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2017 Minerals Yearbook

THORIUM [ADVANCE RELEASE]

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Thorium

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No domestic production of thorium ores and concentrates was reported in 2017; however, some heavy-mineral concentrates produced in the United States may contain thorium from their naturally occurring source. Thorium alloys, compounds, and metal used by the domestic industry were derived from imports or stocks. Significant fluctuations in apparent consumption are caused by intermittent use, especially for applications that do not require annual replenishment of thorium supply.

In 2017, the United States did not import any thorium ore and concentrate. India (98%) was the leading source of thorium compound imports to the United States. Imports for consumption of thorium compounds increased by 173% compared with those in 2016. Although no domestic mine production was reported, on a gross weight basis, the United States was a net exporter of thorium compounds, and the value of thorium compounds exports was $1,340,000. In 2016 and 2017, exports of compounds were unusually high relative to historical exports and may have included misclassified mineral concentrates.

In 2017, the unit value of domestic exports of thorium compounds was $15 per kilogram compared with a unit value of $86 per kilogram for U.S imports for consumption, according to data collected by the U.S. Census Bureau (tables 1, 2). Global mine production of thorium-bearing mineral concentrate was 9,050 metric tons (t) (table 3).

Thorium occurs widely but is concentrated in only 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 placer sands for zircon and titanium minerals (ilmenite and rutile), or for 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.

In 2017, monazite-producing countries included Brazil, India, Malaysia, Nigeria, Thailand, and Vietnam. Other countries, such as China, produced monazite and thorium compounds, but data were inadequate for the formulation of reliable production estimates (table 3). Issues associated with thorium's natural radioactivity were a significant deterrent to its commercial use. Excess thorium that was not designated for commercial use was either disposed of as low-level radioactive waste or stored. In the United States, only minor amounts typically are used annually. Although research into thorium-fueled nuclear reactors continued, no industrial-scale nuclear reactors used thorium in 2017. Principal uses include ceramics, catalysts, lighting, radiotherapy, and welding electrodes.

Production

The U.S. Geological Survey developed domestic mine production data for thorium-bearing minerals from a voluntary canvass of U.S. mining operations and information gathered from publicly available reports. Although monazite may be recovered as a byproduct of processing heavy-mineral sands, monazite was not produced domestically as a salable product in 2017.

Consumption

Thorium consumption worldwide is small compared with that of most other mineral commodities. Thorium is used in a variety of catalysts, ceramics, optics, nuclear medicine, and metal applications.

In catalysts, thorium oxide (ThO_2) is used in petroleum fluid catalytic cracking (converting crude oil into lighter fractions) and in the production of nitric and sulfuric acids. One of the major uses of thorium is in the form of thoriated tungsten metal. Thorium lowers the energy necessary for electrons to escape from a tungsten surface and enhances the thermionic emission. In welding and plasma cutting, thoriated tungsten electrodes improve ignition and arc stability. Thoriated tungsten filaments are used in high-intensity discharge lamps, vacuum tubes for radio transmitters and audio amplifiers, and cathode heaters. As a fluoride, thorium is used within antireflective materials in optical coatings. One of the oldest uses of thorium is in the manufacture of incandescent gas mantles. Gas mantles containing ThO_2 provide an intense white light but were not produced domestically owing to the availability of suitable substitutes. In the past, thorium has been used as an alloying agent in magnesium and nickel alloys for heat-resistant applications. Because of concerns about its naturally occurring radioactivity, thorium has been replaced by nonradioactive materials in many uses. Interest in thorium as a nuclear fuel continues in part owing to its high abundance relative to uranium. A recently commissioned operation in Texas was using an isotope of thorium (thorium-232) as feedstock to produce an isotope of lead (lead-212) that was used in nuclear medicine for cancer treatments (World Nuclear News, 2015).

Insufficient data were collected from thorium processors to determine the consumption of thorium during 2017. Thorium alloys and compounds used by the domestic industry were derived from imports or stockpiled inventory.

