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SELENIUM AND TELLURIUM

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One copper refinery in Texas reported domestic production of primary selenium and tellurium. In 2006, the prices for selenium and tellurium decreased as consumption for the metals decreased and global production increased. Domestic production of primary selenium and tellurium increased in 2006.

Selenium and tellurium, rare elements widely distributed within the Earth's crust, do not occur in concentrations high enough to justify mining solely for their content. They are recovered as byproducts of nonferrous metal mining, mostly from the anode slimes associated with electrolytic refining of copper.

Slimes resulting from primary copper metal refining can average 10% selenium by weight and in a few cases as much as 40%. Tellurium concentrations are generally lower and never exceed 5% (Weerts, 2002).

Selenium and tellurium can also be recovered economically from industrial scrap and chemical process residues. Obsolete and damaged photoreceptor drums from plain paper copy machines are shipped by manufacturers to refineries for recovery of selenium and tellurium metal.

Production

In the United States, ASARCO Incorporated's (Asarco) (Tucson, AZ) copper refinery in Amarillo, TX, was the only producer of refined selenium and tellurium. One copper refinery exported semirefined selenium (90% selenium content) for toll-refining in Asia. Two other refineries generated selenium-containing slimes, but did not produce selenium. Selenium-containing slimes from these refineries were exported for processing. Most of the primary selenium and tellurium (refined and semirefined) recovered in the United States in 2006 came from copper ores in Arizona and Utah. Domestic production of refined selenium increased in 2006 compared with that of 2005 owing to a relatively disruption-free year of production from Asarco.

Asarco produced commercial-grade tellurium at its refinery complex in Amarillo mainly from copper anode slimes but also from lead refinery skimmings. Production increased in 2006 compared with that of 2005 owing to a year of relatively disruption-free production from Asarco. Asarco also produced high-purity selenium, tellurium, and compounds of these metals for specialty applications at its Globe plant in Denver, CO. On July 12, Asarco announced that it would close the Globe plant and transfer portions of the operations to the copper refinery in Amarillo (ASARCO Incorporated, 2006).

Consumption

Selenium.—In 2006, world consumption of selenium was estimated to be higher than that in 2005, with the glass manufacturing industry being the leading consumer (Shaw, 2007). Selenium is used to decolorize the green tint caused by iron impurities in glass containers and other soda-lime silica glass. It is also used in art and other glass, such as that used in traffic lights, to produce a ruby red color and in architectural plate glass to reduce solar heat transmission through the glass.

Selenium was used as an alloy with bismuth to substitute for lead in plumbing in response to requirements of the Safe Drinking Water Act Amendments of 1996 (Public Law 104-182). Metallurgical grade selenium was used as an additive to cast iron, copper, lead, and steel alloys to improve machinability and casting and forming properties. The addition of a small amount, about 0.02% by weight, of selenium to low-antimony lead alloys used in the support grid of lead-acid batteries improves the casting and mechanical properties of the alloy.

Electronics were a diminishing end-use market in 2006. Organic photoreceptor compounds (OPCs) have replaced these high-purity selenium compounds on the drums of plain-paper copiers. While use in photoreceptors has been declining, other electronic uses for selenium, including photoelectric and rectifier applications, have been growing.

Chemical and pigment uses of selenium include agricultural, industrial, and pharmaceutical applications. Selenium added to fertilizer used in growing animal feed and human consumables was the largest portion of this category. This practice is more common outside the United States, especially in countries with selenium-poor soils. Another method of increasing selenium in humans and livestock is through dietary supplements; however, this method consume less selenium than other methods. Selenium's principal pharmaceutical use is in shampoo to control dandruff and dermatitis and as an antifungal agent.

Cadmium sulfoselenide compounds were used as pigments in ceramics, glazes, paints, and plastics, but because of the relatively high cost and the toxicity of cadmium-based pigments, their use is generally restricted to applications where they are uniquely suited.

