

THORIUM

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Worldwide demand for thorium is small. Domestic imports for consumption of refined thorium products increased by 537% in 2003 according to data collected by the U.S. International Trade Commission (USITC). The value of thorium metal and compounds used by the domestic industry in 2003 was estimated to be about \$149,000, an increase from \$22,000 in 2002. Only minor amounts of thorium are used annually (less than 10 metric tons). However, large fluctuations in demand are caused by intermittent use, especially for catalytic applications that do not require annual replenishment.

Thorium and its compounds were produced primarily from the mineral monazite, which was recovered as a byproduct of processing heavy-mineral sands for tin, titanium, or zirconium minerals. Monazite was recovered primarily for its rare-earth content, and only a small portion of the byproduct thorium produced was consumed. Monazite-producing countries were Brazil, India, Malaysia, and Sri Lanka. In 2003, all thorium alloys, compounds, and metal used by the domestic industry were derived from company stocks, imports, or material previously sold from the U.S. Government stockpile.

Problems associated with thorium's natural radioactivity represented a significant cost to those companies involved in its mining, processing, manufacture, and use. The costs to comply with environmental regulations and potential legal liabilities and the excessive costs to purchase storage and waste disposal space were the principal deterrents to its commercial use. Health concerns associated with thorium's natural radioactivity have not been a significant factor in switching to alternative nonradioactive materials (Ed Loughlin, Grace-Davison division of W.R. Grace & Co., oral commun., 1997; Don Whitesell, The Coleman Company, Inc., oral commun., 2002).

Limited demand for thorium, relative to the rare earths, continued to create a worldwide oversupply of thorium compounds and residues. Most major rare-earth processors have switched feed materials to thorium-free intermediate compounds, such as rare-earth chlorides, hydroxides, or nitrates. Excess thorium not designated for commercial use was either disposed of as a radioactive waste or stored for potential use as a nuclear fuel or other application. Principal nonenergy uses have shifted from refractory applications to chemical catalysts, lighting, and welding electrodes.

Legislation and Government Programs

The Bob Stump National Defense Authorization Act for Fiscal Year 2003 (Public Law 107-314) was enacted on December 2, 2002. The Act authorizes the National Defense Stockpile (NDS) manager to obligate up to \$76.4 million from the NDS Transaction Fund for authorized uses under the Strategic and Critical Materials Stock Piling Act (50 U.S.C. 98h), including disposal of hazardous

materials that are environmentally sensitive. Fiscal year 2003 funding increased by \$5.4 million from that of the previous fiscal year. The Annual Materials Plan for fiscal year 2003, released October 1, 2002, authorized the disposal of 3,220,506 kilograms (kg) (7,100,000 pounds) of thorium nitrate from the NDS classified as excess to goal. A revised Annual Materials Plan for fiscal year 2003 was released by the Defense National Stockpile Center (DNSC) on December 23, 2002; however, it did not change the excess-to-goal quantity for thorium nitrate.

The National Defense Authorization Act for Fiscal Year 2004 (Public Law 108-136) was enacted on November 24, 2003. The law authorized the NDS manager to obligate up to \$69.7 million for the uses under section 9(b)(2) of the Strategic and Critical Materials Stock Piling Act, including the disposal of hazardous materials that are environmentally sensitive, which would include thorium nitrate.

Based on the legislated funding, studies were conducted in 2003 on the disposal of thorium nitrate in the NDS. As required under the National Environmental Policy Act (NEPA) (42 U.S.C. 4321 et seq.), an environmental assessment (EA) was prepared to assess the potential environmental impacts associated with the proposed action to transfer the DNSC's thorium nitrate to the Nevada Test Site (NTS) for disposal. The thorium nitrate is stored at DNSC depots at Curtis Bay, MD, and Hammond, IN. Approximately 21,000 drums containing thorium nitrate and 10 drums containing converted thorium nitrate would be loaded into cargo containers and transported to the NTS, where the cargo containers would be placed in disposal cells. The EA also analyzed the no-action alternative. Based on the analysis in the EA, the DNSC determined that the proposed disposal is not a major Federal action significantly affecting the quality of the human environment within the context of the NEPA. Therefore, the preparation of an environmental impact statement is not required (Defense National Stockpile Center, 2003¹). The DNSC proposed that it dispose of the entire NDS stockpile of thorium nitrate from its depots in Maryland and Indiana. The purpose of the proposed action is to end DNSC stewardship of the thorium nitrate stockpile in a safe and environmentally sound manner, with minimum radiation exposure and risk to the workers, the public, and the environment. The DNSC needs to dispose of the thorium nitrate stockpile because it exceeds the needs of the U.S. Department of Defense, no other agency of the Federal Government needs it, and there is no market for it. Following a 30-day public comment period for the EA and draft finding of no significant impact (FONSI), a final FONSI was signed on November 25, 2003 (Defense Logistics Agency, 2003). The DNSC has begun planning for the transfer of the materials to

¹A reference that includes a section mark (§) is found in the Internet Reference Cited section.

the U.S. Department of Energy's NTS. The material is expected to be moved in August 2004.

