignificant.

Figure 3. World Manganese Ore Production

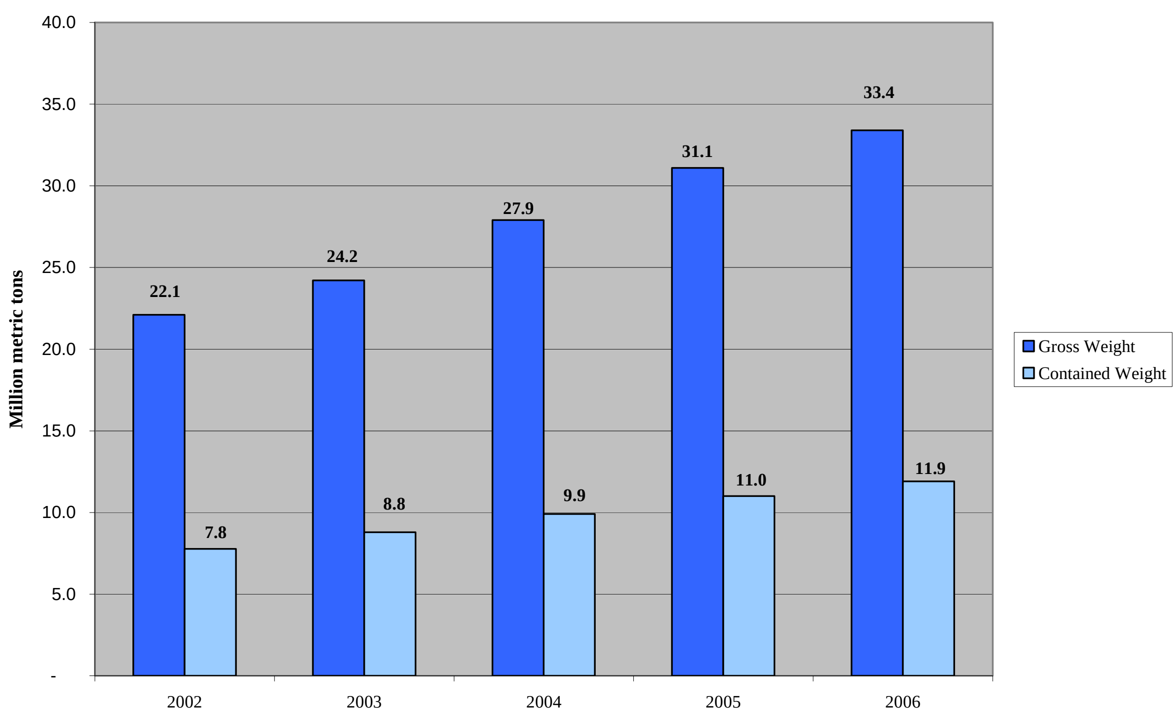
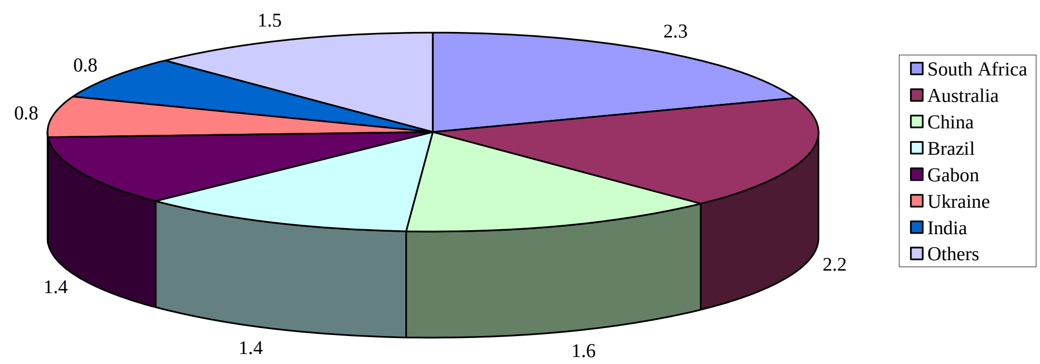


Figure 4. Seven Countries Produced 88% of World Manganese Ore Supply in 2006

Data in million metric tons (metal content)



Production in most of the larger producing countries is by only one or two companies at a limited number of mines, and in some cases, only at one mine. This contrasts with the numerous mines in Brazil, China, and India. Major manganese mining operations are identified on table 1.

TABLE 1
MAJOR MANGANESE ORE PRODUCERS BY COUNTRY

(Annual capacity, thousand metric tons, gross weight)

Major Producers	Mining Operations[1]
Australia	
Consolidated Minerals Limited	Woodie Woodie Mine (1,100)
Groote Eylandt Mining Company Co. Pty. Ltd. (GEMCO)[2]	Groote Eylandt Mine (3,400)
Brazil	
Companhia Vale do Rio Doce (CVRD)	Azul Mine (2,200); Urucum Mine (425)
China	
Guangdong Luoding Xinrong Mengkuang	Guangdong Luoding Xinrong Mine (200)
Guangxi Zhuang Autonomous Region Daxin Manganese Mine	Guangxi Daxin Mine (195)
Hunan Dongfang	Hunan Dongfang (200)
Taojiang, Xiangtaoyuan	Xiangtaoyuan Mine (150)[3]
Xiangtan Manganese Mine	Xiangtan Mine (150)[3]
Gabon	
Eramet Comilog	Moanda Mine (3,000) and sintering plant (600)
Ghana	
Ghana Manganese Company Limited	Ghana, Nstua Mine (1,725)[4]
India	
Manganese Ore India Ltd.	10 mines (1,400)
Kazakhstan	
Eurasian Natural Resources Corporation	4 mines (700)[5]
Ispat-Karmet (formerly Atasuruda Ltd.)	Zapadny Karahal and Bolshoi Ktai Mines (625)[5]
Mexico	
Compañia Minera Autlán S.A.B. de C.V.	Molango Mine (589)[6]
Morocco	
Société Anonyme Chérifienne d'Etudes Minières (Sacem)	Imini Mine (65)[7]
South Africa	
Assmang	Gloria Mine (1,000) and Nchwaning Mine (3,840)
Samancor Manganese	Mamatwan (2,800) and Wessels Mines (1,000)
Ukraine	
Marganetsky GOK	Marganets Mining Complex (3,200)[5]
Ordzhonikidzovsky GOK	Ordzhonikidze Mining Complex (2,300)[5]

[1]Capacity noted in parentheses as of 2006, unless otherwise indicated.
[2]Operated by Samancor Manganese.
[3]Includes ore and sinter production.
[4]Exports, thousand metric tons, gross weight (Ghana Manganese Company Limited, 2004).
[5]Annual concentrate capacity in thousand metric tons, gross weight.
[6]Nodulizing plant capacity.
[7]Capacity taken as highest amount produced from 1986-2006.

Manganese Ferroalloys:

Manganese ferroalloy production waxed and waned in the United States in the 20th century. Until the 1970s, most ferromanganese was produced in blast furnaces operated by steel and merchant alloy producers. Production peaked at slightly more than 1 Mt in 1965. Some FeMn and all SiMn were produced in electric arc furnaces at a number of sites. Particularly in the last quarter of the 20th century, manganese ferroalloy production and the number of producers decreased until production at the turn of the 21st century continued only at Marietta, OH. Production of ferroalloys at this site extended back to the early 1950s, and came under the control of Eramet S.A. (France) in 1999. Since that time, the renamed Eramet Marietta Inc. has produced SiMn and all grades of FeMn. Later, two other companies produced some SiMn in the United States in 2000 to 2005. Felman Productions, Inc. produced SiMn on and off at its New Haven, WV, plant since September 2002. Globe Metallurgical Inc., a historic U.S. ferrosilicon and silicon metal manufacturer, produced SiMn at its Beverly, OH, plant during the first quarter of 2005, but discontinued production shortly thereafter.

Ferroalloy plants originally tended to be located in consuming or steel-producing countries, but the more recent trend is for a greater share of production to take place in the major ore-producing countries. Perhaps the most significant development was China's emergence in the 1990s as the world leader in manganese ferroalloy production and exports. China's combined output of FeMn and SiMn grew from 850,000 t in 1990 to 5.6 Mt in 2006. Production growth in China was spurred by the establishment of toll smelting arrangements whereby major ore producers had ore converted into ferroalloys for export.

World manganese ferroalloy production was 12.3 Mt in 2006 (figure 5). Leading FeMn producers were, in order of production, China, South Africa, Japan, Ukraine, and Brazil (figure 6). Top SiMn producers were China, Ukraine, South Africa, Brazil, and Norway (figure 7). Major manganese ferroalloy operations are identified on table 2.

Figure 5. Manganese Alloy World Production

Gross Weight

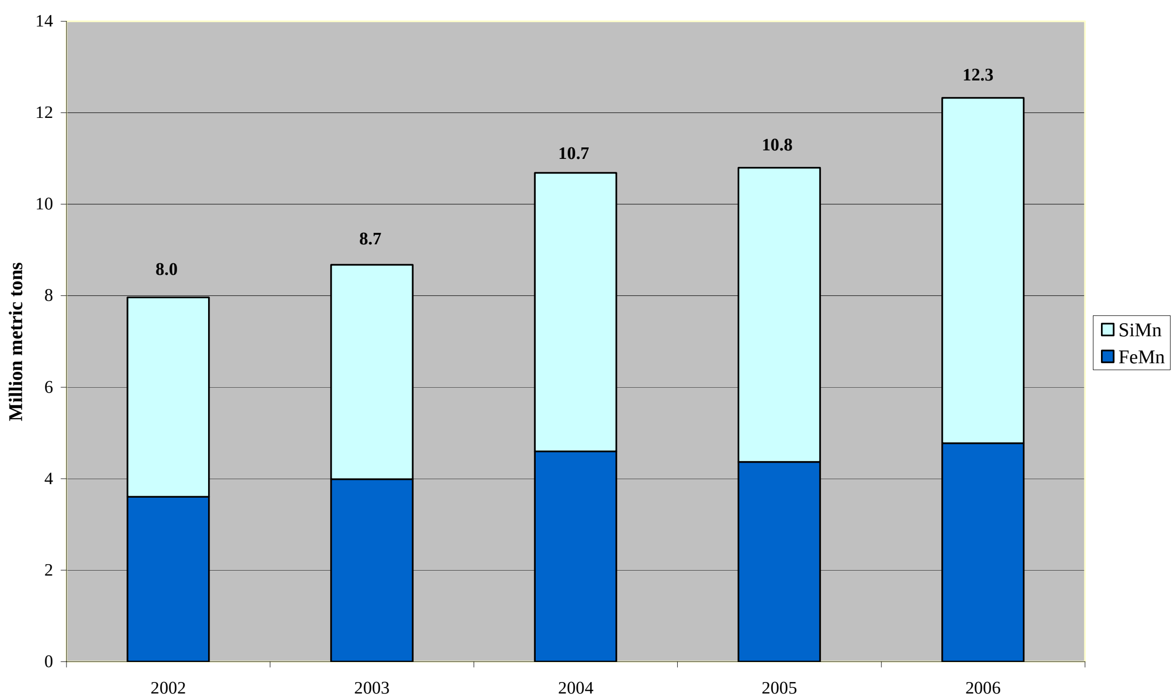


Figure 6. Five Countries Produced 75% of World FeMn Supply in 2006

Data in million metric tons (gross weight)