Additionally, selenium was used in catalysts to enhance selective oxidation; in plating solutions, to it improve appearance and durability; in blasting caps and gun bluing; in coating digital x-ray detectors; and in zinc selenide for infrared windows in carbon dioxide lasers (Amalgamet Canada, 2003). In China, selenium dioxide (SeO_2) was substituted for sulfur dioxide to increase yields in the electrolytic production of manganese (Selenium-Tellurium Development Association, 2002a). By using SeO_2 instead of sulfur dioxide, the plant reduces the power required to operate the electrolytic cells. This method requires about 1 kilogram (kg) of selenium per metric ton of manganese metal produced (Metal-Pages, 2004).

Owing to increased environmental regulation and increased cost in producing electricity, demand for solar cells increased in

2006 and with this, the consumption of selenium. The silicon-based cells are costly to produce and can only be constructed in a sterile and vacuum-sealed room. Though the majority of solar cells are produced using silicon crystals, several companies announced plans to expand production of solar cells within the next couple of years. Some of the new production will come from selenium-based solar cells that are constructed of copper, indium, gallium, and selenium (CIGS). Recent advancements in CIGS thin films have reduced production costs and improved performance as well as having reduced environmental impact during production (Metal-Pages, 2006c, f). According to some industry analysts, advances in solar power technology could increase the global demand for solar power by 5% during the next 13 years (Metal Bulletin, 2006b).

Tellurium.—World demand for tellurium is thought to have decreased slightly in 2006. The leading use for tellurium was as a metallurgical alloying element. Tellurium was used in steel as a free-machining additive, in copper to improve machinability while not reducing conductivity, in lead to improve resistance to vibration and fatigue, in cast iron to help control the depth of chill, and in malleable iron as a carbide stabilizer. With the historical high prices, many metal companies have cut back consumption or replaced tellurium. Consumption in many of the other uses has increased but not enough to offset this reduction.

Chemical and catalyst usage was the next largest end use, followed by electronics uses and miscellaneous, such as an ingredient in blasting caps and as a pigment to produce blue and brown colors in ceramics and glass. Tellurium was used as a vulcanizing agent and an accelerator in the processing of rubber and as a component of catalysts for synthetic fiber production.

Consumption of tellurium in electronics applications was estimated to have increased in 2006. High-purity tellurium is used in electronics applications, such as thermoelectric and photoelectric devices. Thermal imaging devices use mercury-cadmium-telluride, which assists in converting a raw image into a crisp picture on the screen. Semiconducting bismuth telluride is used in thermoelectric cooling devices employed in electronics and consumer products. These devices consist of a series of couples of semiconducting materials which, when connected to a direct current, cause one side of the thermoelement to cool while the other side generates heat.

Thermoelectric coolers were most commonly used in electronics and military applications, such as the cooling of infrared detectors, integrated circuits, laser diodes, and medical instrumentation. Their application in consumer products, such as portable food-and-beverage coolers or automobile car seat cooling systems, continued to increase.

In recent years, there have been discovery of new uses for tellurium, in flash memory and in multiple types of solar cells replacing the silicon technology. The flash memory can be rewritten and will not erase once power is turned off. The potential for this end use could be dramatic since almost all electronics have this type of memory. Potential new solar cells are the cadmium-telluride and a zinc-manganese-tellurium based solar cells. Currently, the best silicon solar cells have a 22% efficiency. The newer tellurium-based solar cells have an efficiency of 36% to 41% (Weiss, 2005; Metal-Pages, 2006a, f).

Prices

The Platts Metals Week's average New York dealer price for selenium was $24.57 per pound in 2006. The price, which began rising sharply in 2003 reached an alltime high in mid-2005, averaging more than $50 per pound for the year. The average price began 2006 at $46 per pound and fell rapidly to $16 per pound in late May. The average price recovered and rose to $25 per pound by July and remained at this level for the rest of the year. The price volatility was attributed to fluctuating demand in China and India (Metal Bulletin, 2006a).

The United Kingdom price for lump and powder, 99.95% tellurium, as published in Mining Journal, started the year at $100 to $120 per kilogram. After the average tellurium price reached an alltime high of $155 per kilogram on June 13, the price fell throughout the year and ended the year at a range of $50 to $70 per kilogram.

