



2008 Minerals Yearbook

THORIUM

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Thorium consumption worldwide is relatively small compared with that of most other mineral commodities. There was no domestic production of thorium in 2008. All thorium alloys, metal, and compounds used by the domestic industry were derived from company stocks, imports, or material previously acquired from the U.S. Government stockpile. Domestic imports for consumption of refined thorium products decreased by 89% in 2008, according to data collected by the U.S. Census Bureau (tables 1, 2). The value of thorium compounds used by the domestic industry in 2008 was estimated to be about \$121,000, a decrease of 62% from \$318,000 in 2007. Only minor amounts, less than 10 metric tons (t) of thorium, are typically used annually. However, large fluctuations in consumption are caused by intermittent use, especially for catalytic applications that do not require annual replenishment. In 2008, thorium compounds were imported from France (91%) and the United Kingdom (9%).

Thorium and its compounds were produced primarily from the mineral monazite, which was recovered as a byproduct of processing heavy-mineral sands for zircon and the titanium minerals ilmenite and zircon, or the tin mineral cassiterite. Monazite was recovered primarily for its rare-earth content, and only a small fraction of the byproduct thorium produced was consumed. Monazite-producing countries in decreasing order of production were India, Malaysia, and Brazil (table 3).

Problems associated with thorium's natural radioactivity represented a significant cost to those companies involved in its mining, processing, manufacture, transport, and use. The costs to comply with environmental regulations and potential legal liabilities and the high costs to purchase storage and waste disposal space were the principal deterrents to its commercial use.

Limited demand for thorium, compared with demand for rare earths produced from thorium-containing minerals, 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, welding electrodes, and heat resistant ceramics, in descending order of use.

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 2008, the mine that had previously produced thorium-bearing monazite continued to produce titanium minerals and zircon and maintained its monazite capacity on standby. Iluka Resources Ltd. 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 evaluating import and export data, and surveying various processors and manufacturers.

Domestic thorium producers and processors that were surveyed reported no consumption of thorium oxide equivalent in 2008. Additional information on domestic consumption was not available. 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 ceramics, chemical catalysts, lighting, and welding electrodes.

In December, Thorium Power Ltd. (McLean, VA) and Punj Lloyd Group (Gurgaon, India) signed a memorandum of understanding to create a joint venture to construct nuclear power generation facilities in India, Southeast Asia, and other regions of the world. The joint venture would couple Thorium Power's nuclear fuel technology with Punj Lloyd's construction expertise (Business Wire, 2008b).

Prices

Thorium oxide prices in 2008, as quoted by Rhodia Inc., (Cranbury, NJ), (a subsidiary of Rhodia Electronics & Catalysis Sas., La Rochelle, Poitou-Charentes, France) increased from those of the previous year (table 1). At yearend, the price for thorium oxide delivered, duty paid, was \$300 per kilogram for 99.9% purity, an increase of 50% from the \$200 per kilogram at yearend 2007. In 2007, the 99.99%-purity thorium oxide product was discontinued. Thorium nitrate prices from Rhodia were unchanged at \$27 per kilogram for mantle-grade material. Thorium nitrate was used in the manufacture of mantles for incandescent "camping" lanterns, including natural gas lamps and oil lamps. Thorium mantles provide an intense white light that is adjusted towards the yellow region by a small addition of cerium. Thoriated mantles were not produced domestically owing to the development of a suitable thorium-free substitute.

Foreign Trade

Exports of thorium compounds from the United States were 12,700 kilograms (kg) valued at \$1.25 million, an increase from

1,630 kg in 2007 (table 2). Principal destinations were, in order of quantity, Mexico and Argentina.

Imports of thorium compounds in 2008 were from France and the United Kingdom and were 692 kg valued at \$121,000, a decrease from 6,370 kg valued at \$318,000 in 2007 (table 2). Rhodia Electronics & Catalysis' rare-earth separation plant in La Rochelle remained the principal source of thorium compounds imported into the United States and was also the source for some of the thorium imported through Canada. Most of the thorium was supplied from older stocks that were produced when the plant was processing monazite. The La Rochelle plant processes intermediate rare-earth concentrates that have had the thorium removed. Neither thorium ores nor concentrates were imported in 2007 or 2008.

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 environmental monitoring to comply with regulations, and the cost of disposal at approved waste burial sites. Interest in thorium increased worldwide as various countries have exhibited an interest in thorium-fueled nuclear power as an alternative to uranium. In 2008, geologic exploration for thorium resources continued in Canada, India, and the United States.