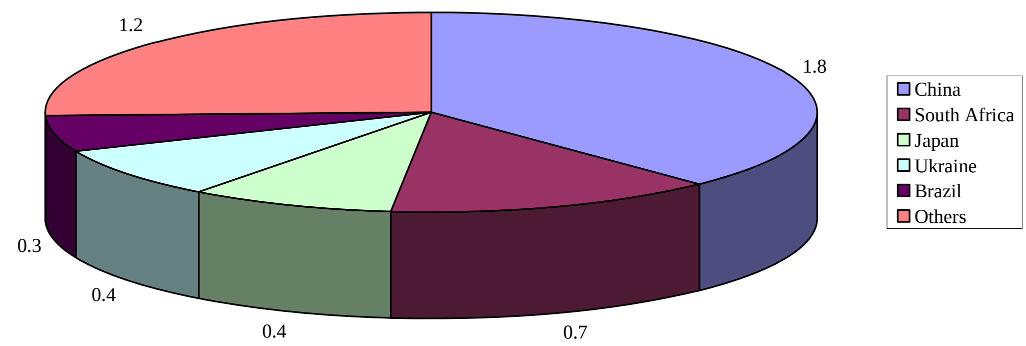


Figure 7. Five Countries Produced 77% of World SiMn Supply in 2006

Data in million metric tons (gross weight)

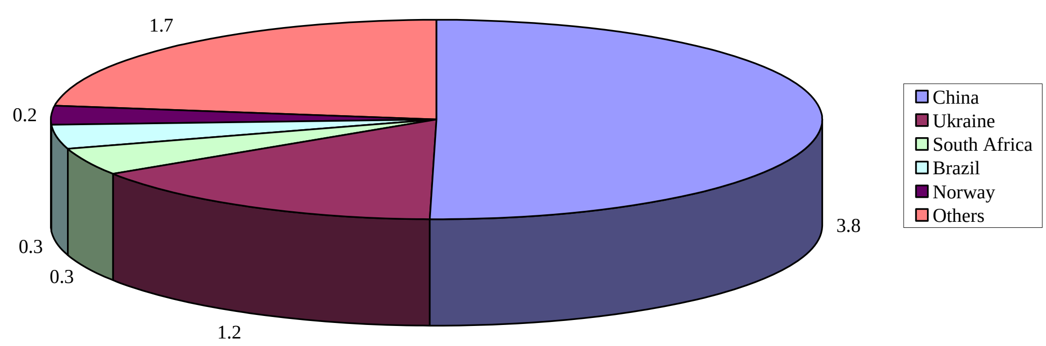


TABLE 2

MAJOR MANGANESE FERROALLOY PRODUCERS BY COUNTRY

(Annual capacity, thousand metric tons, gross weight)

Major Producers	Ferroalloy Operations[1]
Argentina	
Industrias Siderurgica Grassi, S.A.	FeMn, SiMn (45)[2, 3]
Australia	
Tasmanian Electro Metallurgical Company (TEMCO)[4, 5]	HC FeMn (128), SiMn (126)
Brazil	
Companhia Vale do Rio Doce (CVRD)	
CVRD Rio Doce Manganês	HC FeMn, MC FeMn, and SiMn (600)
China	
Eramet S.A.	
Bayhi Ferro-alloy Works	HC FeMn (80)
Guilin Ferro-alloy Works	HC FeMn, SiMn (140)
Erdos EJM Manganese Alloys Co.[6]	SiMn (75)
Henan Anyang Xinxin Ferroalloys	SiMn (70)
Hunan Ferroalloy Group Company Limited	FeMn, SiMn (150)
Jinzhou Nichiden Ferroalloy Company	SiMn (50)
OM Holdings Qinzhou Plant	SiMn (60)
Shanghai Shenjia Ferroalloys Co. Ltd.	HC FeMn, LC FeMn, MC FeMn, SiMn, Nitrided FeMn (200)
Xiangtan Manganese Mine	FeMn (100)[3]
Zunyi Ferroalloy (Group) Co., Ltd.	HC FeMn, LC FeMn, MC FeMn, SiMn (220)
France	
Eramet Comilog Dunkerque (Eramet S.A.)	SiMn (70)
CVRD Rio Doce Manganèse Europe	SiMn (140)
Georgia	
Zestafonskiy Ferro-Alloy Works	FeMn (180)[3], SiMn (240)[3]
India	
Balasore Alloys Ltd.	FeMn, SiMn (60)[3]
Maharashtra Elektrosmelt Ltd.	HC FeMn, LC FeMn, MC FeMn, SiMn (100)[3]
Maithan Alloys Ltd.	FeMn, SiMn (53)
Nava Bharat Ventures Limited	FeMn, SiMn (125)
Japan	
Mizushima Ferroalloy Co. Ltd.	HC FeMn, LC FeMn, MC FeMn, SiMn (230)
Nippon Denko	HC FeMn, LC FeMn, MC FeMn, SiMn (277)[3]
Korea, Rep. of	
Dongbu Group	HC FeMn (45)[3], LC FeMn & MC FeMn (50)[3], SiMn (45)[3]
Dongil Industries Co. Ltd.	HC FeMn (49)[3], SiMn (40)[3]
Han Hap Corp.	HC FeMn (49)[3], SiMn (38)[3]
Macedonia	
Skopski Leguri	SiMn (70)[3]
Mexico	
Compañia Minera Autlán S.A.B. de C.V.	HC FeMn, MC FeMn, and SiMn (225)
Tamós	
Teziutlán	
Gómez Palacia	
Norway	
CVRD Rio Doce Manganese Norway	HC FeMn, SiMn (140)
Eramet	HC FeMn, LC FeMn, MC FeMn, SiMn (360)
Tinfos Jernverk	HC FeMn (240) or SiMn (180)

See footnotes at end of table.

TABLE 2--Continued
MAJOR MANGANESE FERROALLOY PRODUCERS BY COUNTRY

(Annual capacity, thousand metric tons, gross weight)

Major Producers	Ferroalloy Operations[1]
Poland	
Huta Laziska	SiMn (27)[3]
Romania	
Ferom SA	FeMn (176)[3]
Saudia Arabia	
Gulf Ferro Alloys Co.	FeMn, SiMn (83)[2, 3]
South Africa	
Assmang Limited	
Cato Ridge Works	HC FeMn (175)[3], MC FeMn (50)[3]
Cato Ridge Alloys[7]	LC FeMn , MC FeMn (60)
Samancor Manganese	
Metalloys	HC FeMn, MC FeMn, SiMn (490)
Advalloys	LC FeMn (82)
Transalloys[8]	MC FeMn (50)[3], SiMn (175)[3]
Ukraine	
JSC Nikopol Ferroalloys Plant	FeMn, SiMn (1,250)
Zaporozhye Ferroalloy Works	FeMn, SiMn (1,750)[e]
United States	
Eramet Marietta Inc. (Eramet S.A.)	HC FeMn, LC FeMn, MC FeMn, SiMn (200)
Felman Productions, Inc.	SiMn (131)[e]
Venezuela	
Ferroven	FeMn (38)
Hornos Electricos de Venezuela SA	SiMn (70)[3]

[e]Estimated. FeMn, ferromanganese; HC FeMn, high carbon ferromanganese; LC FeMn, low-carbon ferromanganese; MC FeMn, medium-carbon ferromanganese; SiMn, silicomanganese.
[1]Installed capacity noted in parentheses as of 2006, unless otherwise indicated.
[2]Includes production of silicon ferroalloys and/or silicon metal.
[3]Roskill Information Services Ltd, 2003.
[4]Company can also produce up to 335,000 t of manganese sinter.
[5]Operated by Samancor Manganese.
[6]A joint venture between Erdos Electric Power Metallurgy Co., Ltd. (51%), JFE Steel Corporation (24.5%), and Mitsui & Co. (24.5%).
[7]A joint venture between Assmang (50%), Mizushima Ferroalloys Company Limited (40%), and Sumitomo Corporation (10%).
[8]A division of Highveld Steel and Vanadium Corporation.

Manganese Metal:

Manganese metal is produced in higher purity grades as an electrolytic product and in lower purity grades as a metallurgical product, the latter usually based on silicon as a reducing agent, such as at the Zaporozhye Ferroalloys plant in Ukraine. Manganese metal is produced only in a few countries, and, as of 2001, EMM was only produced in China and South Africa. China was by far the dominant producer of EMM with an annual production capacity of about 1.79 Mt in 2007—35 times greater that of the next leading producing country South Africa. China's EMM output grew from 152,000 t in 2001 to 1.02 Mt in 2007. This explosive growth was primarily attributable to ever increasing demand by the country's alloy, special, and stainless steel sectors. Metal from China has contained selenium as an impurity element because of the technology employed; selenium can be toxic to humans in certain forms. South Africa's annual capacity of 51,300 t in 2007 consisted of that at Manganese Metal Company's Krugersdorp and Nelspruit plants. For many years, EMM had been produced in the United States at Hamilton, MS, and Marietta, OH. Production at these sites was discontinued first in the latter half of 2000 at Marietta (Eramet Marietta Inc.) and then in the first half of 2001 at Hamilton (formerly Kerr-McGee Chemical LLC). Major EMM operations are identified on table 3.

