THORIUM

(Data in metric tons of thorium oxide (ThO_2) equivalent, unless otherwise noted)

Domestic Production and Use: The primary source of the world's thorium is the rare-earth and thorium phosphate mineral, monazite. Monazite was not recovered as a salable product during domestic processing of heavy mineral sands in 2001. Past production had been as a byproduct during processing for titanium and zirconium minerals, and monazite was recovered for its rare-earth content. Essentially all thorium compounds and alloys consumed by the domestic industry were derived from imports, stocks of previously imported materials, or materials shipped from U.S. Government stockpiles. About eight companies processed or fabricated various forms of thorium for nonenergy uses, such as high-temperature ceramics, catalysts, and welding electrodes. The value of thorium metal, alloys, and compounds used by the domestic industry was estimated to be about $100,000.

Salient Statistics—United States:	1997	1998	1999	2000	2001[e]
Production, refinery[1]	—	—	—	—	—
Imports for consumption:					
Thorium ore and concentrates (monazite), gross weight	20	—	—	—	—
Thorium ore and concentrates (monazite), ThO_2 content	1.40	—	—	—	—
Thorium compounds (oxide, nitrate, etc.), gross weight	13.50	7.45	5.29	11.10	1.80
Thorium compounds (oxide, nitrate, etc.), ThO_2 content	10.00	5.51	3.91	8.20	2.00
Exports:					
Thorium ore and concentrates (monazite), gross weight	—	—	—	—	—
Thorium ore and concentrates (monazite), ThO_2 content	—	—	—	—	—
Thorium compounds (oxide, nitrate, etc.), gross weight	0.24	1.13	2.52	4.64	6.86
Thorium compounds (oxide, nitrate, etc.), ThO_2 content	0.18	0.84	1.86	3.43	7.60
Shipments from Government stockpile excesses ($ThNO_3$)	—	—	—	—	—
Consumption: Reported, (ThO_2 content[e])	13.0	7.0	7.0	6.0	NA
Apparent	12.0	4.7	3.1	7.7	E
Price, yearend, dollars per kilogram:					
Nitrate, welding-grade[2]	5.46	5.46	5.46	5.46	5.46
Nitrate, mantle-grade[3]	27.00	27.00	27.00	27.00	27.00
Oxide, yearend:					
99.9% purity[4]	82.50	82.50	82.50	82.50	82.50
99.99% purity[4]	107.25	107.25	107.25	107.25	107.25
Stocks, industrial, yearend	12.8	NA	NA	NA	NA
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (1997-2000): Monazite: France, 100%. Thorium compounds: France, 72%; Canada, 11%; Japan, 4%; Singapore, 2%; and other, 11%.

Tariff: Item	Number	Normal Trade Relations 12/31/01
Thorium ores and concentrates (monazite)	2612.20.0000	Free.
Thorium compounds	2844.30.1000	5.5% ad val.

Depletion Allowance: Monazite, 23% on thorium content, 15% on rare-earth and yttrium content (Domestic); 14% (Foreign).

Government Stockpile:

Stockpile Status—9-30-01[6]

Material	Uncommitted inventory	Committed inventory	Authorized for disposal	Disposal plan FY 2001	Disposals FY 2001
Thorium nitrate (gross weight)	3,219	—	2,947	3,218	—

Events, Trends, and Issues: Domestic mine production of thorium-bearing monazite ceased at the end of 1994 as world demand for ores containing naturally occurring radioactive thorium declined. Imports and existing stocks supplied essentially all thorium consumed in the United States in 2001. Domestic demand for thorium ores, compounds, metals, and alloys has exhibited a long-term declining trend. Thorium consumption in the United States decreased in 2000 to 2.0 tons; however, most material was consumed in a nonrecurring application. In 2001, thorium consumption, primarily for use in catalyst applications, is estimated to decrease. On the basis of data through August 2001, the average value

Prepared by **James B. Hedrick [(703) 648-7725, jhedrick@usgs.gov, fax: (703) 648-7722]**

THORIUM

(Data in metric tons of thorium oxide (ThO_2) equivalent, unless otherwise noted)

Domestic Production and Use: The primary source of the world's thorium is the rare-earth and thorium phosphate mineral monazite. Monazite was not recovered as a salable product during processing of heavy mineral sands in 2000. Past production had been as a byproduct of titanium and zirconium mineral processing during which monazite was recovered for its rare-earth content. Essentially all thorium compounds and alloys consumed by the domestic industry were derived from imports, stocks of previously imported materials, or materials shipped from U.S. Government stockpiles. About eight companies processed or fabricated various forms of thorium for nonenergy uses, such as high-temperature ceramics, catalysts, and welding electrodes. The value of thorium metal, alloys, and compounds used by the domestic industry was estimated to be about $420,000.

Salient Statistics—United States:	1996	1997	1998	1999	2000[e]
Production, refinery[1]	—	—	—	—	—
Imports for consumption:					
Thorium ore and concentrates (monazite), gross weight	101	20	—	—	—
Thorium ore and concentrates (monazite), ThO_2 content	7.07	1.40	—	—	—
Thorium compounds (oxide, nitrate, etc.), gross weight	26.30	13.50	7.45	5.29	15.10
Thorium compounds (oxide, nitrate, etc.), ThO_2 content	19.45	10.00	5.51	3.91	11.10
Exports:					
Thorium ore and concentrates (monazite), gross weight	2	—	—	—	—
Thorium ore and concentrates (monazite), ThO_2 content	.14	—	—	—	—
Thorium compounds (oxide, nitrate, etc.), gross weight	.06	.24	1.13	2.52	4.04
Thorium compounds (oxide, nitrate, etc.), ThO_2 content	.04	.18	.84	.79	2.98
Shipments from Government stockpile excesses ($ThNO_3$)	—	.82	—	—	—
Consumption: Reported, (ThO_2 content[e])	4.9	13.0	7.0	7.0	NA
Apparent	26.3	12.0	4.7	3.1	8.2
Price, yearend, dollars per kilogram:					
Nitrate, welding-grade[2]	5.46	5.46	5.46	5.46	5.46
Nitrate, mantle-grade[3]	14.32	27.00	27.00	27.00	27.00
Oxide, yearend: 99.9% purity[4]	88.50	82.50	82.50	82.50	82.50
99.99% purity[4]	107.25	107.25	107.25	107.25	107.25
Stocks, industrial, yearend	35.2	12.8	NA	NA	NA
Net import reliance[5] as a percent of apparent consumption	NA	100	100	100	100

Recycling: None.