Foreign Trade

The export of selenium materials in 2006 decreased by 25% compared with that of 2005 owing to the drop in price in 2006 and a reduced supply of unrefined selenium from a drawdown of stockpiles in 2005. Top destinations for selenium were, in descending order, Belgium, Germany, Venezuela, and Thailand (table 2).

In 2006, imports of selenium (selenium content of SeO_2, unwrought, waste and scrap) decreased by 30% to 413 metric tons (t), compared with 2005 imports (table 3). In 2006, the United States had net imports of 222 t of selenium compared with 335 t in 2005. Belgium, Japan, Canada, Germany, and the Philippines (in order of decreasing quantity) accounted for about 87% of the imports of selenium metal and SeO_2 into the United States in 2006.

Imports of unwrought tellurium and tellurium waste and scrap, on a gross weight basis, decreased by 33% in 2006 compared with that of 2005. The leading suppliers—Belgium, Canada, and China—in order of decreasing quantity, accounted for more than 94% of the total imports of tellurium metal into the United States (table 5). In 2006, tellurium exports fell to 4 t from 51 t in 2005. In 2005 exports had been uncharacteristically high because of increased consumption in the United Kingdom. The main destinations were China, Japan, and Spain, in descending order (table 4).

World Review

Global selenium output cannot be easily determined because not all companies report production and because of the trade in semirefined production. Only about 20 of the approximately 80 copper refineries in operation around the world reported recovery of refined selenium, and less than one-half of that number reported refined tellurium production (Selenium-Tellurium Development Association, Inc., 2002b).

World refinery production of selenium increased by about 8% to 1,510 t (table 6).

Canada.—Yukon Zinc Corporation (Vancouver, British Columbia, Canada) completed a feasibly study and permitting for the Wolverine zinc-silver deposits in the Yukon Territory. The deposit has an unusually high level of selenium, which had previously been considered a negative factor until the rapid price rise beginning in 2003. The company anticipated startup in the first quarter 2009 and expected to produce an average 53,000 metric tons per year (t/yr) of zinc in concentrate (Yukon Zinc Corporation, 2007, p. 4, 9).

Chile.—Corporacion Nacional del Cobre (Codelco) planned to increase copper refinery production capacity to 900,000 t/yr from 720,000 t/yr. With the addition of a fifth furnace at its metal plant in central Chile at a cost of $675,000, the company planned to increase the production of selenium (Platts Metals Week, 2006).

China.—China consumed much of the world's production of selenium. China depended on imports for about 70% of its needs and imported 1,230 t, in 2006, a 58% increase compared with 2005 imports. The increase was owing to an increase in production of electrolytic manganese (Metal-Pages, 2006d, e; 2007a).

Production from Beijing-based Jinchuan Group was up 11%, to 9 t in 2006, compared with production in 2005 (Metal-Pages, 2007b).

Japan.—The major producers of selenium were Mitsubishi Materials Corporation; Mitsui Metal Mining and Smelting Co., Ltd; Nikko Metals Co., Ltd; Shinko Kagaku Kogyo Co., Ltd.; and Sumitomo Metal Mining Co., Ltd. Selenium production increased by 18% in 2006 compared with that of 2005. Of the 242 t of selenium exported in 2006, 45% was exported directly to China. Tellurium production (recovered from recycling photocopier drums) in 2006 increased 6% compared with that of 2005. In 2006, stocks of selenium and tellurium rose 18% and 61%, respectively, as compared with levels in 2005 (Roskill's Letter from Japan, 2007a-c).

Mexico.—In 2006, Southern Copper Corporation (Phoenix, AZ) produced 43,400 kg of selenium at the La Caridad precious metal plant located in the State of Sonora (Southern Copper Corporation, 2007).

Peru.—Southern Copper produced selenium at its Ilo refinery located in the southern part of Peru. In 2006, selenium production was 49,800 kg, up 2% as compared with that of 2005 (Southern Copper Corporation, 2007).

Poland.—The copper producer KGHM Polska Miedź S.A. (Lubin, Poland) reported 87 t of selenium production in 2006, a 6% increase compared with that of 2005. Selenium was produced from anode slimes from their Glogów and Legnica copper refineries at their precious metal plant at the Glogów smelter (KGHM Polska Miedź S.A., 2007).