TABLE 3
MAJOR ELECTROLYTIC MANGANESE METAL PRODUCERS BY COUNTRY

(Annual capacity, thousand metric tons, gross weight)

Country	Capacity[1]
China[2]	
Chongqing Province	
Chongqing Wuling Manganese Industry Corporation	30.2
Guangxi Province	
CITIC Dameng Manganese Mining Co., Ltd.	62.0
Hunan Province	
Hunan Tycoon Group	50.0
Ningxia Province	
Ningxia Tianyuan Manganese Industry Co. Ltd.	72.0
Georgia	
Zestafonskiy Ferro-Alloy Works	5.0
South Africa	
Manganese Metal Company	51.3
Ukraine	
Zaporozhye Ferro-Alloy Works[3]	12.0

[1]Capacity as of yearend 2006.

[2]China had a total annual production capacity of about 1,210,000 metric tons in 2006 (Zhengmao, 2007).

[3]Manganese metal was produced silicothermically rather than electrolytically in 2006.

Manganese Dioxide:

Production of synthetic manganese dioxides as a preferred replacement for natural manganese dioxide in dry cell batteries was stimulated by military requirements of the two World Wars of the 20th century. Globally, EMD has proved to be the principal form of synthetic manganese dioxide. Battery applications have had the highest growth rate of the various manganese end use categories during at least the past several decades. Production of EMD has expanded accordingly and world annual capacity was about 456,000 t in 2007, up from 310,000 t in 2003. China's annual production capacity was 46% of the world total; this was almost triple that of Japan, the next leading producing country, and 3.3 times greater than that of the United States. As of 2007, the U.S. producers were Energizer Holdings, Inc., at Marietta, OH, Erachem Comilog at New Johnsonville, TN, and Tronox Incorporated (formerly Kerr-McGee Chemical LLC) at Henderson, NV. Major EMD operations are identified on table 4.

CMD is an alternative to EMD in batteries; its use is thought to be favored mostly in Western Europe. The principal producer of CMD is Belgium's Erachem Comilog Europe SA (formerly

Sedema SA), whose annual capacity as of the mid-1990s was about 36,000 t. Erachem Comilog also produces CMD at its Baltimore, MD, plant.

TABLE 4
MAJOR ELECTROLYTIC MANGANESE DIOXIDE PRODUCERS BY COUNTRY

(Annual capacity, thousand metric tons, gross weight)

Country	Capacity[1]
Australia	
Delta EMD	27.0
Brazil	
Eletro Manganês Ltda.	5.8
Sociedade Brasilera de Eletrólise	6.0
China	
Eramet S.A.	
Guangxi	20.0
Guizhou Red Star Dalong	16.0
Hunan JMC-Xinshao Co., Ltd. (JMC-XS)	15.0
Xiangtan Electrical Stock Co. Ltd.	40.0
Yizhou Manganese Industry Co. Ltd.	20.0
Zunyi Shuangyuan Chemicals Group Co., Ltd.	20.0
Greece	
Tekkosha Hellas[2]	19.0
India	
Eveready Industries India Ltd.	5.0
Manganese Ore (India) Limited	1.0
Japan	
Japan Metals & Chemicals Co., Ltd.	18.0
Mitsui Mining and Smelting Co.	24.6
Tosoh Corporation	34.0
South Africa	
Delta EMD	35.0
Spain	
Grupo Cegasa	6.0
United States	
Erachem Comilog	25.0
Energizer Holdings Inc., Eveready Battery Co.	12.0
Tronox Incorporated	27.0

[1]Capacity as of yearend 2006.
[2]Owned by Tosoh Corporation (Japan).

Manganese Recycling:

Processing of metal scrap specifically for recovery of manganese is insignificant. Manganese is recycled mostly as a constituent of iron and steel scrap, but the primary purpose is to reclaim iron. One exception is scrap of the relatively small quantities of high-manganese Hadfield steel, for which segregation for its manganese content is perhaps warranted. Recycling of iron and steel scrap is a well-established component of domestic steel production. It is the basis of the electric furnace process for steelmaking, which in 2006 accounted for about 43% of domestic steel production (Fenton, 2008, p. 38.2). In integrated plants, manganese is recycled internally in steelmaking as a constituent of steel slag, some of which may be added to the blast furnace burden. However, slag is recycled primarily to reclaim iron and to utilize the lime and magnesia it contains to achieve proper slag basicity in newly generated slags.

Manganese also is recycled internally at ferroalloy plants. Where production is integrated, slag from production of high-carbon ferromanganese can be part of the charge to a silicomanganese furnace. Fines and off-grade material can be remelted or otherwise used in the plant, such as by use of silicomanganese fines to provide silicon to a silicothermic reduction step. At a number of plants, ferroalloy is being recovered from slags in slag dumps, principally by jigging (Parker, 2000).

In 1998, 218,000 t of manganese was estimated to have been recycled from old scrap, of which 96% was from iron and steel scrap. Recycling efficiency was estimated to be 53% on the basis of the recycling of old iron and steel scrap plus a small amount of old used aluminum beverage cans, and the recycling rate, 37%. Metallurgical loss of manganese was estimated to be about 1.7 times that recycled, mostly into slags from iron and steel production from which recovery of manganese has yet to be shown economically feasible (Jones, 2004, p. H1, H4).

Supply and Demand

Supply-distribution relationships for the United States are shown for 2001 through 2006 in table 5. These data do not include inputs and/or outputs of manganese in steelmaking slags and scrap. Manganese input from iron-bearing pellets and ores charged to iron blast furnaces also is omitted. For such iron feed materials, the overall average manganese content is less than 0.1%, but the quantity is quite large so that from these sources roughly 40,000 t of manganese is fed to U.S. iron blast furnaces in a typical year. The average manganese content of ironmaking feed materials has declined, and has been below the 0.1% level for at least the past decade. This trend is not expected to lead to a significant increase in demand for manganese units.

TABLE 5

U.S. MANGANESE SUPPLY-DEMAND RELATIONSHIPS, 2001-2006

(Thousand metric tons, manganese content)

	2001	2002	2003	2004	2005	2006
COMPONENTS AND DISTRIBUTION OF U.S. SUPPLY						
Domestic mines	--	--	--	--	--	--
EMD production	W	W	W	W	W	W
EMM production	W	--	--	--	--	--
Ferroalloy production[1]	W	W	W	W	W	W
Shipments of Government stockpile excesses	76	71	56	208	72	129
Imports, ore	199	214	175	234	334	270
Imports, EMD	23	22	29	16	19	22
Imports, ferroalloy	378	383	389	635	452	543
Imports, metal	21	22				32
Industry stocks, Jan. 1	173	152	139	123	120	199
Total U.S. supply	870	864	788	1,216	997	1,195
Distribution of U.S. supply:						
Industry stocks, Dec. 31	152	139	123	120	199	115
Exports, ore[2]	5	15	11	64	10	5
Exports, ferroalloy	19	14	11	10	15	22
Exports, metal	2	--				
Industrial demand	694	696	643	1,022	773	1,053
U.S. DEMAND PATTERN						
Appliances and equipment	11	11	8	15	10	12
Batteries	66	51	50	59	63	64
Cans and containers	21	24	14	24	22	17
Chemicals	27	28	28	25	32	21
Construction	212	190	202	296	210	248
Machinery	88	76	71	125	80	104
Oil and gas industries	27	17	17	29	24	29
Transportation	80	74	78	126	76	107
Other[3]	162	225	175	323	256	451
Total U.S. primary demand	694	696	643	1,022	773	1,053

-- Zero. EMD electrolytic manganese dioxide. EMM electrolytic manganese metal. W Withheld to avoid disclosing company proprietary data.

[1]Includes high-, medium-, and low-carbon ferromanganese and silicomanganese.

[2]Includes EMD.

[3]Includes nonspecified and other steel uses, and processing losses.

The United States is 100% import reliant to meet the demand for manganese. U.S. net import reliance, as a percentage of apparent consumption, was 100% for manganese in 2006, the same as it had been since 1985. In U.S. foreign trade of manganese ore, ferroalloys, and metal imports have been much greater than exports. For 2003 through 2006, in terms of manganese content for imports overall, the leading sources were, in descending order, South Africa (35%), Gabon (22%), Australia (8%), and China (7%) (Corathers, 2008b).

In the absence of domestic commercial-grade ore (35% or more manganese) mining, new additions to the manganese supply of the United States have come either from imports or from sales of Government stockpile materials. Imports of manganese in upgraded forms were greater than those of ore, generally 2:1 or greater as measured by the ratio of imports of ferroalloys plus metal divided by imports of ore plus dioxide. Manganese ferroalloys have accounted for the majority of imports of upgraded material.

For the past several decades, sales of NDS materials have supplied a supplementary but significant portion of U. S. demand, mostly as ore (table 6). In keeping with the "just-in-time" approach adopted by industrial users, industry of manganese in all forms have been on a downward trend in recent years.

TABLE 6
U.S. GOVERNMENT PHYSICAL INVENTORIES FOR MANGANESE MATERIALS
AS OF CALENDAR YEAREND[1]

(Metric tons)

Material	2001	2002	2003	2004	2005	2006	2007
Chemical-grade manganese ore							
Gross weight	138,000	112,000	112,000	38,500	27,000	868	456
Mn content[e]	72,000	58,400	58,300	20,000	14,100	452	238
Electrolytic manganese metal							
Gross weight	2,990	2,090	454	--	--	--	--
Mn content[e]	2,990	2,090	454	--	--	--	--
High-carbon ferromanganese							
Gross weight	797,000	760,000	725,000	676,000	627,000	552,000	461,000
Mn content[e]	598,000	570,000	543,000	507,000	470,000	414,000	346,000
Metallurgical-grade manganese ore							
Gross weight	945,000	919,000	890,000	603,000	409,000	372,000	5,200
Mn content[e]	336,000	309,000	303,000	186,000	161,000	102,000	1,300
Natural battery-grade manganese ore							
Gross weight	103,000	100,000	55,300	23,900	18,400	17,600	15,900
Mn content[e]	51,600	50,100	27,700	12,000	9,190	8,780	7,950
Synthetic manganese dioxide							
Gross weight	2,730	2,730	2,730	2,730	266	2,610	1,240
Mn content[e]	1,540	1,540	1,540	1,540	150	1,470	697
Total							
Gross weight	1,990,000	1,900,000	1,780,000	1,340,000	1,080,000	945,000	484,000
Mn content[e]	1,060,000	991,000	935,000	726,000	654,000	526,000	356,000

[e]Estimated. -- Zero.
[1]Data rounded to no more than three significant digits; may not add to totals shown.