Corporations, research institutions, and government agencies were active in the pursuit of commercializing thorium as a nuclear fuel material. Thorium-based nuclear research and development programs have been underway in many countries, including the United States. In the United States, companies known to be involved in these efforts included Alpha Tech Research Corp. (Salt Lake City, UT); Flibe Energy Inc. (Huntsville, AL); Lightbridge Corp. (Reston, VA); Southern Co. (Atlanta, GA); TerraPower, LLC (Bellevue, WA); Terrestrial Energy USA, Inc. (New York, NY); ThorCon USA Inc. (Stevenson, WA); Transatomic Power Corp. (Cambridge, MA); and X-energy, LLC (Greenbelt, MD).

Prices

Published prices for ThO_2 and thorium nitrate were not available. According to export statistics from India's Ministry of Commerce, the unit value of thorium nitrate exports from India was $58 per kilogram, a 7% increase compared with the unit value in 2016 (IHS Markit Inc., 2018). In the United States, the average unit value of imported thorium compounds was $86 per kilogram, a 6% decrease compared with $91 per kilogram in 2016. The average unit value of exported thorium compounds decreased to $15 per kilogram from $28 per kilogram in 2016 (table 2). For imports and exports, the data are often composed of a mix of high-volume, low-unit-value shipments and low-volume, high-unit-value shipments. For example, the monthly unit value for imports by country in 2017 ranged from about $65 per kilogram (India in March) to $5,580 per kilogram (United Kingdom in January).

Foreign Trade

Owing to limited demand, thorium ores and concentrates and thorium compounds are imported and exported sporadically. From 2013 to 2015, no thorium ores and concentrates were imported into the United States. In 2016, imports of thorium ores and concentrates rose to 16 t and then fell to zero in 2017. Imports of thorium compounds in 2017 totaled 8.51 t valued at $731,000, an increase from 3.12 t valued at $284,000 in 2016. India continued to be the leading supplier of thorium compound imports in 2017. United States imports of thorium compounds were primarily from India in the form of thorium nitrate (IHS Markit Inc., 2018). The United States has not reported exports of thorium ores and concentrate since 2010. Exports of thorium compounds from the United States were 88.6 t, a 39% increase from 63.9 t in 2016 (table 2). The principal destinations were Brazil (23%) and Vietnam (54%).

World Review

Thorium demand worldwide was limited by concerns about its naturally occurring radioactivity. In 2017, exploration and development of several rare-earth projects associated with thorium were underway, but progress on most projects slowed because of an oversupply of rare-earth materials and declining prices.

Brazil.—In 2017, Brazil exported 2,900 t of thorium-bearing monazite concentrates to China for the production of rare-earth materials, a 22% decrease compared with those in 2016 (IHS Markit Inc., 2018). Although no monazite production data were available for 2017, according to the Departamento Nacional de Produção Mineral (DNPM), Brazil's prior shipments were derived from Indústrias Nucleares do Brasil S.A.'s (INB) inventories in Sao Francisco do Itabapoana (Andrade, 2016, p. 108, 109). INB reported that it produced 1,654 t of monazite concentrate from previously mined ore and heavy-mineral concentrates at its Buena operations in Sao Francisco de Itabapoana, Rio de Janeiro State (Indústrias Nucleares do Brasil S.A., 2018, p. 25).

Canada.—Medallion Resources Ltd. continued to pursue plans to develop a processing facility for the production of mixed rare-earth compounds from monazite. Medallion's proposed facility would purchase monazite byproduct from heavy-mineral-sand operations and produce rare-earth compounds. In 2017, the company proceeded with pilot-plant studies and tested samples from heavy-mineral sands producers to locate suitable monazite feed (Medallion Resources Ltd., 2017, p. 1, 10, 11).

Commerce Resources Corp. continued work on prefeasibility studies on its Ashram Project. The proposed project was based on the production of 16,900 metric tons per year (t/yr) of rare-earth-oxide (REO) equivalent primarily derived from monazite. Thorium was to be selectively removed from the REO product and was expected to remain in the mill tailings. In 2017, the company continued studies that included resource definition drilling, hydrogeologic survey, and gathering environmental baseline data. The company signed a memorandum of understanding with Ucore Rare Metals Inc. to determine whether mixed carbonate produced from the Ashram deposit would be amenable to processing using Ucore's molecular recognition technology (Commerce Resources Corp., 2015, p. 13; 2018, p. 3, 4).