Import Sources (1996-99): Monazite: Australia, 67%; and France, 33%. Thorium compounds: France, 99.4%; and other, 0.6%.

Tariff: Item	Number	Normal Trade Relations 12/31/00
Thorium ores and concentrates (monazite)	2612.20.0000	Free.
Thorium compounds	2844.30.1000	5.5% ad val.

Depletion Allowance: Monazite, 22% on thorium content, 14% on rare-earth and yttrium content (Domestic); 14% (Foreign).

Government Stockpile:

Stockpile Status—9-30-00[6]

Material	Uncommitted inventory	Committed inventory	Authorized for disposal	Disposal plan FY 2000	Disposals FY 2000
Thorium nitrate (gross weight)	3,218	—	2,944	2,946	—

Events, Trends, and Issues: Domestic mine production of thorium-bearing monazite ceased at the end of 1994 as world demand for ores containing naturally occurring radioactive thorium declined. Imports and existing stocks supplied essentially all thorium consumed in the United States in 2000. Domestic demand for thorium ores, compounds, metals, and alloys has exhibited a long-term declining trend. Thorium consumption in the United States remained level in 1999 at 7.0 tons, however, most material was consumed in a nonrecurring application. In 2000, thorium consumption, primarily for use in catalyst applications, is estimated to increase. On the basis of data through July 2000, the average value of imported thorium compounds decreased to $47.76 per kilogram from the 1999 average of $53.15 per kilogram (gross weight).

Prepared by **James B. Hedrick [(703) 648-7725, jhedrick@usgs.gov, fax: (703) 648-7722]**

THORIUM

A thorium research company announced that it had obtained its fourth and final U.S. patent in February for a thorium-based nonproliferative seed-and-blanket nuclear facility assembly.[7]

A researcher from the University of Vienna's Institute for Experimental Physics presented a paper on the nonproliferative commercial Radkowsky thorium-fuel concept. The reactor was initially designed to use a seed of enriched uranium-zirconium alloy to initiate the thorium fuel cycle. The thorium-fueled reactor design, however, can also be adapted to "burn" plutonium by using a plutonium-zirconium alloy. The design is adaptable to many existing pressurized water reactors (PWR) or Russian-designed Vodo Vodyanyi Energeticheskiy Reaktor (VVER) reactors with either minor or no changes to the existing designs especially because the thorium fuel installs in the same space as the uranium cores. Conventional uranium fueled reactors produce approximately 50 times more plutonium than those using thorium.[8]

The use of thorium in the United States has decreased significantly since the 1980's when consumption averaged 45 tons per year. Increased costs to monitor and dispose of thorium have caused the domestic processors to switch to thorium-free materials. Real and potential costs related to compliance with State and Federal regulations, proper disposal, and monitoring of thorium's radioactivity have limited its commercial value. Use of thorium has been forecast to decline unless a low-cost disposal process is developed or new technology creates renewed demand.

World Refinery Production, Reserves, and Reserve Base:

	Refinery production		Reserves[9]	Reserve base[9]
	1999	2000		
United States	—	—	160,000	300,000
Australia	—	—	300,000	340,000
Brazil	NA	NA	16,000	18,000
Canada	NA	NA	100,000	100,000
India	NA	NA	290,000	300,000
Malaysia	—	—	4,500	4,500
Norway	—	—	170,000	180,000
South Africa	NA	NA	35,000	39,000
Other countries	NA	NA	90,000	100,000
World total (rounded)	NA	NA	1,200,000	1,400,000

Reserves and reserve base are contained primarily in monazite. Without demand for the rare earths, monazite would probably not be recovered for its thorium content. Other ore minerals with higher thorium contents, such as thorite, would be more likely sources if demand significantly increased. No new demand that could not be met from existing stockpiles is expected. Reserves exist primarily in recent and ancient placer deposits. Lesser quantities of thorium-bearing monazite reserves occur in vein deposits and carbonatites.

World Resources: Thorium resources occur in provinces similar to those of reserves. The largest share are contained in placer deposits. Resources of more than 500,000 tons are contained in placer, vein, and carbonatite deposits. Disseminated deposits in various other alkaline igneous rocks contain additional resources of more than 2 million tons. Large thorium resources are found in Australia, Brazil, Canada, Greenland, India, South Africa, and the United States.

Substitutes: Nonradioactive substitutes have been developed for many applications for thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, zirconium, and yttrium can substitute for magnesium-thorium alloys in aerospace applications.

