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# 2005 Minerals Yearbook

## THORIUM

U.S. Department of the Interior
U.S. Geological Survey

June 2006

# Thorium

By James B. Hedrick

**Domestic survey data and table were prepared by Nicolas A. Muniz, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.**

Thorium demand worldwide is relatively small. There was no domestic production of thorium in 2005. All thorium compounds, metal, and alloys used by the domestic industry were derived from imports, company stocks, or material previously acquired from the U.S. Government stockpile. Domestic imports for consumption of refined thorium products decreased by 7% in 2005 according to data collected by the U.S. International Trade Commission (USITC) (table 1). The value of thorium metal and compounds used by the domestic industry in 2005 was estimated to be about $145,000, a decrease from $170,000 in 2004. Only minor amounts, less than 10 metric tons (t), of thorium are used annually. 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 titanium, zirconium, or tin minerals. Monazite was recovered primarily for its rare-earth content, and only a small fraction of the byproduct thorium produced was consumed. Monazite-producing countries were Brazil, India, Malaysia, and Sri Lanka.

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, 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, compared with that for 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 low-level radioactive waste or stored for potential use as a nuclear fuel or in other applications. Principal nonenergy uses have shifted from refractory applications to chemical catalysts, lighting, and welding electrodes.

## Legislation and Government Programs

The Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 authorized the National Defense Stockpile (NDS) manager to obligate up to $59.7 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, which includes thorium nitrate. Fiscal year 2005 funding decreased by $10 million from that of the previous fiscal year. The Annual Materials Plan for fiscal year 2005, released February 1, 2005, authorized the disposal of all 3,218,697 kilograms (kg) (7,100,000 pounds) of thorium nitrate classified as excess to goal from the NDS.

Based on the funding appropriated by Congress, studies were conducted in 2003 on the disposal of thorium nitrate in the NDS. As required under the National Environmental Policy Act (42 U.S.C. 4321 et seq.), an environmental assessment was prepared to evaluate the potential environmental impacts associated with 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 were loaded into cargo containers and transported to the NTS where the cargo containers were placed in disposal cells. The DNSC began the disposal of the entire NDS stockpile of thorium nitrate from its depots in Maryland and Indiana to the NTS, which is about 105 kilometers (65 miles) northwest of Las Vegas, NV. Shipments of thorium nitrate began from the Curtis Bay NDS depot in 2004. Shipments of the stockpile at the Hammond NDS depot began in mid-2005. Shipments to Nevada from both depots were completed by the end of fiscal year 2005.

Researchers at General Atomics, The University of Texas, and Thorium Power Inc. began development of a concept design for a new high-temperature, helium-cooled thorium-fueled nuclear reactor based on an existing high-temperature, gas-cooled reactor design developed by General Atomics. The development of the new design (designated HT3R for High-Temperature, Teaching, and Test Reactor) would be directed by the lead group at The University of Texas of the Permian Basin. Funding and research will be provided by General Atomics, The University of Texas-Arlington, The University of Texas-Austin, The University of Texas-Dallas, and The University of Texas of the Permian Basin; additional backing will be provided by Midland Development Corp., Novastar Resources Ltd., Odessa Development Corp., Thorium Power, Inc., the city of Andrews, TX, and Andrews County, TX. The reactor is planned to be built in Andrews (Lobenz, 2006).

In an effort to dispose of excess weapons-grade plutonium produced by the United States and Russia, the U.S. Department of Energy's National Nuclear Security Administration (NNSA) was funded by Congress with $2.8 billion, most of which was awarded to Areva (a consortium owned by the French Government) to use metal oxide (MOX) nuclear fuel technology to dispose of the excess plutonium. As of the last quarter of 2005, no Russian material had been disposed of and less than one nuclear warhead's worth of plutonium was "burned-up" in the MOX fuel cycle. The NNSA estimated that an additional $7.4 billion would be needed to complete the project.

An alternative method to dispose of the plutonium is to use a thorium-fueled reactor. A study funded by the NNSA in 2004 was awarded to the Kurchatov Institute in Russia. The cost savings of using the thorium-fuel cycle compared with the MOX technology was estimated to be $5 billion to $7 billion. Westinghouse Electric Company LLC, an independent contractor of the NNSA, assessed the thorium-fuel research at the Kurchatov Institute and verified their results. Westinghouse confirmed the Kurchatov Institute's findings that significant cost savings could be achieved by using the thorium-fuel cycle to generate power and "burn-up" the excess weapons-grade plutonium (Weekly Global Report, 2005§[1]). The NNSA, however, disputed Westinghouse's findings and found that the technology for the thorium fuel approach proposed by the Kurchatov Institute was not ready for deployment and its use would not be practicable before 2018 (Fuel Cycle Week, 2006). Thorium-fuel technology had been used effectively in a commercial reactor at Fort St. Vrain, CO, and problems reported at the site related to the reactor design, not the thorium fuel.