Domestic Manganese Ore Supply:

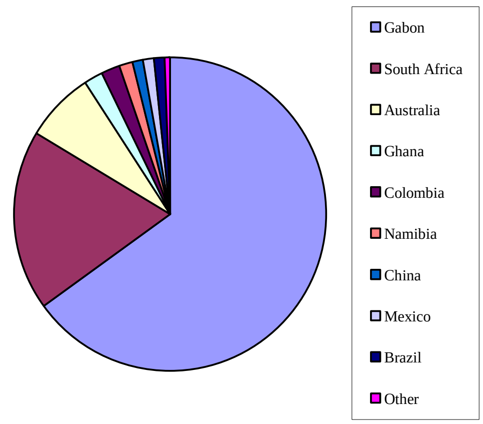
Manganese ore products containing 35% or more manganese have not been produced domestically since 1970. The last year in which there were shipments of domestic ore was 1984, and those were of ferruginous manganese ore (11% average manganese content) that were coproduced during iron ore mining. Since then, the only mining in the United States has been insignificant quantities of the low-grade manganese schists in the Carolinas that are used as a brick colorant. The leading sources of ore imports for 2003 to 2006 are shown in table 7.

TABLE 7
TOTAL U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE (20% OR MORE Mn) FROM 2003-2006

(Metric tons)

Country	Gross weight	Percent of total
Australia	143,124	7.1%
Brazil	21,850	1.1%
China	25,555	1.3%
Colombia	39,152	1.9%
Gabon	1,317,629	65.0%
Ghana	41,293	2.0%
Mexico	23,087	1.1%
Namibia	26,017	1.3%
South Africa	379,285	18.7%
Other[1]	9,654	0.5%
Total:	2,026,646	100.0%

[1]Category represents the combined totals of Belgium, Colombia, France, Georgia, India, Morocco, Poland, and the United Kingdom.



Domestic Manganese Ferroalloy Supply:

Ferroalloy production statistics for the United States are not published by the USGS to avoid disclosing company proprietary data. Even with domestic production, 758,000 t of manganese ferroalloys were imported in 2006. The leading sources of FeMn and SiMn imports for 2003 to 2006 are shown in tables 8 and 9, respectively.

TABLE 8
TOTAL U.S. IMPORTS FOR CONSUMPTION OF FERROMANGANESE FROM 2003-2006

(Metric tons)

Country	Gross weight	Percent of total
Australia	47,841	3.7%
Brazil	67,016	5.2%
China	177,475	13.9%
France	43,598	3.4%
Korea, Rep. of	69,694	5.4%
Mexico	72,286	5.7%
Norway	42,056	3.3%
South Africa	657,749	51.4%
Ukraine	34,133	2.7%
Other[1]	67,008	5.2%
Total:	1,278,856	100.0%

[1]Category represents the combined totals of Austria, Canada, Egypt, France, Georgia, Hong Kong, Italy, Japan, Nauru, the Netherlands, Romania, Russia, Saudia Arabia, Spain, Switzerland, Turkey, the United Kingdom, and Venezuela.

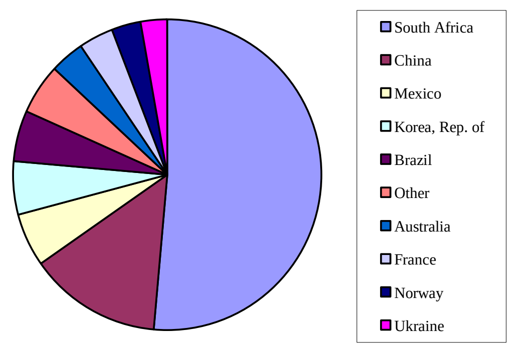
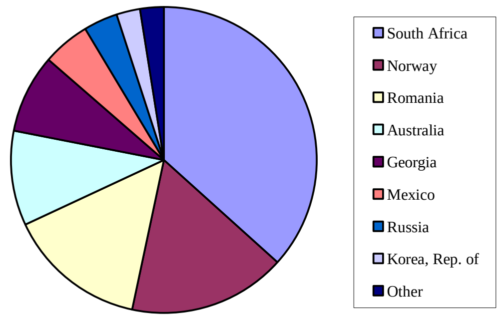


TABLE 9
TOTAL U.S. IMPORTS FOR CONSUMPTION OF SILICOMANGANESE FROM 2003-2006

(Metric tons)

Country	Gross Weight	Percent of Total
Australia	141,699	10.0%
Georgia	118,876	8.4%
Korea, Rep. of	37,516	2.6%
Mexico	68,516	4.8%
Norway	237,076	16.7%
Romania	207,676	14.7%
Russia	51,110	3.6%
South Africa	519,096	36.6%
Other[1]	35,246	2.5%
Total:	1,416,811	100.0%

[1]Category represents the combined totals of Argentina, Austria, Brazil, Canada, France, Gabon, Kazakhstan, Macedonia, Morocco, the Netherlands, Saudi Arabia, Slovak Republic, Spain, Ukraine, the United Kingdom, and Venezuela.



Domestic Manganese Metal Supply:

The United States is wholly dependent on imports of manganese metal to meet its demand. While official U.S. trade statistics for 2006 show nominal imports of unwrought manganese metal coming from Brazil (73 t), Germany (836 t), the Netherlands (18 t), Russia (21 t), and Spain (496 t), the only countries producing manganese metal electrolytically were China and South Africa during the year. Imports from these 2 countries in 2006 were 21,200 t (China) and 39,700 t (South Africa). The leading sources of manganese ferroalloy imports for 2003 to 2006 are shown in table 10.

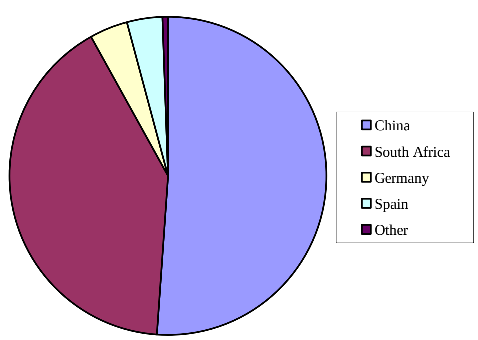
TABLE 10
TOTAL U.S. IMPORTS FOR CONSUMPTION OF MANANGESE METAL (FLAKE, POWDER AND OTHER) FROM 2003-2006

(Metric tons)

Country	Gross weight	Percent of total
China	59,369	51.1%
Germany	4,406	3.8%
South Africa	47,553	40.9%
Spain[1]	4,382	3.8%
Other[2]	542	0.5%
Total:	116,252	100.0%

[1]Spain's production of manganese metal is by electrothermic process.

[2]Category represents the combined totals of Brazil, Hong Kong, the Netherlands, Norway, Poland, Russia, Tawain, and the United Kingdom.



Domestic Manganese Dioxide Supply:

EMD production data in the United States are not published to avoid disclosing company proprietary data. There were 3 U.S. companies that produced EMD in the United States in 2006. In addition to domestic production, about 36,400 t of manganese dioxide, on a gross weight basis, were imported during that year to meet U.S. demand. The leading sources of manganese dioxide imports for 2003 to 2006 are shown in table 11.

TABLE 11

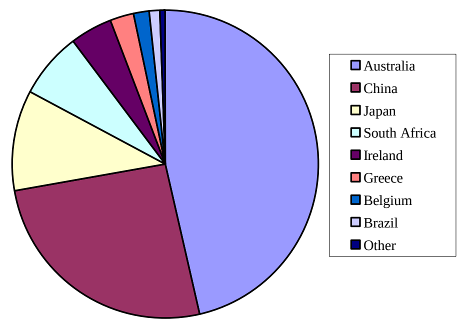
TOTAL U.S. IMPORTS FOR CONSUMPTION OF MANGANESE DIOXIDE (CHEMICAL AND ELECTROLYTIC) FROM 2003-2006

(Metric tons)

Country	Gross weight	Percent of total
Australia	66,502	46.3%
Belgium[1]	2,330	1.6%
Brazil	1,736	1.2%
China	37,283	25.9%
Greece	3,590	2.5%
Ireland	6,605	4.6%
Japan	15,260	10.6%
South Africa	9,727	6.8%
Other[2]	700	0.5%
Total:	143,733	100.0%

[1]Imports from Belgium are chemical manganese dioxide. All other imports are thought to be electrolytic manganese dioxide.

[2]Category represents the combined totals of Colombia, France, Germany, India, Indonesia, Mexico, the Netherlands, Poland, Singapore, Spain, and the United Kingdom.



Domestic and Foreign Suppliers of Manganese Materials:

A list of domestic producers and other suppliers of manganese materials is found in table 12. A list of specific companies who exported manganese materials to the U.S. domestic market in 2007 is found in Appendix A.

TABLE 12
DOMESTIC PRODUCERS AND OTHER SUPPLIERS OF MANGANESE PRODUCTS IN 2007

		Products[1]				
Company	Location	Mn Ore	FeMn	SiMn	MnO_2	EMM
Producers:						
Energizer Holdings, Inc., Eveready Battery Co.	Marietta, OH				X	
Erachem Comilog	Baltimore, MD				X[2]	
Do.	New Johnsonville, TN				X[3]	
Eramet Marietta Inc.	Marietta, OH		X	X		
Felman Productions, Inc.[4]	New Haven, WV			X		
Tronox Incorporated	Henderson, NV				X	
Other Suppliers:						
BHP Billiton Marketing, Inc.[5]	Pittsburgh, PA	X	X	X	X	X
CCMA LLC	Buffalo, NY	X	X	X		
Eramet S.A., Eramet Comilog	Baltimore, MD	X			X	
Do.	New Johnsonville, TN	X			X	
Eramet S.A., Eramet Marietta Inc.	Marietta, OH	X		X		
Globe Specialty Metals Inc.[6]	New York, NY		X	X		
Hascor USA, Inc.	San Antonio, TX					X
Honeywell Specialty Materials	Morristown, NJ				X	
ICD Group International Inc.	New York, NY					X
Matsushita Electric Trading Group[7]	Rolling Meadows, IL				X	
Millbank Materials PA	Zelienople, PA	X	X			
BHP Billiton Marketing, Inc., Samancor Manganese[8]	Pittsburgh, PA	X	X	X		
Shieldalloy Corporation	Newfield, NJ					X
U.S. Defense Logistics Agency, DNSC[9]	Ft. Belvoir, VA	X	X		X	X

DNSC, Defense National Stockpile Center.