[e]Estimated. NA Not available.
[1]All domestically consumed thorium was derived from imported materials.
[2]U.S. Department of Defense, Defense Logistics Agency. Based on sales from the National Defense Stockpile.
[3]Rhodia Canada, Inc., f.o.b. port of entry, duty paid, ThO_2 basis.
[4]Rhodia Rare Earths, Inc., 1 to 950 kilogram quantities, f.o.b. port of entry, duty paid.
[5]Defined as imports - exports + adjustments for Government and industry stock changes.
[6]See Appendix B for definitions.
[7]Radkowsky Thorium Power Corporation news release, 2000, RTPC's fourth and final patent issued for non-proliferative seed-and-blanket fuel assembly. RTPC news, Washington, DC, February 15, 1 p.
[8]Higatsberger, Michael, 1999, The non-proliferative commercial Radkowsky thorium fuel concept: International Atomic Energy Agency Technical Committee on "Utilisation Options in Emerging Nuclear Energy Systems," Vienna, November 15-17, 28 p.
[9]See Appendix C for definitions.

THORIUM

of imported thorium compounds decreased to $36.58 per kilogram from the 2000 average of $47.76 per kilogram (gross weight). A researcher at Los Alamos National Laboratory announced it had derived the first estimates of thorium abundances from the Lunar Prospector mission to Earth's moon. The elemental distribution maps from the Lunar Prospector mission provide twice the resolution of previous missions. Thorium is an important element in modeling lunar evolution because it is a constituent of the mixture potassium-rare earth elements-phosphorous and known to geologists by its acronym, KREEP. KREEP is the last material to solidify from a geologic melt and are evidence of the original material beneath the moon's crust. The existence of KREEP on the moon's surface is indicative of a lunar volcanic event or strong meteor impact that penetrated the crust.[7]

A company in the United States announced that it had developed all-oxide thorium fuel seed, which is reportedly standard for domestic nuclear reactors. Previous thorium fuel seeds had been metallic. In addition the company's fuel technology group developed an 18-month thorium fuel cycle, an increase from the previous 12-month cycle.[8]

The use of thorium in the United States has decreased significantly since the 1980s, when consumption averaged 45 tons per year. Increased costs to monitor and dispose of thorium have caused the domestic processors to switch to thorium-free materials. Real and potential costs related to compliance with State and Federal regulations, proper disposal, and monitoring of thorium's radioactivity have limited its commercial value. It is forecast that thorium's use will continue to decline unless a low-cost disposal process is developed or new technology creates renewed demand.

World Refinery Production, Reserves, and Reserve Base:[9]

	Refinery production 2000	Refinery production 2001	Reserves[10]	Reserve base[10]
United States	—	—	160,000	300,000
Australia	—	—	300,000	340,000
Brazil	NA	NA	16,000	18,000
Canada	NA	NA	100,000	100,000
India	NA	NA	290,000	300,000
Malaysia	—	—	4,500	4,500
Norway	—	—	170,000	180,000
South Africa	—	—	35,000	39,000
Other countries	NA	NA	90,000	100,000
World total (rounded)	NA	NA	1,200,000	1,400,000

Reserves and reserve base are contained primarily in the rare-earth ore mineral, monazite. Without demand for the rare earths, monazite would probably not be recovered for its thorium content. Other ore minerals with higher thorium contents, such as thorite, would be more likely sources if demand significantly increased. No new demand, however, is expected. Reserves exist primarily in recent and ancient placer deposits. Lesser quantities of thorium-bearing monazite reserves occur in vein deposits and carbonatites.

World Resources: Thorium resources occur in provinces similar to those of reserves. The largest share are contained in placer deposits. Resources of more than 500,000 tons are contained in placer, vein, and carbonatite deposits. Disseminated deposits in various other alkaline igneous rocks contain additional resources of more than 2 million tons. Large thorium resources are found in Australia, Brazil, Canada, Greenland, India, South Africa, and the United States.

Substitutes: Nonradioactive substitutes have been developed for many applications for thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, zirconium, and yttrium can substitute for magnesium-thorium alloys in aerospace applications.

[e]Estimated. E Net exporter. NA Not available. — Zero.

[1]All domestically consumed thorium was derived from imported materials.

[2]Source: U.S. Department of Defense, Defense Logistics Agency. Based on sales from the National Defense Stockpile.

[3]Source: Rhodia Canada, Inc., f.o.b. port of entry, duty paid, ThO_2 basis.

[4]Source: Rhodia Rare Earths, Inc., 1-950 kilogram quantities, f.o.b. port of entry, duty paid.

[5]Defined as imports - exports + adjustments for Government and industry stock changes.

[6]See Appendix B for definitions.

[7]Los Alamos National Laboratory, 1999, Thorium maps reveal complicated lunar history: Los Alamos, NM, Los Alamos National Laboratory, news release, March 16, 1 p.

[8]Thorium Power, Inc., 2001, What's New—2001: Washington, DC, Thorium Power, Inc., February, 1 p.

[9]Estimates, based on thorium contents of rare-earth ores.

[10]See Appendix C for definitions.

THORIUM

(Data in metric tons of thorium oxide (ThO_2) equivalent, unless otherwise noted)

Domestic Production and Use: The primary source of the world's thorium is the rare-earth and thorium phosphate mineral, monazite. Monazite was not recovered as a salable product during processing of heavy mineral sands in 1999. Past production had been as a byproduct during processing for titanium and zirconium minerals, and monazite was recovered for its rare-earth content. Essentially all thorium compounds and alloys consumed by the domestic industry were derived from imports, stocks of previously imported materials, or materials shipped from U.S. Government stockpiles. About eight companies processed or fabricated various forms of thorium for nonenergy uses, such as high-temperature ceramics, catalysts, and welding electrodes. The value of thorium metal, alloys, and compounds used by the domestic industry was estimated to be about $400,000.

