THORIUM

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Worldwide demand for thorium continues to decline. Domestic consumption of refined thorium products decreased by 65% in 2002, according to data collected by the U.S. Geological Survey (USGS). The value of thorium metal and compounds used by the domestic industry was estimated to be about \$22,000, down from the \$70,000 estimate in 2001.

Thorium and its compounds were produced primarily from the mineral monazite, which was recovered as a byproduct of processing heavy-mineral sands for titanium and zirconium minerals or tin 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 2002, all thorium compounds, metal, and alloys used by the domestic industry were derived from imports, company stocks, or material previously sold from the U.S. Government stockpile.

Problems associated with the natural radioactivity of thorium 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 the natural radioactivity of thorium have not been a significant factor in switching to alternative nonradioactive materials (Lance Swearingen, The Coleman Company, Inc., oral communication, 2003; Martin Bourquin, Grace-Davison division of W.R. Grace & Co., oral communication, 2003).

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, nitrates, or hydroxides. 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 Floyd D. Spence National Defense Authorization Act for Fiscal Year 2002, Public Law 107-107, was enacted on December 28, 2001. The law authorized the disposal of 272,155 kilograms (kg) (600,000 pounds) of thorium nitrate in the National Defense Stockpile (NDS) considered obsolete and excess. The NDS manager was authorized to obligate up to \$65.2 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. The revised Annual Materials Plan for fiscal year 2002 authorized the disposal of 2,946,033 kg (6,494,891 pounds) of thorium nitrate from the NDS classified as excess to goal.

The Bob Stump National Defense Authorization Act for Fiscal Year 2003, Public Law 107-314, was enacted on December 2, 2002. The NDS manager may 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. The fiscal year 2003 funding was an increase of \$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 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 on December 23, 2002; however, it did not change the excess-to-goal quantity for thorium nitrate.

Production

Domestic mine production data for thorium-bearing minerals were developed by the USGS 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 2002, 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 imports, company stocks, or materials sold from the NDS. Domestic companies processed or fabricated various forms of thorium for nonenergy uses, such as lighting, chemical catalysts, and welding electrodes.

Consumption

Statistics on domestic thorium consumption are developed by surveying various processors and manufacturers, evaluating import-export data, and analyzing Government stockpile shipments. Domestic thorium consumption, based on imports for consumption, was 0.48 metric ton (t) of thorium oxide equivalent in 2002, a decrease from the 1.37 t of thorium oxide equivalent onsumed in 2001 (table 1). Because of the high melting point of thorium oxide, it was used in several refractory applications. High-temperature uses were in ceramic parts, investment molds, and crucibles.

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 a suitable thorium-free substitute mantle containing yttrium and other rare earths was developed.

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 (TWTs). 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, weapon systems, and to heat food in microwave ovens.

Thorium was used in other applications as a chemical catalyst, in electron-emitting tubes, as an element in special-use light bulbs, in fuel cell elements, in high-refractivity glass, in photoconductive films, in radiation detectors, and in 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 3,218,177 kg (7,094,865 pounds) on December 31, 2002. The NDS inventory included 273,181 kg (602,262 pounds) of containerized thorium nitrate allocated to meet the NDS goal requirements and 2,944,995 kg (6,492,603 pounds) classified as excess to the goal. No stocks of thorium nitrate were sold or shipped during 2002; however, the NDS received additional stocks of 1,349 kg (2,974 pounds) of thorium nitrate.

Prices

Thorium oxide prices in 2002, quoted by Rhodia Electronics and Catalysis, Inc., were unchanged from the previous year’s level. At yearend, thorium oxide prices delivered duty paid (d.d.p.) 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 disposal costs at approved waste burial sites.

Outlook

The use of thorium in the United States decreased substantially during the past decade. Domestic demand is forecast 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. Its future use in nonenergy applications, such as a chemical catalyst, in specialty lighting, and in welding electrodes, is expected to continue at lower levels. Manufacturers have successfully developed acceptable substitutes for thorium-containing ceramics, incandescent lamp mantles, investment molds, magnesium alloys, and paint and coating evaporation materials. The potential for growth in nonenergy applications for thorium is limited by its natural radioactivity. Its greatest potential exists in energy applications as a source of nuclear energy as an atomic fuel, using atomic fission in the thorium-isotope-Th^{232}/uranium-isotope-U^{233} cycle; or as a subatomic fuel, using a particle accelerator to produce protons (subatomic particles) that interact with Th^{232} and U^{233} to produce fast neutrons (subatomic particle) in a process called spallation, resulting in nuclear cascading effect rather that the self-sustaining chain reaction of a conventional reactor. In both processes, the use of thorium as a nuclear fuel may resume in the next decade because of its ability to generate low quantities of radionuclide byproducts that could be used in nuclear weapons. In the long term, high disposal costs, increasingly stringent regulations, and public concerns related to the natural radioactivity of thorium are expected to continue to depress its future use in nonenergy applications, especially in the United States.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Nuclear Fuels. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Thorium. Ch. in Mineral Commodity Summaries, annual.

Other

Thorium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Uranium Industry Annual 2002. U.S. Department of Energy.

TABLE 1
SALIENT U.S. REFINED THORIUM STATISTICS[1]

(Kilograms of thorium dioxide unless otherwise specified)

	1998	1999	2000	2001	2002
Exports, compounds	840	1,860	3,430	5,390	650
Imports:					
Thorium ore, including monazite	--	--	--	--	--
Compounds	5,510	3,910	8,200	1,370	480
Consumption, reported nonenergy applications[2]	7,000	7,000	6,000	NA	NA
Prices, yearend:					
Nitrate[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

NA Not available. -- Zero.

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

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

[3]Source: Rhodia Canada, Inc., free on board port of entry, duty paid, ThO_2 basis.

[4]Source: Rhodia Electronics and Catalysis, Inc.

TABLE 2
U.S. FOREIGN TRADE OF THORIUM COMPOUNDS[1]

	2001		2002		
	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Principal destinations/sources, and quantities, 2002
Exports	7,300	\$291,000	880	\$260,000	Japan 298; Singapore 289; Egypt 130; Nigeria 51; Trinidad and Tobago 40; Germany 27; United Kingdom 25.
Imports	1,850	68,400	650	22,100	France 650.

[1]Data 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, gross weight)

Country[3]	1998	1999	2000	2001	2002
Brazil	200	200	200	200	200
India	5,000	5,000	5,000	5,000	5,000
Malaysia	517 [4]	1,147 [4]	818 [4]	510	500
Sri Lanka	200	200	--	--	--
Total	5,920	6,550	6,020	5,710	5,700

-- Zero.

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

[2]Table includes data available through April 18, 2003.

[3]In 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.

[4]Reported figure.