[1]Mn ore, manganese ore; FeMn, ferromanganese; SiMn, silicomanganese; MnO_2, synthetic manganese dioxide; EMM, electrolytic manganese metal (includes aluminum manganese briquettes, manganese briquettes, manganese flake, manganese powder, and nitrided manganese products).

[2]Chemical manganese dioxide and other manganese chemicals.

[3]Electrolytic manganese dioxide and other manganese chemicals.

[4]Formerly Highlanders Alloys LLC. Product information obtained from various industry trade publications.

[5]BHP Billiton Marketing, Inc. is a sales arm of BHP Billiton Limited. BHP Billiton Limited has partial ownership in the following manganese operations: Australia, Grooyte Eylandt Mining Company (60%)—manganese ore—and Tasmanian Electro Metallurgical Company Pty Ltd. (60%)—manganese alloys; South Africa, Samancor Manganese (51%)—manganese ore and alloys—and Manganese Metal Company (31%)—electrolytic manganese metal.

[6]Includes Argentinian companies Globe Metales, S.A. and Stein Ferroaleaciones, S.A.

[7]Includes Panasonic Battery Corporation of North America, Panasonic Gobel Battery Indonesia, and Panasonic Industrial Asia Pte Ltd.

[8]Samancor Manganese operates two manganese alloys plants (Advalloys and Metalloys) and two manganese mines (Mamatwan and Wessels) in South Africa.

[9]Some DNSC sales may have been shipped overseas.

Sources: U.S. Geological Survey (producers) and Port Import Export Reporting Services (other suppliers).

U.S. and Global Manganese Ore Consumption:

U.S. demand for manganese principally has come from the steel industry, which with ferrous foundries, have historically accounted for 85% to 90% of total demand. Distribution of demand among the various steel-related use categories has been relatively stable. Of these, construction, machinery, and transportation have been the largest consumption sectors. Steel-related demand has been apportioned among end uses on the basis of American Iron and Steel Institute data on shipments by market classification and assumptions as to average manganese content of steels for the respective markets (figure 1).

The manganese demand pattern in other industrialized countries is generally similar to that of the United States, with steel-related uses predominant. Consumption of manganese ore for nonmetallurgical purposes is variable, as this small component of consumption depends upon whether a particular country has processing facilities for batteries, chemicals, or other minor uses. World manganese ore consumption is approximately equal to mine production. Camaj (2007) reported that world manganese consumption in 2006 was about 11.6 Mt, roughly 9% less than that produced during the year (figure 3).

U.S. and Global Manganese Ferroalloy Consumption:

Most of the demand for manganese ferroalloys was for steelmaking, for which domestic and global trends in crude steel production during 1980-2006 are shown in figure 8. Raw steel production in 2006 increased by 3.5% to 98,200 t in the United States and by 9% to 1.17 billion metric tons globally from that of 2005. U.S. reported consumption of manganese ferroalloys in the United States was 388,000 t in 2006, up 2% from that in 2005 (table 13). U.S. apparent consumption of these materials indicated that the amount consumed was considerably underreported (at least 3 times less) to the USGS voluntary consumption survey. U.S. apparent consumption was about 10% of the total consumed worldwide (11.6 Mt) in 2006.

Figure 8. U.S. and World Steel Production

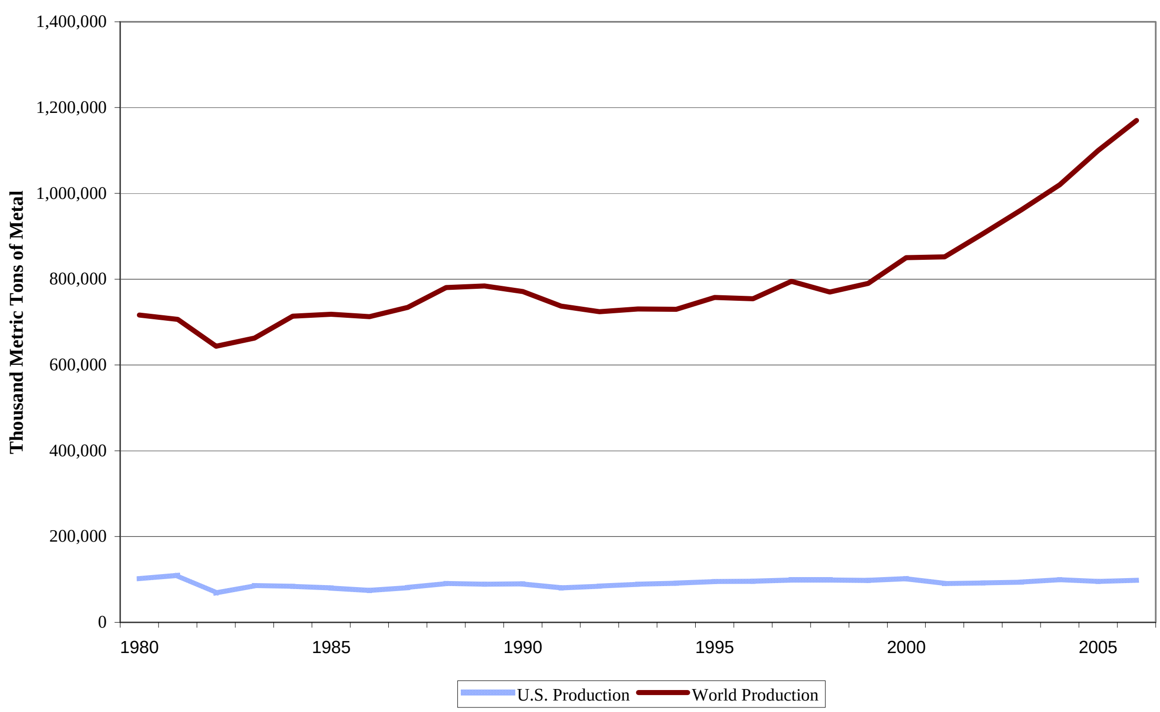


TABLE 13
U.S. CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF MANGANESE FERROALLOYS AND METAL IN 2006[1]

(Metric tons, gross weight)

End use	Ferromanganese: High carbon	Ferromanganese: Medium and low carbon	Ferromanganese: Total	Silicomanganese	Manganese metal
Steel:					
Carbon	131,000	87,100	218,000	53,400	843
High-strength, low-alloy	17,100	7,500	24,600	3,490	(2)
Stainless and heat-resisting	7,720	(2)	7,720	13,600	1,050
Full alloy	18,200	5,700	23,900	19,500	(2)
Unspecified[3]	1,450	1,560	3,010	777	1,950
Total	175,000	102,000	277,000	90,700	3,840
Cast irons	6,760	445	7,210	390	(4)
Superalloys	W	W	W	--	434
Alloys (excluding alloy steels)	6,660	6,270	12,900	(4)	13,300
Miscellaneous and unspecified	W	W	W	(4)	(4)
Grand total	189,000	109,000	297,000	91,100 [6]	17,500
Total manganese content[7]	147,000	86,800	234,000	60,100	17,500
Stocks, December 31, consumers and producers	12,000	19,300	31,300	10,400	716

W Withheld to avoid disclosing company proprietary data; included with "Alloys (excluding alloy steels)." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Withheld to avoid disclosing company proprietary data; included with "Steel: Unspecified."
[3]Includes electrical and tool steel, and items indicated by footnote (2).
[4]Withheld to avoid disclosing company proprietary data.
[5]Approximately 87% of this combined total was for consumption in aluminum alloys.
[6]Internal evaluation indicates that silicomanganese consumption is considerably understated.
[7]Estimated based on typical percentage manganese content.

Source: Corathers, 2008a.

U.S. and Global Manganese Metal Consumption:

Demand for manganese metal comes primarily from the aluminum industry followed by the steel industry. Reported consumption of manganese metal by U.S. companies was 17,500 t in 2006, which was equal to about 58% of the amount of manganese metal imported for consumption during the year. Of the amount reported, about 66% was consumed to produce aluminum alloys and 22% was consumed to produce steel and steel alloys (particularly stainless steels). In 2005, the global demand for EMM was estimated at about 520,000 t, and was expected to grow to about 900,000 t by 2007 (Saffy, 2005). The world EMM market in 2007 was wrought with overcapacity, with annual production capacity 1.42 times greater than estimated demand requirements. As a result, South African producer Manganese Metal Company curtailed operations at its 24,300-metric ton per year (t/yr) plant Krugersdorp plant in 2006 (Manganese Metal Company, 2008).

U.S. and Global EMD Consumption:

Demand for EMD comes from the primary and secondary battery industries. As a rough indicator of EMD demand, U.S. demand for primary and secondary batteries was projected to increase 4.3% annually through 2011 to $14.9 billion. Primary battery sales were forecast to rise faster than those of secondary batteries, owing in part to the growing need for replacement primary (throw-away) batteries in portable devices. Sales of secondary (rechargeable) batteries were expected to increase at an annual rate of 4% through 2011 (Freedonia Group, Inc., The, 2007).

In 2006, the global demand for EMD was estimated at 310,000 t. Demand was led by China (37%), followed by North America (29%), Europe (11%), Asia, excluding China and Japan (10%), Japan (9%), and South America (4%) (Tongqing, 2006, p. 12). The world EMD market remained oversupplied in 2006, and as a result the following producers curtailed production during the year: Mitsui Mining and Smelting Co. of Japan (24,000 t/yr); Sociedade Brasilera de Eletrolise (6,000 t/yr) and Eletro Manganes Ltda. of Brazil (5,800 t/yr); and Eveready Industries India Ltd. of India (5,000 t/yr). Australian producer Delta EMD (27,000 t/yr) ceased production in 2008 as overcapacity continued to plague the industry during 2007 (Tongqing, 2008, p.6). As of 2008, world EMD production capacity was still about 25% greater than demand (assuming 2006 demand level).

Challenges

Manganese is widely recognized as vital to national defense because military applications require steels, batteries, ferrites, and many alloys containing manganese. It is also important to the economic well-being of the nation in civilian applications that also require those materials. The National Research Council Committee on Critical Mineral Impacts on the U.S. Economy (2007, p. 9, 100-101) underscored these points when it found that manganese is one of 11 minerals studied that have the highest degree of criticality.