Salient Statistics—United States:	1995	1996	1997	1998	1999[e]
Production, refinery[1]	—	—	—	—	—
Imports for consumption:					
Thorium ore and concentrates (monazite), gross weight	40	101	20	—	—
Thorium ore and concentrates (monazite), ThO_2 content	2.80	7.07	1.40	—	—
Thorium compounds (oxide, nitrate, etc.), gross weight	20.51	26.30	13.50	7.45	6.77
Thorium compounds (oxide, nitrate, etc.), ThO_2 content	15.16	19.45	10.00	5.51	5.00
Exports:					
Thorium ore and concentrates (monazite), gross weight	—	2	—	—	—
Thorium ore and concentrates (monazite), ThO_2 content	—	.14	—	—	—
Thorium compounds (oxide, nitrate, etc.), gross weight	.08	.06	.24	1.13	1.07
Thorium compounds (oxide, nitrate, etc.), ThO_2 content	.06	.04	.18	.84	.79
Shipments from Government stockpile excesses ($ThNO_3$)	—	—	.82	—	—
Consumption: Reported, (ThO_2 content[e])	5.4	4.9	13.0	7.0	NA
Apparent	NA	NA	33.6	6.9	4.1
Price, yearend, dollars per kilogram:					
Nitrate, welding-grade[2]	5.46	5.46	5.46	5.46	5.46
Nitrate, mantle-grade[3]	23.30	14.32	27.00	27.00	27.00
Oxide, yearend: 99.9% purity[4]	88.50	88.50	82.50	82.50	82.50
99.99% purity[4]	107.25	107.25	107.25	107.25	107.25
Stocks, industrial, yearend	NA	35.2	12.8	NA	NA
Net import reliance[5] as a percent of apparent consumption	NA	NA	100	100	100

Recycling: None.

Import Sources (1995-98): Monazite: Australia, 75%; and France, 25%. Thorium compounds: France, 99.7%; and other, 0.3%.

Tariff: Item	Number	Normal Trade Relations 12/31/99
Thorium ores and concentrates (monazite)	2612.20.0000	Free.
Thorium compounds	2844.30.1000	5.5% ad val.

Depletion Allowance: Percentage method: Monazite, 23% on thorium content, 15% on rare-earth and yttrium content (Domestic); 14% (Foreign).

Government Stockpile:

Stockpile Status—9-30-99[6]

Material	Uncommitted inventory	Committed inventory	Authorized for disposal	Disposal plan FY 1999	Disposals FY 1999
Thorium nitrate (gross weight)	3,217	—	2,945	454	—

Events, Trends, and Issues: Domestic mine production of thorium-bearing monazite ceased at the end of 1994 as world demand for ores containing naturally occurring radioactive thorium declined. Imports and existing stocks supplied essentially all thorium consumed in the United States in 1999. Domestic demand for thorium ores, compounds, metals, and alloys has exhibited a long-term declining trend. Thorium consumption in the United States decreased in 1998 to 7.0 tons, however, most material was consumed in a nonrecurring application. Thorium consumption in 1999 is estimated to decrease. Based on data through July 1999, the average value of imported thorium compounds increased to $53.15 per kilogram from the 1998 average of $23.00 per kilogram (gross weight).

Prepared by **James B. Hedrick [(703) 648-7725, jhedrick@usgs.gov, fax: (703) 648-7722]**

THORIUM

A team of researchers from a university in Massachusetts, a U.S. Government research laboratory, a university in Israel, a nuclear research facility in Moscow, Russia, and a nuclear fuel manufacturer in Russia, have joined with a U.S. company in Washington, DC, to study the commercialization of nonproliferative thorium energy.[7] The researchers in Massachusetts will assess the application of "seed-blanket" thorium fuel to Light Water Reactors with regard to neutronics and fission control. A study of the toxicity of various nuclear fuels determined that after 100 to 200 years, thorium produces only one sixth of the actinide toxicity produced by other nuclear fuels, such as uranium.[8] The toxicity, measured in conjunction with the uranium used in the Th/U fuel cycle, still was reduced by a factor of 3 compared to the other actinides.

The use of thorium in the United States has decreased significantly since the 1980's, when consumption averaged 45 tons per year. Increased costs to monitor and dispose of thorium have caused the domestic processors to switch to thorium-free materials. Real and potential costs related to compliance with State and Federal regulations, proper disposal, and monitoring of thorium's radioactivity have limited its commercial value. It is forecast that thorium's use will continue to decline unless a low-cost disposal process is developed or new technology creates renewed demand.

World Refinery Production, Reserves, and Reserve Base:

	Refinery production		Reserves[9]	Reserve base[9]
	1998	1999		
United States	—	—	160,000	300,000
Australia	—	—	300,000	340,000
Brazil	NA	NA	16,000	18,000
Canada	NA	NA	100,000	100,000
India	NA	NA	290,000	300,000
Malaysia	—	—	4,500	4,500
Norway	—	—	170,000	180,000
South Africa	NA	NA	35,000	39,000
Other countries	NA	NA	90,000	100,000
World total (rounded)	NA	NA	1,200,000	1,400,000

Reserves and reserve base are contained primarily in the rare-earth ore mineral, monazite. Without demand for the rare earths, monazite would probably not be recovered for its thorium content. Other ore minerals with higher thorium contents, such as thorite, would be more likely sources if demand significantly increased. No new demand, however, is expected. Reserves exist primarily in recent and ancient placer deposits. Lesser quantities of thorium-bearing monazite reserves occur in vein deposits and carbonatites.

World Resources: Thorium resources occur in provinces similar to those of reserves. The largest share are contained in placer deposits. Resources of more than 500,000 tons are contained in placer, vein, and carbonatite deposits. Disseminated deposits in various other alkaline igneous rocks contain additional resources of more than 2 million tons. Large thorium resources are found in Australia, Brazil, Canada, Greenland, India, South Africa, and the United States.

Substitutes: Nonradioactive substitutes have been developed for many applications for thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, zirconium, and yttrium can substitute for magnesium-thorium alloys in aerospace applications.