India.—The Indian Government continued to advance its three-stage plan to use its modest uranium and vast thorium resources. Its vast thorium resources are contained in numerous heavy-mineral sands deposits in the States of Andhra Pradesh, Kerala, Orissa, and Tamil Nadu. Thorium mineral resource wealth is considered the stable basis for the future of India's nuclear power program.

The Advanced Heavy Water Reactor (AHWR) critical facility, a prerequisite for building a 300-megawatt electrical (MWe) AHWR, was commissioned in December at the Bhabha Atomic Research Centre in Mumbai. The purpose of this critical facility was to prove the physical design of the AHWR and to understand the physics of the AHWR better. The AHWR was scheduled to be built in the 11th plan period of the project and will signal the beginning of the third stage of the country's nuclear power program. The AHWR would be powered by the naturally available thorium and the fissile material uranium-233 (Subramanian, 2008).

India sent its first lunar orbiter, Chandrayaan-1, into space to join a group of scientific instruments aboard the spacecraft that are of Indian origin. Chandrayaan-1 was carrying 11 scientific instruments. These included five instruments entirely designed and developed in India, three instruments from European Space Agency (one developed jointly with India and another with Indian contribution), one from Bulgaria, and two from the United States. Chandrayaan-1 was to use a high-energy x-ray spectrometer (HEX) to carry out the first spectral studies of 'hard' x-ray energies using energy resolution detectors. HEX was designed to help explore the possibility of identifying polar regions covered by thick water-ice deposits as well as in

identifying regions of high uranium and thorium concentrations (Thaindian, 2008).

Russia.—Thorium Power signed a post-irradiation examination agreement with the Kurchatov Institute, one of Russia's nuclear research facilities. After testing in Kurchatov Institute's IR-8 research reactor, irradiated uranium-zirconium metal seed fuel samples of Thorium Power's proprietary fuel design were cooled and examined in accordance with standard industry protocols. This work was being conducted to confirm the fuel performance and provide key irradiation testing data required for regulatory licensing of Thorium Power's fuel designs. The agreement would give Thorium Power access to additional world-class nuclear fuel analysis capabilities (Business Wire, 2008a).

Outlook

Thorium has been found to some extent in every continent of the world, but is concentrated in few geologic deposit types. There are three principal sources of thorium that are of commercial interest—monazite in heavy-mineral sand placer and vein deposits, thorite ores in vein deposits, and thorium recovered as a byproduct of uranium mining. Thorium use in the United States has decreased substantially during the past decade. Domestic consumption is expected to remain at recent low levels unless thorium's use as a nonproliferative nuclear fuel becomes widely commercialized or a low-cost technology is developed to dispose of thorium residues created as a byproduct during mineral processing, specifically monazite. In the long term, high disposal costs, increasingly stringent regulations, and public concerns related to thorium's natural radioactivity are expected to continue to discourage its use in nonenergy applications in the United States as well as worldwide.

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GENERAL SOURCES OF INFORMATION

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TABLE 1
SALIENT U.S. REFINED THORIUM STATISTICS¹

(Kilograms and dollars per kilogram)

	2004	2005	2006	2007	2008
Exports, gross weight:					
Thorium ore, including monazite	18,000	--	--	-- ²	-- ²
Compounds	731	737	1,090	1,630	12,700
Imports, gross weight:					
Thorium ore, including monazite	--	--	10,000	--	--
Compounds	5,320	4,930	48,600	6,370	692
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	175.00	200.00	300.00

-- Zero.

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

²Data estimated by U.S. Geological Survey.

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

	2007		2008		Principal destinations/sources and quantities, 2008
	Quantity (kilograms)	Value	Quantity (kilograms)	Value	
Exports:					
Thorium ore, monazite concentrate ²	--	--	--	--	
Compounds	1,630	\$500,000	12,700	\$1,250,000	Mexico 9,930; Argentina 1,800; United Kingdom 372; Singapore 280; Japan 154; Israel 26; Other 152.
Imports:					
Thorium ore, monazite concentrate	--	--	--	--	
Compounds	6,370	318,000	692	121,000	France 632; United Kingdom 60.

-- Zero.

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

²Data estimated by the U.S. Geological Survey.

Source: U.S. Census Bureau.

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

(Metric tons, gross weight)

Country ³	2004	2005	2006	2007	2008
Brazil	731 ⁴	958 ⁴	958 ^{r,4}	1,173 ^{r,4}	1,200 ^p
India	5,000	5,000	5,000	5,000	5,000
Malaysia	1,683 ⁴	320 ⁴	894 ⁴	682 ^{r,4}	700
Total	7,410	6,280	6,850	6,860 ^r	6,900

^pPreliminary. ^rRevised.

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 May 10, 2009.

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.