



2009 Minerals Yearbook

THORIUM

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By E. Lee Bray

Domestic survey data and tables were prepared by Shonta E. Osborne, statistical assistant, and the world production table was prepared by Lisa D. Miller, international data coordinator.

Thorium consumption worldwide is relatively small compared with that of most other mineral commodities. There was no domestic production of thorium reported in 2009. All thorium alloys, compounds, and metal 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 increased by 224% in 2009, according to data collected by the U.S. Census Bureau (tables 1, 2). The value of thorium compounds used by the domestic industry in 2009 was \$275,000, an increase of 128% from \$121,000 in 2008. 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 2009, thorium compounds were imported from France (50%) and India (50%).

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 rutile, 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, Brazil, and Malaysia (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. Thorium was not produced

in the United States in 2009, and the mine that had previously produced thorium-bearing monazite at Green Cove Springs, FL, (Iluka Resources Inc., a wholly owned subsidiary of Iluka Resources Ltd.) ceased production of zircon from tailings during the year. The monazite production capacity has been on standby for several years. 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 2009 and were temporarily shut down owing to the lack of thorium demand. 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 National Defense Stockpile. Domestic companies processed or fabricated various forms of thorium for nonenergy uses, such as ceramics, chemical catalysts, lighting, and welding electrodes.

In August 2009, Lightbridge Corp. (formerly Thorium Power Ltd.) (McLean, VA) signed an agreement to provide consulting services to Areva Inc. (Paris, France) on the design of a light water reactor using thorium (Thorium Power Inc., 2009).

Prices

Thorium oxide prices in 2009, as quoted by Rhodia Inc., (Cranbury, NJ), (a subsidiary of Rhodia Electronics & Catalysis Sas., La Rochelle, Poitou-Charentes, France) were estimated to be the same as those of the previous year (table 1). At yearend, the estimated price for thorium oxide delivered, duty paid, was \$300 per kilogram for 99.9% purity, the same as at yearend 2008. In 2007, the 99.99%-pure thorium oxide product was discontinued. Thorium nitrate prices from Rhodia were estimated to be 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 4,730 kilograms (kg) valued at \$379,000, a decrease from

12,700 kg in 2008 (table 2). Principal destinations were, in order of quantity, China and Luxembourg.

Imports of thorium compounds in 2009 were from France and India and were 2,250 kg valued at \$275,000, an increase from 692 kg valued at \$121,000 in 2008 (table 2). Rhodia Electronics & Catalysis' rare-earth separation plant in La Rochelle remained the principal source of thorium compounds imported into the United States. 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. Imports of thorium ores and concentrates including monazite were 26,000 kg in 2009; no thorium ores or concentrates were imported in 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 2009, geologic exploration for other resources associated with thorium continued in Canada, India, and the United States.

China.—Atomic Energy of Canada Ltd. signed a cooperation agreement with three Chinese organizations for the assessment of thorium use in the Candu pressurized heavy water reactor. Third Qinshan Nuclear Power Co., the Nuclear Power Institute of China, and China North Nuclear Fuel Corp. would jointly develop and demonstrate the use of thorium in the Candu reactor. The joint venture would lead to the construction of Candu reactors fueled by thorium in China, if proven feasible (World Nuclear News, 2009).

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.

Russia.—In October, Lightbridge and Russian Limited Liability Research and Development Co. (SOSNY) (Moscow, Russia) signed an agreement for SOSNY to manage the research

and development activities related to testing thorium in a Russian-designed nuclear reactor. Lightbridge had conducted initial analysis of safety and design aspects of its thorium fuel technology for the VVER-1000 reactor (Lightbridge Corp., 2009).

Outlook

Thorium has been found to some extent in every continent of the world, but is concentrated in a 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)

	2005	2006	2007	2008	2009
<u>Exports, gross weight:</u>					
Thorium ore, including monazite	--	--	-- ²	-- ²	18,000
Compounds	737	1,090	1,630	12,600	4,730
<u>Imports, gross weight:</u>					
Thorium ore, including monazite	--	10,000	--	--	26,000
Compounds	4,930	48,600	6,370	692	2,250
<u>Prices, yearend:</u>					
Nitrate, gross weight ^{3,4}	27.00	27.00	27.00	27.00	27.00 ^e
Oxide, 99.9% purity ⁴	82.50	175.00	200.00	300.00	300.00 ^e

^eEstimated. -- 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

	2008		2009		Principal destinations/sources and quantities, 2009
	Quantity (kilograms)	Value	Quantity (kilograms)	Value	
<u>Exports:</u>					
Thorium ore, monazite concentrate	-- ²	-- ²	18,000	\$269,000	Canada 9,000; China 2,000; Other 7,000.
Compounds	12,700	\$1,250,000	4,730	379,000	China 2,100; Luxembourg 1,300; France 404; Indonesia 250; Canada 230; Singapore 221; United Kingdom 144; Other 75.
<u>Imports:</u>					
Thorium ore, monazite concentrate	--	--	26,000	19,500	United Kingdom 26,000.
Compounds	692	121,000	2,250	275,000	France 1,130; India 1,120.

-- Zero.

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

²Data estimated by 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	2005	2006	2007	2008	2009
Brazil	958 ⁴	958 ⁴	1,173 ⁴	1,200	1,200
India	5,000	5,000	5,000	5,000	5,000
Malaysia	320 ⁴	894 ⁴	682 ⁴	700	600
Total	6,280	6,850	6,860	6,900	6,800

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 9, 2010.

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 information is inadequate for formulation of reliable estimates of output levels.

⁴Reported figure.