[e]Estimated. NA Not available.
[1]All domestically consumed thorium was derived from imported materials.
[2]Source: U.S. Department of Defense, Defense Logistics Agency. Based on sales from the National Defense Stockpile.
[3]Source: Rhodia Canada, Inc., f.o.b. port of entry, duty paid, ThO_2 basis.
[4]Source: Rhodia Rare Earths, Inc., 1-950 kilogram quantities, f.o.b. port of entry, duty paid.
[5]Defined as imports - exports + adjustments for Government and industry stock changes.
[6]See Appendix B for definitions.
[7]Radkowsky Thorium Power Corporation news release, 1999, MIT joins Radkowsky thorium fuel team—findings to be presented at Global 99 International Conference on Future Nuclear Systems: RTPC news, Washington, D.C., July 8, 2 p.
[8]Radkowsky Thorium Power Corporation news release, 1999, Environmental advantages achieved in reduced toxicity of new thorium fuel: RTPC news, Washington, D.C., August 2, 2 p.
[9]See Appendix C for definitions.

THORIUM

(Data in metric tons of thorium oxide (ThO_2) equivalent, unless otherwise noted)

Domestic Production and Use: The primary source of the world's thorium is the rare-earth and thorium phosphate mineral, monazite. Monazite was not recovered as a salable product during processing of heavy mineral sands in 1998. Past production had been as a byproduct during processing for titanium and zirconium minerals and monazite was recovered for its rare-earth content. Essentially all thorium compounds and alloys consumed by the domestic industry were derived from imports, stocks of previously imported materials, or materials shipped from U.S. Government stockpiles. About eight companies processed or fabricated various forms of thorium for nonenergy uses, such as high-temperature ceramics, catalysts, and welding electrodes. The value of thorium metal, alloys, and compounds used by the domestic industry was estimated to be about $600,000.

Salient Statistics—United States:	**1994**	**1995**	**1996**	**1997**	**1998[e]**
Production, refinery[1]	—	—	—	—	—
Imports for consumption:					
Thorium ore and concentrates (monazite), gross weight	—	40	101	20	—
Thorium ore and concentrates (monazite), ThO_2 content	—	2.80	7.07	1.40	—
Thorium compounds (oxide, nitrate, etc.), gross weight	3.12	20.51	26.30	13.50	10.50
Thorium compounds (oxide, nitrate, etc), ThO_2 content	2.31	15.16	19.45	10.00	7.77
Exports:					
Thorium ore and concentrates (monazite), gross weight	33	—	2	—	—
Thorium ore and concentrates (monazite), ThO_2 content	2.31	—	.14	—	—
Thorium compounds (oxide, nitrate, etc.), gross weight	.01	.08	.06	.24	1.15
Thorium compounds (oxide, nitrate, etc.), ThO_2 content	.01	.06	.04	.18	.85
Shipments from Government stockpile excesses ($ThNO_3$)	—	—	—	.82	—
Consumption: Reported, (ThO_2 content[e])	3.6	5.4	4.9	13.0	5.0
Apparent	NA	NA	NA	33.6	6.9
Price, yearend, dollars per kilogram:					
Nitrate, welding-grade[2]	5.46	5.46	5.46	5.46	5.46
Nitrate, mantle-grade[3]	23.30	23.30	14.32	27.00	27.00
Oxide, yearend: 99.0% purity[4]	63.80	NA	64.45	65.55	65.55
99.9% purity[4]	NA	88.50	90.00	90.00	90.00
99.99% purity[4]	107.25	107.25	107.25	107.25	107.25
Stocks, industrial, yearend	NA	NA	35.2	12.8	NA
Net import reliance[5] as a percent of apparent consumption	NA	NA	NA	100	100

Recycling: None.

Import Sources (1994-97): Monazite: Australia, 50%; and France, 50%. Thorium compounds: France, 99%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations (NTR) 12/31/98**	**Non-NTR[6] 12/31/98**
Thorium ores and concentrates (monazite)	2612.20.0000	Free	Free.
Thorium compounds	2844.30.1000	6.0% ad val.	35% ad val.

Depletion Allowance: Percentage method: Monazite, 22% on thorium content, 14% on rare-earth and yttrium content (Domestic); 14% (Foreign).

Government Stockpile:

Stockpile Status—9-30-98[7]

Material	**Uncommitted inventory**	**Committed inventory**	**Authorized for disposal**	**Disposal plan FY 1998**	**Disposals FY 1998**
Thorium nitrate (gross weight)	3,217	—	2,945	454	—

Events, Trends, and Issues: Domestic mine production of thorium-bearing monazite ceased at the end of 1994 as world demand for ores containing naturally occurring radioactive thorium declined. Imports and existing stocks supplied essentially all thorium consumed in the United States in 1998. Domestic demand for thorium ores, compounds, metals, and alloys has exhibited a long term declining trend. Thorium consumption in the United States increased in 1997 to 13.0 tons, however, most material was consumed in a nonrecurring application. Thorium consumption in 1998 is estimated to decrease. Based on data through July 1998, the average value of imported thorium compounds decreased to $23.00 per kilogram from the 1997 average of $42.46 per kilogram (gross weight).