China.—China produced substantial but unknown quantities of thorium byproducts during the processing of domestic and imported mineral concentrates for the production of rare-earth compounds. In 2017, China's imports of thorium ores and concentrates were 6,004 t (gross weight), a 16% decrease compared with those in 2016. The leading import sources were Brazil (2,900 t), Thailand (2,560 t), Vietnam (359 t), and Malaysia (130 t). Thorium also may be present in imports of mixed heavy-mineral concentrates not explicitly classified as thorium bearing (IHS Markit Inc., 2018).

Greenland.—Greenland Minerals and Energy Ltd. (GMEL) continued to advance its Kvanefjeld Project for production of fluorspar, rare earths, uranium, and zinc concentrates and refined compounds. Unspecified quantities of thorium byproduct contained in the concentrates were expected to be removed during the processing of the mineral concentrates. In the fourth quarter of 2016, Shenghe Resources Holding Ltd., a China-based company engaged in the mining and processing of rare earths, acquired a 12.5% interest in GMEL. In 2017, Shenghe Resources was providing technical support to reduce operating and capital costs for the Kvanefjeld project (Greenland Minerals and Energy Ltd., 2018, p. 2–6).

India.—India's producers of monazite concentrate included Indian Rare Earths Ltd. (IREL) and Kerala Metals & Minerals Ltd. Because of Government regulations governing the mining, processing, and storage of radioactive minerals, India produced and had a stockpile of monazite-rich tailings from heavy-mineral-sand operations. The tailings were reported by India's Atomic Energy Regulatory Board to fall in two categories—large quantities containing less than 5% monazite mixed with silica sand and small amounts consisting of greater than 5% monazite, stored in trenches and topped with silica sand. The stockpiled tailings were not quantified (Bhattacharya, 2015, p. 41).

IREL's Aluva Rare Earth Division in the Ernakulam district, Kerala State, was capable of processing 10,000 t/yr of monazite into rare-earth compounds and thorium hydroxide. In Odisha State, IREL's production capacity included 2,000 t/yr of thorium oxalate and 150 t/yr of thorium nitrate (Singh, 2016, p. 13). According to the Indian Bureau of Mines, IREL had stockpiled impure thorium hydroxide at its rare-earths operations (Indian Bureau of Mines, 2018). According to India's Department of Atomic Energy (DAE), IREL's production of thorium oxalate and thorium nitrate was 248 t and 82 t, respectively, for the fiscal year beginning April 1, 2016.

India's exports in 2017 included thorium ores and concentrates (60 kilograms), thorium nitrate (9 t), and other thorium compounds (4 t). The leading destinations for thorium compounds were the United States (73%) and Japan (25%) (IHS Markit Inc., 2018).

DAE's estimate of monazite resources for 128 deposits totaled 12 million metric tons (Mt) containing about 1.1 Mt of ThO_2. The leading States for these resources were Andhra Pradesh (3.7 Mt), Odisha (3.1 Mt), Tamil Nadu (2.5 Mt), Kerala (1.8 Mt), and West Bengal (1.2 Mt) (Indian Department of Atomic Energy, 2017).

Kazakhstan.—Summit Atom Rare Earth Co. (SARECO) became a wholly owned venture of JSC National Atomic Company Kazatomprom in 2017. SARECO had been a joint venture between Japan's Sumitomo Corp. (49%) and Kazatomprom (51%), and the company's operations were designed to recover 1,500 t/yr of REEs from uranium-ore residue in Stepnogorsk. After several years of commissioning, the operating status was idle at yearend (JSC National Atomic Company Kazatomprom, 2017, p. 66).