Import Reliance and Potential Supply Vulnerabilities:

The United States is 100% import reliant for its manganese needs. There is no domestic mining of commercial-grade manganese ore, nor does the country produce manganese metal or synthetic manganese dioxide. Even with domestic production of manganese ferroalloys, more than 750,000 t of these materials were imported in 2006, which was greater than 70% of U.S. manganese apparent consumption for the year. China and South Africa were the dominant producers of manganese ferroalloys (FeMn), manganese metal, and synthetic manganese dioxide, and supplied a large amount of these materials to the United States. South Africa accounts for about 80% of the world’s identified manganese ore resources, and Ukraine accounts for 20% (table 14).

U.S. import reliance is exacerbated because there are no substitutes for manganese in its major applications, nor are materials recycled for their manganese content—rather it is recycled incidentally as a minor constituent of ferrous and nonferrous scrap. Further, the United States must compete for manganese with other parts of the world, particularly the BRIC countries of Brazil, Russia, India, and China, where steel consumption is continually increasing.

World apparent consumption of finished steel products in 2006 increased by 9% to 1.121 billion metric tons from that of 2005. China alone consumed about 374 Mt, a 14% increase from that of 2005. The BRIC countries accounted for about 41% of the total (International Iron and Steel Institute, 2006). Global steel apparent consumption was projected to increase by 7% in 2007 and 2008. The BRIC countries were expected to lead this growth with a combined increase in steel consumption of 13% and 11% in 2007 and 2008, respectively. Steel consumption in North America was forecast to decrease by about 5% to about 148 Mt in 2007 compared with that in 2006 because of a downturn in residential construction, but increase by 4% between 2007 and 2008 (International Iron and Steel Institute, 2007).

Domestic Manganese Resources:

Because the United States is dependent on imports of manganese ore, no assessment of domestic manganese resources can be done without an evaluation of foreign deposits. In 1982, the U.S. Bureau of Mines assessed manganese resources as part of its Minerals Availability System (MAS) program—domestic deposits by Kilgore and Thomas (1982) and foreign deposits by Coffman and Palencia (1984). Current estimates of foreign manganese ore reserves and reserve base are shown in table 14. The future supply of refined manganese materials is contingent upon the availability of manganese ore. At the estimated level of mine production in 2007 (11.6 Mt contained manganese), world reserves could supply industrial requirements for about four decades and the reserve base for an additional 41 decades. Should the price of manganese ore undergo a sustained rise or fall, the volumes of reserves and reserve base would automatically tend to grow or decrease. However, should world steel production continue to increase during the next 20 years at the rate at which it has over the past 5 years (figure 8)—which is probable given the potential for economic growth in the BRIC countries and other parts of the world—manganese consumption would increase commensurately. The result would be a significant decrease in the time that manganese would be supplied to the world market from world reserves and reserve base.

TABLE 14

WORLD MANGANESE PRODUCTION, RESERVES, AND RESERVE BASE[1]

(Thousand metric tons, contained weight)

	Ore production[2]			
	2006	2007 [e]	Reserves[3]	Reserve base[3]
Australia	2,190	2,200	32,000	160,000
Brazil	1,370 [4]	1,000	25,000	51,000
China[5,6]	1,600	1,600	40,000	100,000
Gabon	1,350	1,550	20,000	160,000
India	811	650	93,000	160,000 [7]
Mexico	133	130	4,000	9,000
South Africa	2,300	2,300	32,000	4,000,000 [7]
Ukraine	820	820	140,000	520,000
Other[8]	1,330	1,360	Small	Small
Total (rounded)[2]	11,900	11,600	440,000	5,200,000

[e]Estimated.

[1]Data are rounded to three significant digits; may not add to totals shown.

[2]Total for gross weight is about three times that for contained weight.

[3]Estimated through 2007.

[4]Reported figure.

[5]Includes manganiferous ore.

[6]The International Manganese Institute estimated Chinese manganese ore production, in gross weight and manganese content, respectively, to be as follows: 2004—8,500,000 metric tons (t) and 1,700,000 t; 2005—12,000.000 t and 2,400,000 t; and 2006--11,000,000 t and 2,200,000 t.

[7]Includes inferred resources.

[8]Category represents Kazakhstan and Ghana, which produced an estimated 600,000 t and 540,000 t, respectively, in 2006, and combined totals from 18 other countries.

Source: Corathers, 2008b.

Eight domestic manganese deposits were analyzed; the deposits were estimated to contain almost 38 Mt of manganese. The average grade of manganese in these deposits is less than 20%, generally less than 10%. If money, land access, and regulatory issues were not factors, these deposits could supply U.S. industrial requirements for about 4 decades based on 2006 total apparent consumption of manganese materials.

A panel of the National Materials Advisory Board (NMAB) of the National Research Council concluded in 1976 that domestic land-based resources "should not be developed except in a dire emergency," and that under such circumstances, the two deposits best suited for consideration were those of the Cuyuna Range, MN, and Aroostook County, ME (National Materials Advisory Board Panel on Manganese Recovery Technology, 1976). The 1982 MAS study indicated profitable utilization of domestic deposits would require an ore price ranging from about 5 to nearly 20 times the then prevailing price of $1.70 per long ton unit of contained manganese ($1.73 per metric ton unit (mtu) of contained manganese) (Kilgore and Thomas, 1982). In terms of 2006 constant dollars, the equivalent ore price would be $3.61 per mtu of contained manganese. Therefore, the price required today for the economic development of these manganese deposits would range between $18.05 and $72.20 per mtu of contained manganese. The average year-to-date spot market prices through May 31, 2008, are $15.75 per mtu for ore containing 44% manganese, and $17.50 per mtu for ore graded at 48% manganese. These prices were more than triple (44% manganese ore) and quadruple (48% manganese ore) those at the end of January 2005.

The principal targets for finding domestic reserves or resources of conventional type were described in the USGS Professional Paper 820. These include finding 1) the source of manganese of the Pierre Shale (central and western Montana); 2) another Molango-type deposit in miogeosynclinal carbonate rocks; or 3) the source of high manganese concentrations in the Salton Sea brines (California). The paper also identified 2 of the 8 manganiferous deposits evaluated in the 1982 MAS study as known potential sources of manganese in the United States—the Cuyuna Range, Minnesota, and Aroostook County, Maine (Dorr, Crittenden, and Worl, 1973).

With increased spot market prices for manganese ore, there is increased interest in developing domestic manganese deposits. In mid-2007, a Canadian company, Rocher Deboule Minerals Corp., purchased 90 unpatented mining claims in the vicinity of the Artillery Peak manganese deposit located in Mohave County, AZ (Rocher Deboule Minerals Corp, 2007). (This deposit was described in Kilgore and Thomas (1982)). Rocher Deboule has continued exploration activities since its purchase.

Concentrations of manganese have been discovered over wide areas of the ocean floors as oxide nodules and along mid-ocean ridges as oxide crusts. The sea-floor manganese potential is considerable, although their future commercial utilization is quite uncertain (Glasby, 2000, p. 365-367). The elements of primary interest in the nodules are nickel, copper, and cobalt, and it is unlikely that they would be processed solely for their manganese values. Considerable money and effort have been expended on developing systems and processes for recovering metal values from nodules, but serious problems have arisen as to the international legal framework under which their recovery might proceed. Nodule resources in the most promising area known, the Clarion-Clipperton zone of the northeastern tropical Pacific Ocean, are estimated to contain about 1,650 Mt of manganese out of 7,500 Mt (Morgan, 2000). The potential mineralization of mid-ocean crusts has yet to be determined.

Manganese Material Prices:

Manganese materials are not traded openly on a global metals exchange but predominantly through contractual arrangements between producers and consumers. Such arrangements create added risks of supply disruptions to consumers.

Spot prices for manganese ore and manganese ferroalloys have soared since January 2005 (Appendix B). (There are no publicly available prices for manganese dioxide; the unit value of manganese dioxide imports has remained essentially flat since 2005—within 1% to 2% of $2,130 per metric ton, contained manganese—owing to oversupply.) The reasons behind these price increases vary, but decreased supply of manganese ore caused by curtailment of production at some mines in 2007 during a period of increased global demand and rising fuel costs are key factors. While high prices for manganese ore are starting to encourage earnest exploration of manganese deposits in the United States, they are also contributing to escalating costs associated with producing intermediate manganese products, such as manganese ferroalloys. Conversely, spot prices for manganese metal have decreased since the second quarter of 2007 because of decreasing demand by the aluminum industry and oversupply. Even so, manganese prices are more than double those at the beginning of January 2005. How long these prices will be sustained depends on the global supply and demand for these materials.

Additionally, the United States assesses antidumping duties on unwrought EMM and silicomanganese imports from certain countries which affect the prices of those imports. There is a 14% ad valorem duty on all imports of unwrought EMM, except for unwrought EMM flake from South Africa. Various antidumping duty rates are in place on silicomanganese imports from Brazil, China, India, Kazakhstan, Ukraine, and Venezuela. These duties vary depending on the import periods of review and sometimes by company within the countries.

Steel Needs Assessment:

One guiding principle identified by a committee of the NMAB in 2007 for the operation of a defense materials management system was the establishment of an analytical process that would "include gathering information on short-term and long-term needs for primary and secondary (component) materials" (National Materials Advisory Board Committee on Assessing the Need for a Defense Stockpile, 2007, p. 1-11). Trying to assess the component needs would be especially challenging in the case of steel, as there are so many forms and types of steel used by the military.

Reported Manganese Consumption and Production:

The National Materials Advisory Board Committee on Assessing the Need for a Defense Stockpile (2007, p. 1-7 and 1-11) recommended improving the way the Federal government gathered data on the availability of materials for defense needs. The Council acknowledged that the efforts of the USGS' Minerals Information Team were essential to collecting data on mineral materials availability. As evidenced in figure 1, industry reporting on the consumption of manganese materials is often incomplete, owing to the voluntary nature of responding to the USGS consumption survey. Industry may also elect whether or not to report manganese production-related information to the USGS voluntary manganese ore and products survey. The voluntary nature of responding to USGS surveys poses a challenge to obtaining the necessary data for accurately assessing defense needs.