Prepared by **James B. Hedrick [(703) 648-7725, jhedrick@usgs.gov, fax: (703) 648-7722]**

THORIUM

A theory developed by Italian physicist and past director of the European Laboratory for Particle Physics (CERN) to create a fuel cycle using subatomic particles and thorium gained support in Europe. The theory advanced that thorium should produce 140 times more energy than uranium using accelerated subatomic particles. The process would involve accelerating the subatomic particles to speeds of several million kilometers per hour in particle accelerators and then firing them at thorium.[8] Fission would occur based on a nuclear cascade generated by the particle accelerator instead of the conventional chain reaction generated from the neutron bombardment from uranium or plutonium fuel. Several European industrial companies were reportedly preparing to fund a prototype of the energy amplifier needed to demonstrate the process.[9]

The use of thorium in the United States has decreased significantly since the 1980's, when consumption averaged 45 tons per year. Increased costs to monitor and dispose of thorium have caused the domestic processors to switch to thorium-free materials. Real and potential costs related to compliance with State and Federal regulations, proper disposal, and monitoring of thorium's radioactivity have limited thorium's commercial value. It is forecast that thorium's use will continue to decline unless a low-cost disposal process is developed or new technology creates renewed demand.

World Refinery Production, Reserves, and Reserve Base:

	Refinery production		Reserves[10]	Reserve base[10]
	1997	1998		
United States	—	—	160,000	300,000
Australia	—	—	300,000	340,000
Brazil	NA	NA	16,000	18,000
Canada	NA	NA	100,000	100,000
India	NA	NA	290,000	300,000
Malaysia	—	—	4,500	4,500
Norway	—	—	170,000	180,000
South Africa	NA	NA	35,000	39,000
Other countries	NA	NA	90,000	100,000
World total (rounded)	NA	NA	1,200,000	1,400,000

Reserves and reserve base are contained primarily in the rare-earth ore mineral, monazite. Without demand for the rare earths, monazite would probably not be recovered for its thorium content. Other ore minerals with higher thorium contents, such as thorite, would be more likely sources if demand significantly increased. No new demand, however, is expected. Reserves exist primarily in recent and ancient placer deposits. Lesser quantities of thorium-bearing monazite reserves occur in vein deposits and carbonatites.

World Resources: Thorium resources occur in provinces similar to those of reserves. The largest share are contained in placer deposits. Resources of more than 500,000 tons are contained in placer, vein, and carbonatite deposits. Disseminated deposits in various other alkaline igneous rocks contain additional resources of more than 2 million tons. Large thorium resources are found in Australia, Brazil, Canada, Greenland, India, South Africa, and the United States.

Substitutes: Nonradioactive substitutes have been developed for many applications for thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, zirconium, and yttrium can substitute for magnesium-thorium alloys in aerospace applications.

[e]Estimated. NA Not available.
[1]All domestically consumed thorium was derived from imported materials.
[2]Source: U.S. Department of Defense, Defense Logistics Agency. Based on sales from the National Defense Stockpile.
[3]Source: Rhône-Poulenc Basic Chemical Co., f.o.b. port of entry, duty paid, ThO_2 basis. Rhône-Poulenc Basic Chemicals Co., Shelton, CT, 1994-98.
[4]Source: Rhône-Poulenc Basic Chemicals Co., f.o.b. port of entry, duty paid.
[5]Defined as imports - exports + adjustments for Government and industry stock changes.
[6]See Appendix B.
[7]See Appendix C for definitions.
[8]The Washington Post, Reuters, 1993, In theory, a new route to nuclear energy: November 24, p. A18.
[9]Sacks, Tony, 1997, Nuclear nirvana?: Electrical Review, v. 230 no. 12, June 10, p. 24-26.
[10]See Appendix D for definitions.

THORIUM

(Data in metric tons of thorium oxide (ThO_2) equivalent, unless otherwise noted)

Domestic Production and Use: Monazite, a rare-earth and thorium phosphate mineral, is the primary source of the world's thorium. It was not mined domestically in 1997. Past production had been as a byproduct during processing for titanium and zirconium minerals and monazite was recovered for its rare-earth content. Essentially all thorium compounds and alloys consumed by the domestic industry were derived from imports, stocks of previously imported materials, or materials shipped from U.S. Government stockpiles. About eight companies processed or fabricated various forms of thorium for nonenergy uses, such as ceramics, magnesium-thorium alloys, and welding electrodes. The value of thorium metal, alloys, and compounds used by the domestic industry was estimated to be about $1 million.

Salient Statistics—United States:	1993	1994	1995	1996	1997[e]
Production, refinery[1]	—	—	—	—	—
Imports: Thorium ore and concentrates (monazite), gross weight	—	—	40	101	5
Compounds	18	3	20	26	12
Exports: Thorium ore and concentrates (monazite), gross weight	—	33	—	2	—
Compounds	([2])	([2])	([2])	([2])	([2])
Shipments from Government stockpile excesses (thorium nitrate)	—	—	—	—	0.9
Consumption, reported[e]	8.3	3.6	5.4	4.9	NA
Price, yearend, dollars per kilogram:					
Nitrate, welding-grade[3]	5.46	5.46	5.46	5.46	5.46
Nitrate, mantle-grade[4]	22.25	23.30	23.30	14.32	27.00
Oxide, yearend: 99.0% purity[5]	65.00	63.80	NA	64.45	65.55
99.9% purity[5]	NA	NA	88.50	90.00	90.00
99.99% purity	107.00	107.25	107.25	107.25	107.25
Stocks, industrial, yearend	NA	NA	NA	NA	NA
Employment, mine	—	—	—	—	—
Net import reliance[6] as a percent of apparent consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (1993-96): Monazite: Australia, 80%, and France, 20%. Thorium compounds: France, 100%.

Tariff: Item	Number	Most favored nation (MFN) 12/31/97	Non-MFN[7] 12/31/97
Thorium ores and concentrates (monazite)	2612.20.0000	Free	Free.
Thorium compounds	2844.30.1000	6.4% ad val.	35% ad val.

Depletion Allowance: Percentage method: Monazite, 22% on thorium content, 14% on rare-earth and yttrium content (Domestic); 14% (Foreign).