The Oak Ridge National Laboratory monitored the Kurchatov Institute's thorium-fuel program. The Kurchatov Institute is implementing the Radkowski thorium plutonium incinerator (RTPI) fuel design in 1,000-megawatt vodo-vodyanoy energetichskyi reaktory [water-water-moderated energetic reactors] (VVER-1000 MW). The retrofit to the Russian-designed VVER-1000 MW reactors, which presently use uranium fuel, will engage a thorium-plutonium fuel cycle that will "burn-up" plutonium converting it to non-weapons-grade plutonium. Westinghouse was providing expertise to review and analyze the Kurchatov Institute's nuclear reactor's technical designs and economic benefits (Westinghouse Electric Company LLC, 2005§).

**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 2005, the mine that had previously produced thorium-bearing monazite continued to produce titanium and zirconium minerals and maintained its monazite capacity on standby. Production of monazite in Florida was expected to resume in 2006; Iluka Resources Limited planned to reprocess tailings mainly for the zircon content. Monazite was last produced in the United States in 1994.

**Consumption**

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

Domestic thorium producers and processors that were surveyed in 2005 reported no consumption of thorium oxide equivalent in 2005. Additional information on domestic consumption was not available (table 1). Essentially all thorium alloys and compounds used by the domestic industry were derived from imports, company stocks, or materials previously sold from the NDS. Domestic companies processed or fabricated various forms of thorium for nonenergy uses, such as chemical catalysts, lighting, and welding electrodes.

**Stocks**

Government stocks of thorium nitrate in the NDS were about 3,218,697 kg (actual stockpile, 7,096,012 pounds) on December 31, 2004. At yearend 2005, all stocks of thorium nitrate in the NDS were shipped for disposal to the NTS.

**Prices**

Thorium oxide prices in 2005, as quoted by Rhodia Electronics and Catalysis, Inc.'s U.S. subsidiary, Rhodia, 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.

**Foreign Trade**

Exports of thorium compounds from the United States were 737 t valued at $281,000, an increase in quantity from the 731 t in 2004 (table 2). Principal destinations, in order of quantity were Singapore, United Kingdom, Germany, and Paraguay.

U.S. imports of thorium in 2005 were entirely from France and were 4,930 t valued at $145,000, a decrease from the 5,320 t valued at $170,000 in 2004 (table 2). Rhodia Electronics & Catalysis' rare-earth separation plant in La Rochelle remained the principal source of imported thorium compounds for the United States. Most of the thorium is supplied from older stocks that were produced when the plant was processing monazite. The La Rochelle plant currently processes intermediate rare-earth concentrates that have had the thorium removed.

**World Review**

Thorium demand worldwide remained depressed because of concerns over its naturally occurring radioactivity. Industrial consumers expressed concerns about the potential liabilities, the cost of complying with environmental monitoring and regulations, and the cost 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 thorium residues created as a byproduct

[1]References that include a section mark (§) are found in the Internet References Cited section.

during mineral processing or thorium's use as a nonproliferative nuclear fuel gains widespread commercialization. In the long term, high-disposal costs, increasingly stringent regulations, and public concerns related to thorium's natural radioactivity are expected to continue to depress its use in nonenergy applications in the United States as well as worldwide.

### References Cited

Fuel Cycle Week, 2006, NNSA assessors—Russians' thorium fuel risky, expensive: Fuel Cycle Week, v. 5, no. 168, February 7, p. 5-7.

Lobenz, George, 2006, Advanced reactor plans get off the ground in Texas: The Energy Daily [King Publishing Group], February 21, p. 1-2.

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Westinghouse Electric Company LLC, 2005, Program for disposition of weapons grade plutonium in a plutonium-thorium cycle, accessed August 16, 2005, at URL http://www.thoriumpower.com/files/latest%20news/Westinghouse%20Assessment.pdf.

## 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. U.S. Department of Energy, 2002.

TABLE 1

SALIENT U.S. REFINED THORIUM STATISTICS[1]

(Kilograms and dollars per kilogram)

| | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|
| Exports, gross weight: | | | | | |
| Thorium ore, including monazite | -- | -- | 23,000 | 18,000 r | -- |
| Compounds | 7,300 | 880 | 590 | 731 | 737 |
| Imports, compounds, gross weight[2] | 1,850 | 650 | 4,140 | 5,320 | 4,930 |
| Prices, yearend: | | | | | |
| Nitrate, gross weight[3] | 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. -- Zero.

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

2Source: U.S. International Trade Commision.

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 MATERIALS[1]

(Kilograms and dollars)

| | 2004 | | 2005 | | |
|---|---|---|---|---|---|
| | Quantity | Value | Quantity | Value | Principal destinations/sources and quantities, 2005 |
| Exports: | | | | | |
| Thorium ore, monazite concentrate | 18,000 r | 4,710 r | -- | -- | XX. |
| Compounds | 731 | 298,000 | 737 | 281,000 | Singapore 299; United Kingdom 280; Germany 110; Paraguay 29. |
| Imports, compounds | 5,320 | 170,000 | 4,930 | 145,000 | France 4,930. |

rRevised. XX Not applicable. -- 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, gross weight)

| Country[3] | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|
| Brazil | -- | -- | -- | 731 [4] | 800 [p] |
| India | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 |
| Malaysia | 643 [4] | 441 [4] | 795 [4] | 1,683 [r, 4] | 700 |
| Total | 5,640 | 5,440 | 5,800 | 7,410 [r] | 6,500 |

[p]Preliminary. [r]Revised. -- 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, 2006.

[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.