Russia.—In March the Joint Stock Company Uralelectromed, Verkhnaya Pyshma, Russia, (a subsidiary of Urals Mining and Metal Company), announced plans to invest $43.15 million to increase copper, selenium, and tellurium production. Historically, the company has produced almost 90 t of selenium (Metal-Pages, 2006g).

Outlook

The supply of selenium and tellurium are directly affected by the production of the principal product from which it is derived, copper, and to a lesser extent, by the production of lead, nickel, or zinc, produced from a sulfide ore. Since global production of selenium and tellurium-bearing copper ore was expected to rise in 2007, global selenium and tellurium production will probably also increase. Recycling of obsolete copiers and other electronic waste material has been increasing during the last couple of years. Increased environmental regulation and prices have encouraged the recycling of electronic scrap and have increased secondary production of selenium and tellurium. The main source is still as a byproduct of copper refining. Since selenium and tellurium price does not influence copper production, an increase in selenium demand is not likely to result in a concurrent significant increase in the production of copper and its byproducts.

Chinese demand for selenium is expected to increase owing to a potential expansion of demand from a rise in manganese production, in which selenium is used. Global demand for selenium from the glass and solar cell manufacturers should also increase as there are few substitutes in glass manufacturing and the expansion of solar cell production is expected to continue. The increases will be offset slightly by a likely steady decrease of demand for selenium in photoreceptors. Promising prostate cancer research and other health benefits may eventually lead to increased consumption of selenium; however, recent developments have linked selenium consumption with an increases risk of diabetes. Dosages taken directly for human consumption will not create large increases in demand for the metal because only minute quantities are necessary for effective therapy. Nevertheless, there could be a relatively large consumption increase if selenium is increasingly applied to the soil for crops to be consumed by humans or livestock.

In 2007, tellurium consumption was expected to increase further, chiefly from the electronics manufacturers and solar cell. Production is expected to increase, but less than the increase in demand owing to the introduction of newer applications for tellurium.

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TABLE 1
SALIENT SELENIUM AND TELLURIUM STATISTICS[1]

(Kilograms, contained metal, unless otherwise specified)

		2002	2003	2004	2005	2006
Selenium:						
United States:						
Production, primary refined		W	W	W	W	W
Shipments to consumers		W	W	W	W	W
Exports		86,700	249,000	160,000	254,000	191,000
Imports for consumption		422,000	367,000	412,000	589,000	413,000
Apparent consumption, metal		W	W	W	W	W
Dealers' price, average, commercial grade[2]	dollars per pound	$4.27	$5.68	$24.89	$51.43	$24.57
World, refinery production		1,410,000 r	1,470,000 r	1,370,000 r	1,430,000 r	1,540,000 e
Tellurium, United States:						
Exports		3,510	10,200	6,160	51,000 r	3,550
Imports for consumption		28,100	48,900	62,800	42,200	31,100
Price at yearend, commercial grade[3]	dollars per kilogram	$7.00	$10.00	$22.50	$110.00	$60.00

e Estimated. r Revised. W Withheld to avoid disclosing company proprietary data.
[1] Data are rounded to no more than three significant digits, except prices.
[2] Source: Platts Metals Week.
[3] Average yearend price published by Mining Journal for United Kingdom lump and powder, 99.95% tellurium.

TABLE 2

U.S. EXPORTS OF SELENIUM[1]