Government Stockpile:

Stockpile Status—9-30-97[8]

Material	Uncommitted inventory	Committed inventory	Authorized for disposal	Disposal plan FY 1997	Disposals FY 1997
Thorium nitrate	3,218	—	2,969	—	—

Events, Trends, and Issues: Domestic mine production of thorium-bearing monazite ceased at the end of 1994 as world demand for thorium-bearing ores declined. Imports and existing stocks supplied essentially all thorium consumed in the United States in 1997. Imports of thorium compounds decreased from the previous year. Overall, domestic demand for thorium metal, alloys, and compounds continues to decline. Thorium consumption in the United States declined in 1996 and remained small at 4.9 tons. Worldwide demand for thorium remained low.

Based on data through July 1997, the average value of thorium compounds was $25.77 per kilogram gross weight. A

Prepared by **James B. Hedrick, (703) 648-7725 [Fax: (703) 648-7722].**

THORIUM

theory developed by Italian physicist and past director of the European Laboratory for Particle Physics (CERN) to create a fuel cycle using subatomic particles and thorium gained support in Europe. The theory advanced that thorium should produce 140 times more energy than uranium using accelerated subatomic particles. The process would involve accelerating the subatomic particles to speeds of several million kilometers per hour in particle accelerators and then firing them at thorium.[9] Fission would occur based on a nuclear cascade generated by the particle accelerator instead of the conventional chain reaction generated from the neutron bombardment from uranium or plutonium fuel. The process reportedly creates much less hazardous waste than uranium fuels and would generate energy equivalent to 3 million tons of crude oil per ton of thorium fuel. Several European industrial companies were reportedly preparing to fund a prototype of the energy amplifier needed to demonstrate the process.[10]

The use of thorium in the United States has decreased significantly since 1990. Increased costs to monitor and dispose of thorium have caused the domestic processors to switch to thorium-free materials.

Real and potential costs related to compliance with State and Federal regulations, proper disposal, and monitoring of thorium's radioactivity have limited thorium's commercial value. It is forecast that thorium's use will continue to decline unless a low-cost disposal process is developed or new technology creates renewed demand.

World Refinery Production, Reserves, and Reserve Base:

	Refinery production		Reserves[11]	Reserve base[11]
	1996	1997		
United States	—	—	160,000	300,000
Australia	—	—	300,000	340,000
Brazil	NA	NA	16,000	18,000
Canada	NA	NA	100,000	100,000
India	NA	NA	290,000	300,000
Malaysia	—	—	4,500	4,500
Norway	—	—	170,000	180,000
South Africa	NA	NA	35,000	39,000
Other countries	NA	NA	90,000	100,000
World total (rounded)	NA	NA	1,200,000	1,400,000

Reserves and reserve base are contained primarily in the rare-earth ore mineral, monazite. Without demand for the rare earths, monazite would probably not be recovered for its thorium content. Other ore minerals with higher thorium contents, such as thorite, would be more likely sources if demand significantly increased. No new demand, however, is expected. Reserves exist primarily in recent and ancient placer deposits. Lesser quantities of thorium-bearing monazite reserves occur in vein deposits and carbonatites.

World Resources: Thorium resources occur in provinces similar to those of reserves. The largest share are contained in placer deposits. Resources of more than 500,000 tons are contained in placer, vein, and carbonatite deposits. Disseminated deposits in various other alkaline igneous rocks contain additional resources of more than 2 million tons. Large thorium resources are found in Australia, Brazil, Canada, Greenland, India, South Africa, and the United States.

Substitutes: Nonradioactive substitutes have been developed for many applications for thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, zirconium, and yttrium can substitute for magnesium-thorium alloys in aerospace applications.

[e]Estimated. NA Not available.
[1]All domestically consumed thorium was derived from imported materials.
[2]Less than ½ unit.
[3]Source: U.S. Department of Defense, Defense Logistics Agency. Based on sales from the National Defense Stockpile.
[4]Source: Rhône-Poulenc Basic Chemicals Co., f.o.b. port of entry, duty paid, ThO_2 basis, f.o.b. Ontario, Canada, duty unpaid, 1993. Rhône-Poulenc Basic Chemicals Co., Shelton, CT, 1994-97.
[5]Source: Rhône-Poulenc Basic Chemicals Co., f.o.b. port of entry, duty paid.
[6]Defined as imports - exports + adjustments for Government and industry stock changes.
[7]See Appendix B.
[8]See Appendix C for definitions.
[9]The Washington Post, Reuters, 1993, In theory, a new route to nuclear energy: November 24, p. A18.
[10]Sacks, Tony, 1997, Nuclear nirvana?: Electrical Review, v. 230, no. 12, June 10, p. 24-26.
[11]See Appendix D for definitions.

THORIUM

(Data in metric tons of thorium oxide (ThO_2) equivalent, unless otherwise noted)

Domestic Production and Use: Monazite, a rare-earth and thorium phosphate mineral, is the primary source of the world's thorium. It was not mined domestically in 1996. In prior years, monazite had been recovered by dredging methods by a company at Green Cove Springs, FL. Production had been as a byproduct during processing for titanium and zirconium minerals and monazite was recovered for its rare-earth content. Essentially all thorium compounds and alloys consumed by the domestic industry were derived from imports, stocks of previously imported materials, or materials shipped from U.S. Government stockpiles. About eight companies processed or fabricated various forms of thorium for nonenergy uses, such as ceramics, carbon arc lamps, magnesium-thorium alloys, and welding electrodes. The value of thorium metal, alloys, and compounds used by the domestic industry was estimated to be about $1 million.