Production

Domestic mine production data for thorium-bearing minerals were developed by the U.S. Geological Survey from a voluntary canvass of U.S. thorium operations. The one mine to which a canvass form was sent responded. Although thorium was not produced in the United States in 2003, the mine that had previously produced thorium-bearing monazite continued to operate and maintained capacity on standby. Monazite was last produced in the United States in 1994.

Essentially all thorium alloys and compounds used by the domestic industry were derived from company stocks, imports, or materials sold from the NDS. Domestic companies processed or fabricated various forms of thorium for nonenergy uses, such as chemical catalysts, lighting, and welding electrodes.

Consumption

Statistics on domestic thorium consumption were developed by surveying various processors and manufacturers, evaluating import-export data, and analyzing Government stockpile shipments.

Domestic thorium producers and processors that were surveyed in 2003 reported no consumption of thorium oxide equivalent in 2003. Additional information on domestic consumption was not available (table 1).

Because of thorium oxide's high melting point, it was used in several refractory applications. High-temperature uses were in ceramic parts, crucibles, and investment molds.

Thorium nitrate was used in the foreign manufacture of lamp mantles for use in incandescent camping lanterns, natural gas lamps, and oil lamps. Thorium mantles provide an intense white light that is adjusted towards the yellow region by the addition of a small amount of cerium. Thoriated mantles have not been produced domestically since the development of a suitable thorium-free substitute mantle containing yttrium and other rare earths.

Thorium nitrate also was used to produce thoriated tungsten welding electrodes. These electrodes were used to join stainless steels, nickel alloys, and other alloys requiring a continuous and stable arc to achieve precision welds.

The nitrate form of thorium also was used to produce thoriated tungsten elements used in the negative pole (cathode) of magnetron tubes and traveling wave tubes. Thorium was used because it emits free electrons at ambient temperatures when heated in a vacuum. With an improved work function and lower operating temperature, thoriated-cathodes last longer than nonthoriated filaments. Magnetron tubes were used to emit electrons at microwave frequencies in radar systems for air traffic control, surveillance, weather monitoring, and weapons systems and to heat food in microwave ovens.

Thorium was used in other applications, such as chemical catalysts (ammonia to nitric acid, hydrogenation of olefins, and activation of carbon-hydrogen bonds), electron-emitting tubes, elements in special-use light bulbs, fuel-cell elements, high-refractivity glass, photoconductive films, radiation detectors, and target materials for x-ray tubes.

In metallurgical applications, thorium can be alloyed with other metals, primarily magnesium. Thorium metal has a high melting temperature of 1,750° C and a boiling point of about 4,790° C. Magnesium-thorium alloys were used by the aerospace industry for their lightweight, high-strength, and excellent creep resistance attributes at elevated temperatures. Thorium-free magnesium alloys with similar properties and without naturally occurring radiation have been developed and have replaced most of the thorium-magnesium alloys. Small quantities of thorium were used in dispersion-hardened alloys for high-strength, high-temperature applications.

Stocks

Government stocks of thorium nitrate in the NDS were 3,218,697 kg (7,096,012 pounds) on December 31, 2003. At yearend 2003, all stocks of thorium nitrate in the NDS were uncommitted (not previously sold) and authorized for disposal. The NDS inventory increased 520 kg (1,146 pounds) during the year but no stocks of thorium nitrate were sold or shipped in 2003.

Prices

Thorium oxide prices in 2003, quoted by Rhodia Electronics and Catalysis, Inc., were unchanged from the previous year (table 1). At yearend, thorium oxide prices delivered duty paid were \$82.50 per kilogram for 99.9% purity and \$107.25 per kilogram for 99.99% purity. Thorium nitrate prices from Rhodia were \$27.00 per kilogram for mantle-grade material.