Appendix G

Rhenium

Report on Domestic Suppliers of Selected Materials and their Reliance on Foreign Sources of Production

Every 2 years, the U.S. Geological Survey prepares metal commodity analyses for the Institute for Defense Analyses on materials that are, or were, held in the National Defense Stockpile (NDS) or that are of strategic importance. Chromium and nickel, currently included in the NDS, are important components in nickel-based superalloys used in high-performance jet engines for fighter aircraft. Rhenium (Re) is not included in the NDS.

Uses

Since the late 1960s, Re has been used in rocket thrusters for space applications. Since 1971, Re has been extensively used in platinum-rhenium (Pt-Re) catalysts for converting crude oil to gas-oil and high-octane fuels. High-performance jet engines have evolved to include turbine blades made with nickel-based superalloys (so called single-crystal blades). Since the late 1990s, Re has been used in the turbine blades closest to the combustion zone in these gas turbine engines. This allows the engine to be designed with closer tolerances and allows operation at higher temperatures, which prolongs engine life and increases operating efficiency and engine performance. Since nickel-based superalloys were first used in high-performance jet engines, the Re content in the turbine blades has increased from zero in the first generation blade (1980s), to 3% in second generation blades (mid 1990s), and 6% in the third generation blades used in current engine production. Rhenium-bearing turbine blades are also used in gas turbine engines on some Navy vessels, in gas-fired, land-based powerplants, and also in commercial aircraft engines. In some applications, such as catalysts and powerplants, substitution is possible if performance is sacrificed; however, in jet engine single-crystal turbine blades, substitution is not an option due to loss of performance.

Sources

There are no mines that produce Re as their primary product; Re is recovered as a byproduct of copper or molybdenum processing. It is associated with porphyry copper-molybdenum ores that occur in a series of mountain ranges known as the American Cordillera that runs from Alaska, through British Columbia, the United States and Mexico, and down into Peru and Chile in South America. The ore is mined for its copper content, and beneficiation produces a copper concentrate. The copper concentrate is further cleaned to produce a molybdenum concentrate which can contain 100 to 600 parts per million of Re. The molybdenum concentrate is roasted to drive off sulfur, and the stack gases can be scrubbed to capture the Re compounds. Rhenium is also associated with copper minerals in sedimentary deposits in Kazakhstan where ore is processed for copper recovery and the rhenium-bearing residues are recovered at the copper smelter. Rhenium-bearing residues from both sources are processed for recovery either as ammonium perrhenate (APR) for catalyst uses, or as metal powder for superalloys. Since Re supply depends either on production of copper or byproduct molybdenum, increasing Re production in response to increased consumption may be difficult.

Production

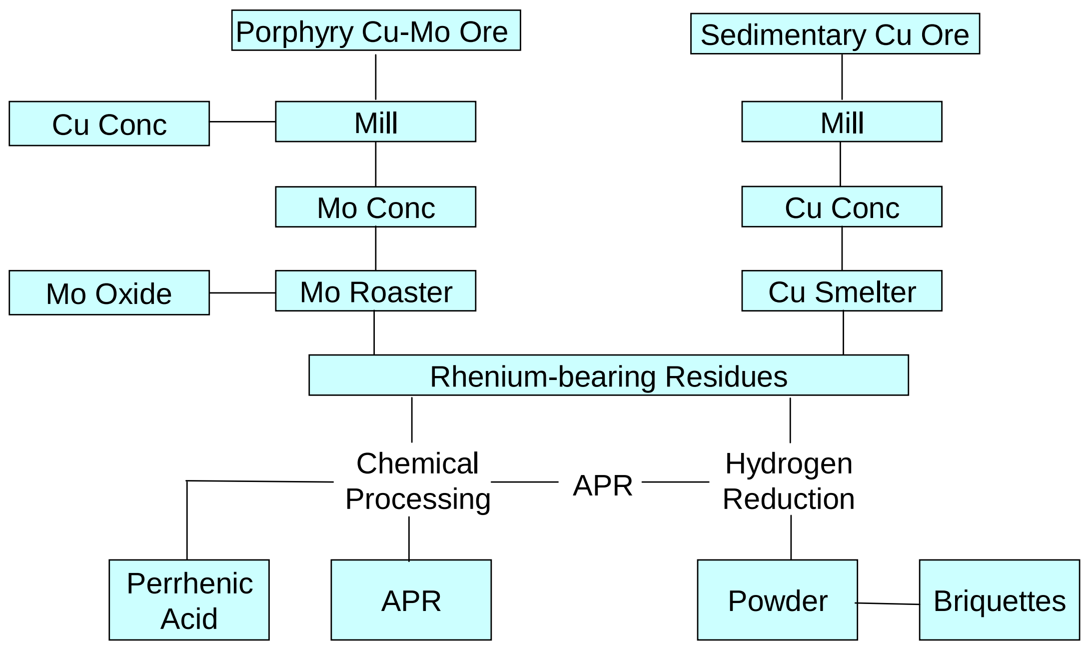
In 2007, the United States produced byproduct molybdenum concentrates at 8 copper mines (4 mines in Arizona, and one each in Montana, Nevada, New Mexico, and Utah). Rhenium recovery requires roasting in a facility equipped to capture the Re compounds in the stack gases. In the United States, only one of the three molybdenum concentrate roasting facilities is so equipped; the Freeport-McMoRan Copper and Gold, Inc. (Freeport) Sierrita facility in Arizona. Byproduct molybdenum concentrates from 4 of the 8 mines were roasted there, representing about 50% of the U.S. byproduct concentrate production. The remaining molybdenum concentrates were exported for roasting and whether or not the contained Re is recovered is unknown. Freeport recovers an estimated 7,000 to 8,000 kilograms (kg) of contained Re per year as metal powder from roasting byproduct concentrates at Sierrita. Freeport also operates a roaster in Rotterdam, the Netherlands where Re residues are recovered.

Byproduct molybdenum concentrates are also produced in Canada, Chile, Mexico, and Peru. The Chilean company Molymet maintains roasting facilities equipped for Re recovery in Belgium, Chile, and Mexico. Molymet primarily toll roasts byproduct molybdenum concentrates for Codelco, the national mining company of Chile, but also sources concentrates from Canada, Mexico, Peru, and the United States. Rhenium-bearing residues from the three Molymet roasters are processed for Re recovery at Molymet's facility in Chile. Codelco and Xstrata, plc. also roast byproduct molybdenum concentrates in Chile, but those roasters are not equipped for Re recovery. In mid-summer 2007, Molymet increased its roasting capacity by 40%, which should increase its Re recovery capacity from an estimated 20,000 to 22,000 kilograms per year (kg/yr) up to 28,000 to 30,000 kg/yr of contained Re as metal powder at full capacity.

Zhezkazganredmet (Redmet), Kazakhstan's state-owned Re producer, receives rhenium-bearing residues from the Dzhezkazgan Copper Works mine and smelter complex in Kazakhstan. Dzhezkazgan is controlled by Kazakh Copper, and its parent Samsung Corp., which receives 50% of Redmet's production as payment for the Re residues. Redmet's production capacity is estimated to be about 8,000 kg/yr of contained Re as APR. An estimated 5,000 kg/yr of contained Re in rhenium-bearing residues is recovered at copper smelters in Poland and in Armenia, Russia, and other former Soviet Union states.

Figure 1 presents a generalized processing flowsheet for rhenium-bearing residues.

Figure 1 - Rhenium Processing Flowsheet



Supply

All Re production from Freeport and Molymet is sold to U.S. consumers under long-term contract. The principal U.S. consumers are Cannon Muskegon Corp., General Electric Co., and Pratt & Whitney. General Electric consumes Re for engine manufacture and land-based power generation. Cannon Muskegon supplies the rhenium-bearing, nickel-based superalloys to Rolls-Royce plc. for engine manufacture. Pratt & Whitney consumes Re for engine manufacture. In addition, a leading Pt-Re catalyst producer, UOP LLC, is based in the United States. In 2007, domestic imports were estimated to be about 41,000 kg of Re with the leading sources being Chile (Molymet) at 24,300 kg metal powder; Kazakhstan (Redmet) at 6,900 kg APR; and the Netherlands (Freeport) at 3,500 kg metal powder. Germany (3,500 kg), China (1,900 kg), and the United Kingdom (900 kg) imported a mix of metal powder and APR. Apparent consumption in the United States (including Freeport’s domestic production) was estimated at about 48,000 kg in 2007; therefore, import reliance was about 85%.

