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THORIUM

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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 ores and concentrates reported in 2012. All thorium alloys, compounds, and metal used by the domestic industry were derived from imports or stocks. Domestic imports for consumption and exports of thorium compounds decreased significantly in 2012, according to data collected by the U.S. Census Bureau (tables 1–2). The United States was a net importer of thorium compounds.

The value of thorium compounds used by the domestic industry in 2012 was $300,000, a decrease of 25% from $398,000 in 2011. Only minor amounts, less than 10 metric tons (t) of thorium, are typically used annually. However, large fluctuations in apparent consumption are caused by intermittent use, especially for catalytic applications that do not require annual replenishment. In 2012, India (91%) and France (9%) were the sources of thorium compound imports to the United States. India continued to dominate the supply of thorium, accounting for 74% of global mine production, which totaled 6,650 t in 2012 (table 3).

Thorium has been found to some extent in every continent of the world, but is concentrated in a few geologic deposit types. Three principal sources of thorium 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 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 element (REE) content, and only a small fraction of the byproduct thorium produced was consumed. Monazite-producing countries were, in decreasing order of production, India, Malaysia, Vietnam, and Brazil (table 3).

Issues 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 deterrents to its commercial use.

Limited demand for thorium, compared with demand for REEs 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 include 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 2012, 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 2009. The monazite production capacity has been on care-and-maintenance status 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 processors and manufacturers. Domestic thorium producers and processors that were surveyed reported no consumption of thorium oxide equivalent in 2012 and were idle 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 or stockpiled inventory. Domestic companies processed or fabricated various forms of thorium for nonenergy uses, such as ceramics, chemical catalysts, lighting, and welding electrodes.

Lightbridge Corp. (McLean, VA) continued work on the development of nuclear technology using thorium. Lightbridge's thorium-based seed-and-blanket fuel assembly design consisted of metallic fuel rods in the central region called the seed that is surrounded by oxide fuel rods in the outer region called the blanket. The blanket is composed of thorium-uranium oxide pelletized fuel rods similar to conventional fuel rods used in commercial light water reactors. The blanket fuel rods used a thorium-uranium oxide mixture rather than uranium oxide in conventional uranium fuel rods. According to Lightbridge, the design offered compatibility with existing light water reactor designs and enhanced proliferation resistance of the used fuel (Lightbridge Corp., 2013, p. 7).

Prices

Published prices for thorium oxide and nitrate were not available. The average unit value of imported thorium compounds was $68.1 per kilogram, a slight decrease compared with $69.7 per kilogram in 2011. Owing to falling prices for rare

earths contained in thorium ores and concentrates, the average unit value of imported thorium ores and concentrates decreased to $613 per metric ton, a significant decrease compared with $1,660 per metric ton in 2011.

Foreign Trade

Exports of thorium ores and concentrates are minor relative to world production. In 2012, the United States did not export thorium ores and concentrates. Exports of thorium compounds from the United States were 3.16 t valued at $734,000, a decrease from 4.28 t in 2011 (table 2). Principal destinations were, in order of quantity, China, Singapore, the United Kingdom, and Poland.

Owing to limited demand, thorium ores and concentrates, and thorium compounds are imported sporadically. In 2012, 43 t of thorium ores or concentrates valued at $26,400 was imported from inventory in the United Kingdom (table 2). Imports of thorium compounds in 2012 totaled 4.40 t valued at $300,000, a decrease from 5.71 t valued at $398,000 in 2011. India and France were, in order of quantity, the leading suppliers of thorium compound imports in 2012.

World Review

Thorium demand worldwide remained depressed because of concerns about 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, however, as various countries exhibited interest in thorium-fueled nuclear power as an alternative to uranium. In 2012, exploration and development of rare-earth projects associated with thorium were underway in Australia, Brazil, Canada, Greenland, India, South Africa, the United States, and Vietnam.

China.—The Chinese Academy of Sciences continued a research initiative to develop thorium molten-salt reactor (TMSR) technologies. The effort was led by the TMSR Center at the Shanghai Institute of Applied Physics. By 2017, two 2-megawatt (MW) research reactors based on two molten salt technologies were expected to be constructed, and in the 2030s, construction of a 1,000-MW reactor was expected to help demonstrate the commercial feasibility of the technology (Endicott, 2013, p. 14).

India.—Indian Rare Earths Ltd. (IREL) is the only entity which has been permitted to produce and process monazite in India. In 2012, IREL was commissioning a processing plant that was expected to produce several thousand metric tons of rare-earth oxide (REO) derived from monazite produced at IREL's Orissa operations in Kerala, India. Any thorium products extracted during monazite processing were required to be returned to India's Department of Atomic Energy (International Business Times, 2012; Kaul, 2012).

Toyotsu Rare Earths India Pvt. Ltd. was constructing an REO separation plant in Visakhapatnam, Andhra Pradesh. The plant was expected to use monazite process residue to produce rare-earth compounds. Construction of the facility began in July 2011 (Toyotsu Rare Earths India Pvt Ltd., 2013).