World Review

Thorium demand remained depressed because industrial consumers expressed concerns with the potential liabilities, the cost of complying with environmental monitoring and regulations, and the costs of disposal at approved waste burial sites.

Outlook

Thorium use in the United States has decreased substantially during the past decade. Domestic demand is expected to remain at recent depressed levels unless low-cost technology is developed to dispose of residues or its use as a nonproliferative nuclear fuel gains widespread commercialization. Thorium's future use in nonenergy applications, such as a chemical catalyst, in specialty lighting, and in welding electrodes, is expected to continue at reduced levels. Manufacturers have successfully developed acceptable substitutes to replace thorium in ceramics, incandescent lamp mantles, investment molds, magnesium alloys, and paint and coating evaporation materials. Thorium's potential for increased use in nonenergy applications is limited by its natural radioactivity. The greatest potential exists in energy applications as a source of nuclear energy as an atomic fuel, using atomic fission in the thorium isotope Th²³²/uranium isotope U²³³ cycle, or as a subatomic fuel, using a particle accelerator to produce protons (subatomic particles) that interact with Th²³² and U²³³ to produce fast neutrons (subatomic particles) in a process

called spallation, which results in a nuclear cascading effect rather than the self-sustaining chain reaction of a conventional reactor. In the long term, high-disposal costs, increasingly stringent regulations, and public concerns related to thorium's natural radioactivity are expected to depress its use in nonenergy applications, especially in the United States.

Finding of No Significant Impact, accessed March 10, 2004, at URL <http://www.dla.mil/ThNFinal.FONSI.pdf>.

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GENERAL SOURCES OF INFORMATION

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Uranium Industry Annual 2002. U.S. Department of Energy.

TABLE 1
SALIENT U.S. REFINED THORIUM STATISTICS¹

		1999	2000	2001	2002	2003
Exports, gross weight:						
Thorium ore, including monazite	kilograms	--	--	--	--	23,000
Compounds	do.	2,520 ^r	4,640 ^r	7,300 ^r	1,930 ^r	1,930
Imports, compounds, gross weight						
	do.	5,290 ^r	11,100 ^r	1,850 ^r	650 ^r	4,140
Consumption, reported nonenergy applications, gross weight²						
	do.	7,000	6,000	NA	NA	NA
Prices, yearend:						
Nitrate, gross weight ^{3,4}		\$27.00	\$27.00	\$27.00	\$27.00	\$27.00
Oxide, 99.9% purity ⁴		\$82.50	\$82.50	\$82.50	\$82.50	\$82.50

^rRevised. NA Not available. -- Zero.

¹Data are rounded to no more than three significant digits, except prices.

²All domestically consumed thorium was derived from imported metals, alloys, and compounds.

³Source: Rhodia Canada, Inc., free on board port of entry, duty paid, thorium oxide basis.

⁴Source: Rhodia Electronics and Catalysis, Inc.

TABLE 2
U.S. FOREIGN TRADE IN THORIUM AND THORIUM-BEARING MATERIALS¹

	2002		2003		Principal destinations/sources and quantities, 2003
	Quantity (kilograms)	Value	Quantity (kilograms)	Value	
Exports:					
Thorium ore, monazite concentrate	--	--	23,000	\$2,610	Qatar 23,000.
Compounds	1,930 ^r	\$374,000 ^r	1,930	299,000	Japan 1,320; Singapore 210; Canada 177; United Kingdom 70; Taiwan 59; Saudi Arabia 45; France 26.
Imports, compounds					
	650	22,100	4,140	149,000	France 4,100; India 41.

^rRevised. -- Zero.

¹Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

TABLE 3
 MONAZITE CONCENTRATE: ESTIMATED WORLD PRODUCTION, BY COUNTRY^{1,2}

(Metric tons of gross weight)

Country ³	1999	2000	2001	2002	2003
Brazil	200	200	200	200	200
India	5,000	5,000	5,000	5,000	5,000
Malaysia	1,147 ⁴	818 ⁴	643 ^{r,4}	509 ^{r,4}	450
Sri Lanka	200	--	--	--	--
Total	6,550	6,020	5,840 ^r	5,710 ^r	5,650

^rRevised. -- Zero.

¹World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Table includes data available through April 18, 2004.

³In addition to the countries listed, China, Indonesia, Nigeria, North Korea, the Republic of Korea, and countries of the Commonwealth of Independent States may produce monazite; available general information is inadequate for formulation of reliable estimates of output levels.

⁴Reported figure.