Salient Statistics—United States:	1992	1993	1994	1995	1996[e]
Production, refinery[1]	—	—	—	—	—
Imports: Thorium ore and concentrates (monazite), gross weight	—	—	—	40	12
Compounds	14	18	3	20	29
Exports: Thorium ore and concentrates (monazite), gross weight	5	—	33	—	([2])
Compounds	([2])	([2])	([2])	([2])	([2])
Shipments from Government stockpile excesses	—	—	—	—	—
Consumption, reported[e]	40	13	17.3	18.1	NA
Price, yearend, dollars per kilogram:					
Nitrate, welding-grade[3]	5.46	5.46	5.46	5.46	5.46
Nitrate, mantle-grade[4]	21.36	22.25	23.30	23.30	23.30
Oxide, yearend: 99.0% purity[5]	63.80	65.00	63.80	NA	NA
99.9% purity[5]	NA	NA	NA	88.50	90.00
99.99% purity	107.00	107.00	107.25	107.25	107.25
Stocks, industrial, yearend	NA	NA	NA	NA	NA
Employment, mine	—	—	—	—	—
Net import reliance[6] as a percent of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (1992-95): Monazite: Australia, 89%; and Malaysia, 11%. Thorium compounds: France, 99%; and Canada, Switzerland, and United Kingdom, 1%.

Tariff: Item	Number	Most favored nation (MFN) 12/31/96	Non-MFN[7] 12/31/96
Thorium ores and concentrates (monazite)	2612.20.0000	Free	Free.
Thorium compounds	2844.30.1000	6.9% ad val.	35% ad val.

Depletion Allowance: Percentage method: Monazite, 22% on thorium content, 14% on rare-earth and yttrium content (Domestic); 14% (Foreign).

Government Stockpile:

Stockpile Status—9-30-96

Material	Uncommitted inventory	Committed inventory	Authorized for disposal	Disposals Jan.-Sept. 96
Thorium nitrate	3,219	—	2,969	—
(thorium oxide equivalent in thorium nitrate)	1,539	—	1,420	—

Prepared by **James B. Hedrick, (703) 648-7725 [Fax: (703) 648-7722].**

THORIUM

Events, Trends, and Issues: Domestic mine production of thorium-bearing monazite ceased at the end of 1994 as world demand for thorium-bearing ores remained depressed. Imports supplied essentially all of the thorium consumed in the United States in 1996. Imports of thorium compounds increased from the previous year to meet demand in catalysis. Overall, domestic consumption remained small at 18.1 tons, a slight increase from the previous year.

Based on import data through July 1996, the unit value of imports of thorium ore and concentrates (monazite), was $406 per metric ton gross weight. The average value of thorium compounds, imported during the same time period, was $58 per kilogram.

Worldwide demand for thorium-bearing rare-earth ores remained low. A French firm continued to seek approval to build a monazite separation plant in Pinjarra, Western Australia, Australia. The disposal of thorium is the primary concern in obtaining permitting for the Australian plant. The company reinitiated development of the Pinjarra project as a result of the French Government's decision in 1994 to disallow any further disposal of thorium residues within the country.

The use of thorium in the United States has decreased significantly since 1990. Increased costs to monitor and dispose of thorium have caused the domestic processors to switch to thorium-free materials.

Real and potential costs related to compliance with State and Federal regulations, proper disposal, and monitoring of thorium's radioactivity have limited thorium's commercial value. It is forecast that thorium's use will continue to decline unless a low-cost disposal process is developed.

World Refinery Production, Reserves, and Reserve Base:

	Refinery production		Reserves[8]	Reserve base[8]
	1995	1996		
United States	—	—	160,000	300,000
Australia	—	—	300,000	340,000
Brazil	NA	NA	16,000	18,000
Canada	NA	NA	100,000	100,000
India	NA	NA	290,000	300,000
Malaysia	—	—	4,500	4,500
Norway	—	—	170,000	180,000
South Africa	NA	NA	35,000	39,000
Other countries	NA	NA	90,000	100,000
World total (rounded)	NA	NA	1,200,000	1,400,000

Reserves and reserve base are contained primarily in the rare-earth ore mineral, monazite. Without demand for the rare earths, monazite would probably not be recovered for its thorium content. Other ore minerals with higher thorium contents, such as thorite, would be more likely sources if demand significantly increased. No new demand, however, is expected. Reserves exist primarily in recent and ancient placer deposits. Lesser quantities of thorium-bearing monazite reserves occur in vein deposits and carbonatites.

World Resources: Thorium resources occur in provinces similar to those of reserves. The largest share are contained in placer deposits. Resources of more than 500,000 tons are contained in placer, vein, and carbonatite deposits. Disseminated deposits in various other alkaline igneous rocks contain additional resources of more than 2 million tons. Large thorium resources are found in Australia, Brazil, Canada, Greenland, India, South Africa, and the United States.

Substitutes: Nonradioactive substitutes have been developed for many applications for thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, zirconium, and yttrium can substitute for magnesium-thorium alloys in aerospace applications.

[e]Estimated. NA Not available.
[1]All domestically consumed thorium was derived from imported materials.
[2]Less than ½ unit.
[3]Source: U.S. Department of Defense, Defense Logistics Agency. Based on sales from the National Defense Stockpile.
[4]Source: Rhône-Poulenc Basic Chemicals Co., f.o.b. port of entry, duty paid, ThO_2 basis, f.o.b. Ontario, Canada, duty unpaid, 1992-93. Rhône-Poulenc Basic Chemicals Co., Shelton, CT, 1994-96.
[5]Source: Rhône-Poulenc Basic Chemicals Co., f.o.b. port of entry, duty paid.
[6]Defined as imports - exports + adjustments for Government and industry stock changes.
[7]See Appendix B.
[8]See Appendix C for definitions.