The Indian Department of Atomic Energy continued development of a 300-MW advanced heavy water reactor (AHWR) fueled by a thorium-mixed oxide fuel (MOX). Construction on the AHWR was expected to begin in 2014, with a start date in 2019 (Todosow and others, 2012, p. 1). The AHWR was expected to take advantage of India's significant reserves of thorium.

Malaysia.—In September, the Malaysian Atomic Energy Licensing Board issued a temporary operating license (TOL) to the Lynas Corp. Ltd. for the Lynas Advanced Materials Plant (LAMP). Initial feedstock of rare-earth concentrates was received in November and initial production of rare-earth carbonates and oxides was expected in 2013 (Lynas Corp. Ltd., 2013, p. 4). In a review by the International Atomic Energy Agency (IAEA) in 2011, the activity concentration in the feedstock and the water leach purification residue was expected to be about 6 becquerel per gram (Bq/g). By IAEA safety guidelines, materials with activity concentrations between 1 and 10 Bq/g were regarded as radioactive for the purpose of regulation, but should be considered for possible exemption depending on the dosage received by individuals (International Atomic Energy Agency, 2011, p. 13). According to a statement by the Malaysian Ministry of Natural Resources and Environment issued in December, the TOL required Lynas to remove residues generated by LAMP out of Malaysia (Ministry of Natural Resources and Environment, 2012).

Norway.—Thor Energy AS, in partnership with an international consortium of utilities, industry, and research organizations, made plans for a 4-year test of thorium-MOX. The objective of the test was to gather data and demonstrate that thorium-MOX fuel could operate safely in a commercial reactor. The testing was being performed by the Institute for Energy Technology, at a fuel-testing reactor in Halden, Norway. Thor Energy is owned by Thor Corp. (81.3%), Steenkampskraal Thorium Ltd. (15%), and Statoil Ventures AS (3.7%) (Thor Energy AS, 2013).

South Africa.—Great Western Minerals Group Ltd. (GWMG) was proceeding with the refurbishment of its Steenkampskraal (SKK) monazite mine for the production of rare-earth minerals. In 2012, the company was preparing a preliminary economic assessment whose final results were to be published in 2013. In 2012, GWMG applied for additional prospecting rights covering more than 500 square kilometers surrounding the SKK Project. GWMG planned to store thorium produced during the processing of monazite in underground casements in a recoverable form (Great Western Minerals Group Ltd., 2013, p. 3).

Outlook

For the next few years, domestic consumption of thorium is expected to remain at low levels. In the long term, thorium's consumption will increase if its use as a nuclear fuel becomes commercialized. Although most rare-earth companies have shifted away from using monazite, new rare-earth production from naturally occurring radioactive ores is expected to generate excess thorium supply.

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

		2008	2009	2010	2011	2012
Exports, gross weight:						
Thorium ore, including monazite	metric tons	61	18	1	--	--
Compounds	do.	12.62	4.73	1.50	4.28	3.16
Imports for consumption, gross weight:						
Thorium ore, including monazite	do.	--	26	--	30	43
Compounds	do.	0.69	2.25	3.03	5.71	4.40
Prices, yearend:						
Nitrate, gross weight[2]	dollars per kilogram	NA	NA	NA	NA	NA
Oxide, 99.9% purity[2]	do.	252	252	252	NA	NA

do. Ditto. NA Not available. -- Zero.

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

[2]Source: Rhodia, Inc., free on board port of entry, duty paid, thorium oxide basis.

TABLE 2
U.S. FOREIGN TRADE IN THORIUM AND THORIUM-BEARING MATERIALS[1]

	2011		2012		
	Quantity (metric tons)	Value	Quantity (metric tons)	Value	Principal destinations/sources and quantities, 2012
Exports:					
Thorium ore, monazite concentrate	--	--	--	--	XX
Compounds	4.28	$762,000	3.16	$734,000	China, 1.97; Singapore, 0.50. United Kingdom, 0.29.
Imports for consumption:					
Thorium ore, monazite concentrate	30	49,800	43	26,400	United Kingdom, 43.
Compounds	5.71	398,000	4.40	300,000	India, 4.00.

XX Not applicable. -- Zero.

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

Source: U.S. Census Bureau.

TABLE 3
MONAZITE CONCENTRATE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country[3]	2008	2009	2010	2011	2012[e]
Brazil	834	303	249	290 [r]	250
India[e]	5,000	5,000	5,200	5,200	5,400
Malaysia	233	25	732	779	600
Vietnam[4]	1,226 [r]	-- [r]	309 [r]	361 [r]	369 [5]
Total	7,290 [r]	5,330 [r]	6,490 [r]	6,630 [r]	6,620

[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]Includes data available through December 11, 2013.

[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 information is inadequate for formulation of reliable estimates of ouput levels.

[4]Exports to China.

[5]Reported figure.