South Africa.—Steenkampskraal Thorium Ltd. (STL) continued work to support the recommissioning of the idled Steenkampskraal (SKK) Mine in the Western Cape Province. The SKK Mine produced monazite concentrates from 1952 to 1963. STL reported significant efforts to restart the Steenkampskraal monazite mine and planned to produce thorium compounds and mixed rare-earth nitrates through hydrometallurgical treatment of monazite concentrates (Blench and Slabber, 2016, p. 9–11). According to an NI 43–101-compliant study completed in 2013, using a 1% REO cutoff grade, SKK's in situ measured resources were 85,000 t containing about 2.82% ThO_2. Using the same 1% REO cutoff grade, indicated resources were estimated to be 154,000 t containing about 2.09% ThO_2 (Great Western Minerals Group Ltd., 2014, p. 133).

Outlook

During the next decade, concerns related to thorium's natural radioactivity are expected to continue to limit its use in nonenergy applications. At the same time, the potential supply of thorium from rare-earths production is projected to increase.

In the long term, consumption of thorium will increase substantially if its use as a nuclear fuel becomes commercialized. Many countries are developing nuclear reactor designs that incorporate thorium-bearing fuels. In India, a reactor design incorporating thorium fuel is expected to be commercialized by 2022. In Norway, Thor Energy AS is working toward obtaining regulatory approval for the commercial use of Th-Add (a thorium-bearing fuel rod designed for existing commercial reactors) by 2018 (World Nuclear Association, 2017). In China, the Chinese Academy of Sciences is developing two types of thorium molten salt reactors with commercialization targeted for the early 2030s (Xu, 2017, p. 41). In the United States, the Department of Energy is supporting the development of innovative nuclear energy technologies, including the use of thorium fuels, through the Office of Advanced Reactor Technologies.

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

		2013	2014	2015	2016	2017
Exports, gross weight, thorium compounds	metric tons	1.01	14.8	2.16	63.9	88.6
Imports for consumption, gross weight:						
Thorium ores and concentrates, including monazite	do.	--	--	--	16	--
Thorium compounds	do.	2.83	11.0	2.74	3.12	8.51
Price, yearend, thorium compounds, gross weight,[2] India	dollars per kilogram	65	65	63	65	78

do. Ditto. -- Zero.
[1]Table includes data available through August 14, 2018. Data are rounded to no more than three significant digits.
[2]Source: U.S. Census Bureau.

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

	2016		2017	
	Quantity (metric tons)	Value	Quantity (metric tons)	Value
Exports, thorium compounds (2844.30.1000):				
Brazil	15.0	$37,000	20.0	$229,000
Chile	3.10	59,700	1.26	41,100
China	14.2	438,000	(2)	87,000
El Salvador	--	--	5.09	160,000
Peru	--	--	3.78	53,900
United Arab Emirates	(2)	14,300	7.40	47,200
Vietnam	20.1	67,000	48.2	119,000
Other	11.5 r	1,180,000 r	2.96	603,000
Total	63.9	1,790,000	88.6	1,340,000
Imports for consumption:				
Thorium ore, monazite concentrate (2612.20.0000), Canada	16	4,050 r	--	--
Thorium compounds (2844.30.1000):				
India	3.00	195,000	8.30	607,000
Other	0.12 r	88,800	0.21	124,000
Total	3.12 r	284,000	8.51	731,000

Revised. -- Zero.
[1]Table includes data available through August 14, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Less than ½ unit.

Source: U.S. Census Bureau.

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

(Metric tons, gross weight)

Country or locality[2]	2013	2014	2015	2016	2017
Brazil	600	-- e	1,600 e	3,700 e	2,900 e
India[e]	3,000	3,000	3,000	2,500	3,000
Malaysia	261	372	499	230 [3]	130 e
Nigeria	NA	104	110	--	55 e
Thailand[e]	210	3,200	1,300	2,600	2,600
Vietnam[4]	180	--	460	400	360 e
Total	4,250	6,680 r	6,970 r	9,430	9,050

[e]Estimated. [r]Revised. NA Not available. -- Zero.
[1]Table includes data available through May 29, 2018. All data are reported unless otherwise noted. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]In addition to the countries and (or) localities listed, China, Indonesia, North Korea, the Republic of Korea, and countries and (or) localities of the Commonwealth of Independent States may have produced monazite, but available information is inadequate to make reliable estimates of output.
[3]China's imports from Thailand.
[4]China's imports from Vietnam.