Figure 1 - U.S. Rhenium Imports

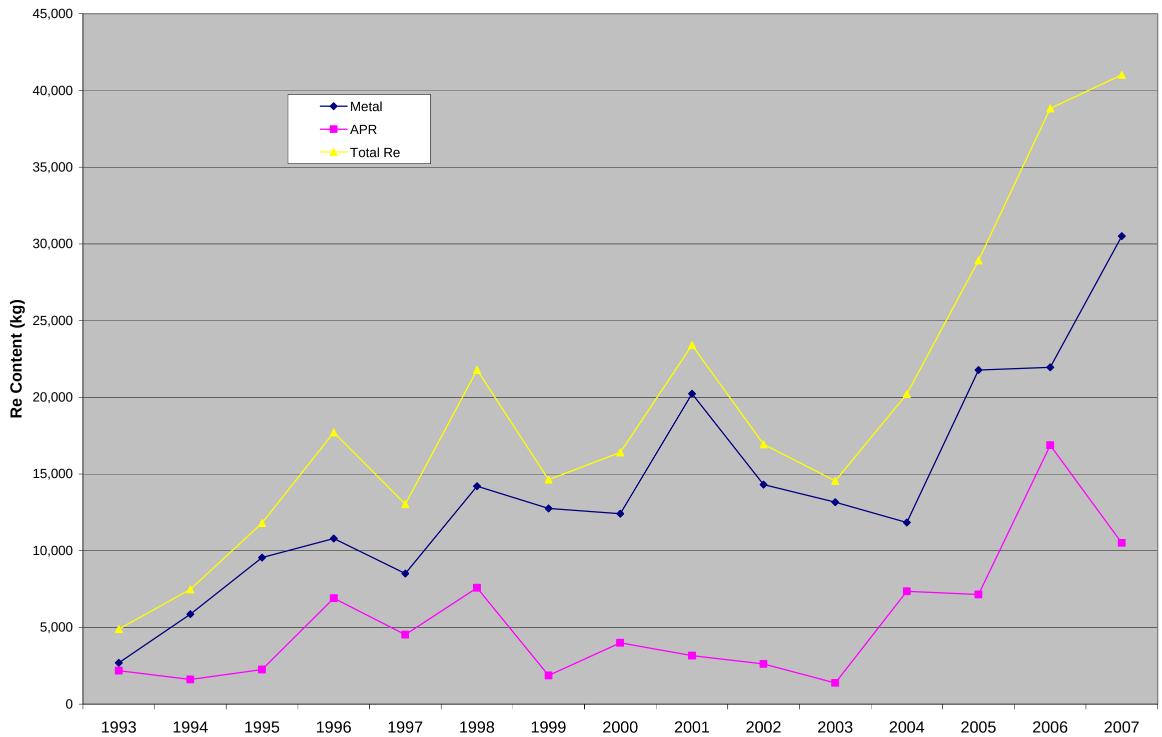


Figure 1 shows U.S. Re imports from 1993 to 2007. In the early 1990s, less than 5,000 kg/yr of Re were consumed, which represented baseline uses in thermocouples, filament wires, and rocket nozzles. Then increased Pt-Re catalyst use coupled with increased Re content in nickel-based superalloys began to take place. Catalyst usage consists of about 5 metric tons per year (t/yr) of Re from recycled catalysts and about 2-3 t/yr of virgin material. Since the late 1990s, about 60% to 70% of U.S. Re consumption has gone into second and third generation nickel-based superalloys for aerospace applications. Airline travel dropped significantly after September 11, 2001, but the Boeing Co. and Airbus S.A.S. have reported record new aircraft orders since 2006.

Challenges

The F-16 A/B had first flight in 1979. By the 1990s, the F-16s were being upgraded to the F-16 C/D, and the second generation of superalloys with 3% Re content was incorporated into the turbine blades. Subsequent retrofits incorporated the third generation superalloys with 6% Re into the turbine blades of the F-16 E/F series. The turbine blades with 3%- 6% Re are used close to the combustion chamber, which allows operation at higher engine temperature for greater thermal efficiency. Without Re, the turbine blades in the F-15, F-16, and F-18, as currently configured, either would fail or have to be redesigned to sacrifice performance. In other military applications, such as rocket nozzles, Re is the only material that can withstand going from the absolute cold of outer space to over 2,000 °C and then back again without failure. In terms of its other military uses, Re is used to make parts that control high-temperature exhaust gases from the jet engines of stealth aircraft. Rhenium allows heat to be radiated away from the aircraft quickly before infrared heat seeking missiles can target the engine.

The F-22 Raptor is going into production now and the F-35 Joint Strike Fighter (JSF) is scheduled to be in production by 2010. To date, about 3,000 JSF orders have been placed as well as over 700 orders for Raptors as compared with about 4,600 F-16s built to date. The Typhoon Eurofighter will use third-generation nickel-based superalloys. The new Boeing 777 Dreamliner uses two Trent engines from Rolls Royce. Without the 6% Re content in the blades, these engines would not be capable of developing the 90,000 pounds of thrust needed to fly such a large plane. Trent engines are also featured in the new Airbus jets. Clearly, Re consumption in military and domestic jet applications is increasing.

Rolls Royce has over $40 billion in orders for its Trent engine systems making it the world's second leading engine manufacturer. General Electric has been using the 3% nickel-based superalloy in its turbines since the mid-1990s. The next generation of military aircraft is expected to use the 6% Re superalloy with a similar number of aircraft as those currently in service. Cannon Muskegon's patents on the 3% superalloy expired in 2007, which could destabilize the long-term agreements enjoyed by Pratt & Whitney and General Electric, and disrupt the supply of nickel-based superalloys. In addition to the needs of Re consumers in the West, both Russia and China are expected to modernize their military and domestic air fleets, which would increase pressure on Re supply in the future.

In addition to continued growth in Re consumption in single-crystal superalloys for use in gas engine and land-based powerplant turbine blades, increased Re consumption for catalysts is expected. There are five gas-to-liquid (GTL) plants under development in the United States and at least two of them are considering using Re catalysts. A GTL industry with a 1-million-barrel-per-day capacity would use an estimated 25,000,000 kg of catalysts. If only one-half of the planned GTL plants that would use Re-promoted catalysts are built within the next decade, Re consumption could increase by 12,500 kg/yr which, in a 45,000- to 50,000-kg/yr worldwide market, would require increased overall production or reduced consumption in superalloys. Figures 3 and 4 present the estimated consumption by end use for the years 2000 and 2011 based on information from Platts Executive Commodity Reports, Lipmann Walton & Co. Ltd., and Roskill Information Services Ltd.

Figure 3 - Estimated Consumption by End Use
Year 2000

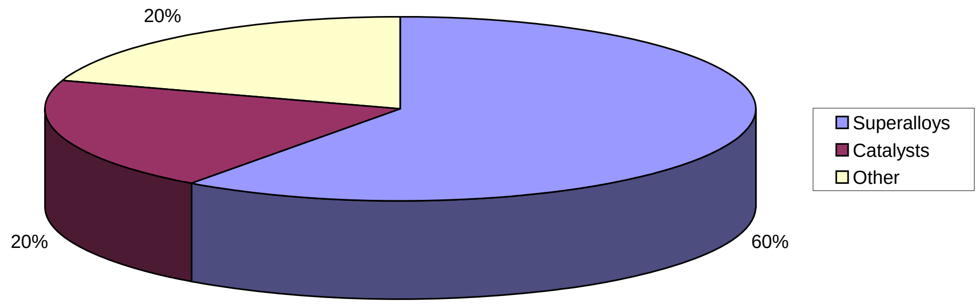
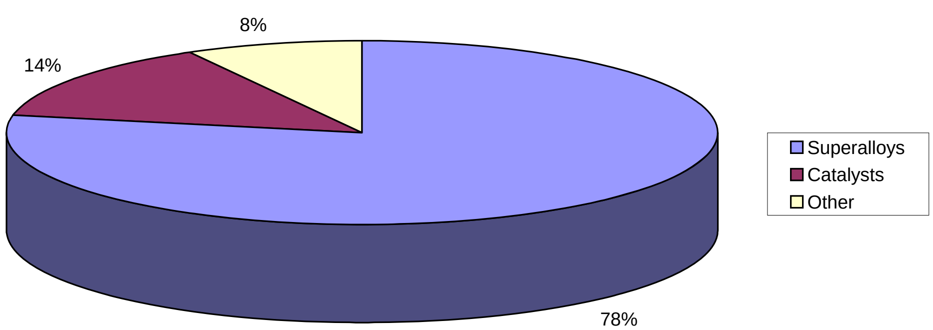


Figure 4 - Estimated Consumption by End Use
Year 2011



All of Molymet's present Re production is sold to the United States under long-term contracts, but Molymet controls no mine production. Presently, Molymet has a combined roasting capacity in its three facilities of about 140 million pounds (Mlb) of molybdenum out of a worldwide total of about 440 Mlb of molybdenum and plans to expand to 180 Mlb by 2010. Codelco and Xstrata currently roast molybdenum concentrates in Chile, without Re recovery, and are considering expanding roasting capacity by 30 Mlb and 20 Mlb respectively by 2010. This could limit the availability of byproduct molybdenum concentrates for roasting by Molymet.

Redmet produces 15% to 20% of the world's Re supply and represents the majority of the Re available to the open market. However, when majority ownership of the Dzhezkazgan Mine and smelter was sold to a private company by the Government of Kazakhstan, Redmet no longer controlled production of the Re residues that are its feedstock. Due to a dispute over ownership of the residues, Redmet exported no Re from the summer of 2005 to the spring of 2006, which disrupted the worldwide supply chain, causing the price of Re to rise from $1,200 to $5,500 per kg. Since resolution of the dispute in 2006, increased demand and inelastic supply have pushed the price over $9,000 per kg.

Options

World production of byproduct molybdenum concentrates in 2006 was estimated at about 215,000 metric tons (t). Similar levels of production are expected in 2007. Roasting capacity of Molymet's three facilities, including the summer 2007 expansion in Chile, combined with Freeport's Sierrita and Rotterdam facilities, was estimated to be about 180,000 t of molybdenum concentrates. Therefore, about 35,000 t of byproduct molybdenum concentrates were roasted without Re recovery, equating to about 6,000 to 8,000 kg of Re that potentially could be recovered. Existing roasters at Codelco and Xstrata in Chile could be retrofitted with Re recovery equipment to capture the lost Re compounds. Molymet has planned an expansion at its Belgium facility and development of a new facility in Chile by 2010, totaling about 35,000 t of additional molybdenum concentrate roasting capacity. That equals about 2 to 3 years of growth in molybdenum production at the predicted growth rate of 3% to 4% per year that has been observed since 1995, and would equate to an additional 6,000 kg to 8,000 kg of Re production. Beyond 2010-2011, additional roasting capacity will be required if present growth rates are maintained in the molybdenum industry. Expansion of the domestic roasting capacity, including Re recovery technology, would reduce import reliance and help ensure continuity of Re supply.

As the life cycle of turbine blades in jet engines is about 4 years, significant quantities of second-generation blades (3% Re) are accumulating. If technology was developed to allow recycled, second-generation blades to be used in the manufacture of new third-generation blades, requirements for virgin Re could potentially be reduced by 50%. General Electric and Cannon Muskegon currently have begun investigating this possibility, and Re recycling is being pursued by H.C. Starck GmbH and Heraeus Holding GmbH in Germany. A coordinated, joint federal-private sector research program could speed development of such technology and keep the United States at the forefront of the Re industry. It could also help ensure an adequate supply of Re for domestic military and civilian applications.

Presently, concentrates from the Utah's Bingham Canyon Mine of Kennecott Utah Copper (a wholly owned subsidiary of the Rio Tinto Group) are exported for roasting. Kennecott has announced a mine expansion to dramatically increase reserves coupled with development of a hydrometallurgical technique for treatment of byproduct molybdenum concentrates to avoid roasting, while simultaneously recovering Re. A similar technique reportedly is being used in China to treat byproduct concentrates from Mongolia for Re recovery. Successful development of such a technique could provide a stable supply of Re in the future as new low-cost copper production methods utilize solvent extraction-electrowinning and eliminate molybdenum concentrate production entirely. It is unknown if Re recovery in such a circuit is even possible.

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