Country	2005 Quantity (kilograms, contained Se)	2005 Value	2006 Quantity (kilograms, contained Se)	2006 Value
Argentina	--	--	1,280	$19,800
Australia	20,000	$86,100	2,820	43,700
Belgium	9,010	140,000	54,000	837,000
Brazil	4,470	69,300	--	--
Canada	378	11,400	5,230	156,000
China	25,000	320,000	7,080	124,000
Colombia	--	--	1,450	22,500
Costa Rica	1,530	23,700	2,240	34,700
Dominican Republic	--	--	788	12,200
El Salvador	--	--	7,630	118,000
France	9,770	42,900	1,110	20,900
Germany	49,600	314,000	25,500	396,000
Guatemala	6,600	102,000	4,330	67,100
Hong Kong	48,800	756,000	2,960	45,900
India	429	10,300	1,420	30,900
Indonesia	140	7,120	--	--
Italy	--	--	221	3,430
Japan	424	6,580	6,800	77,000
Korea, Republic of	--	--	4,190	48,600
Mexico	34,000	535,000	13,800	214,000
Netherlands	2,130	33,000	5,960	92,400
Philippines	15,900	246,000	5,370	83,300
Singapore	4,310	60,900	3,970	56,800
South Africa	447	9,260	435	8,460
Sweden	1,180	18,300	--	--
Taiwan	1,030	16,400	2,350	38,700
Thailand	8,550	74,700	11,900	124,000
United Arab Emirates	--	--	224	4,760
United Kingdom	355	5,500	3,410	52,800
Venezuela	9,600	149,000	14,200	221,000
Vietnam	--	--	273	16,500
Total	254,000	3,040,000	191,000	2,970,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF SELENIUM[1]

Class and country	2005 Quantity (kilograms, contained Se)	2005 Value	2006 Quantity (kilograms, contained Se)	2006 Value
Selenium:				
Australia	1,980	$59,400	--	--
Belgium	304,000	17,700,000	149,000	$6,960,000
Canada	103,000	5,410,000	56,500	3,010,000
China	37,800	1,170,000	17,000	751,000
France	3,690	168,000	6,080	223,000
Germany	29,300	3,080,000	41,500	2,090,000
Hong Kong	2,000	191,000	--	--
India	4	10,600	--	--
Japan	13,600	975,000	57,100	1,940,000
Korea, Republic of	17,400	713,000	5,000	242,000
Netherlands	5,740	265,000	3,330	136,000
Peru	3,830	388,000	600	22,300
Philippines	41,500	3,030,000	41,400	1,590,000
Russia	10	9,940	--	--
United Kingdom	10,200	683,000	20,400	1,070,000
Total	575,000	33,900,000	398,000	18,000,000
Selenium dioxide:[2]				
Germany	10,800	930,000	12,500	695,000
India	1,250	93,000	--	--
Japan	1,500	99,000	499	36,600
Philippines	500	59,400	2,000	73,800
United Kingdom	20	4,280	--	--
Total	14,100	1,190,000	15,000	805,000
Grand total	589,000	35,100,000	413,000	35,100,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Calculated using 71% of gross weight of material.

Source: U.S. Census Bureau.

TABLE 4
U.S. EXPORTS OF TELLURIUM[1]

Class and country	2005 Quantity (kilograms, contained Te)	2005 Value	2006 Quantity (kilograms, contained Te)	2006 Value
Belgium	3,500	$270,000	98	$4,880
Brazil	110	8,000	145	23,600
China	--	--	730	101,000
France	157	127,000	279	207,000
Germany	114	130,000	212	137,000
Hong Kong	499 r	53,900 r	--	--
Japan	1,690 r	172,000 r	700	26,900
Korea, Republic of	68	7,770	--	--
Malaysia	--	--	168	4,920
Philippines	4,150	622,000	--	--
Spain	490	118,000	500	118,000
Sweden	--	--	238	35,700
Taiwan	--	--	340	31,400
Turkey	--	--	97	13,800
Ukraine	--	--	45	5,000
United Kingdom	40,200	2,460,000	--	--
Total	51,000 r	3,970,000 r	3,550	711,000

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF TELLURIUM[1]

Class and country	2005 Quantity (kilograms, contained Te)	2005 Value	2006 Quantity (kilograms, contained Te)	2006 Value
Belgium	23,500	$1,910,000	18,200	$1,310,000
Canada	11,500	1,330,000	7,410	1,420,000
China	5,250	1,190,000	3,490	642,000
France	--	--	100	3,970
Germany	267	38,300	64	33,900
India	79	3,670	--	--
Japan	40	67,100	45	11,800
Peru	--	--	1,010	55,600
Russia	23	4,180	--	--
Ukraine	1,460	108,000	738	127,000
United Kingdom	31	9,200	82	23,500
Total	42,200	4,650,000	31,100	3,630,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6

SELENIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Kilograms, contained selenium)

Country[3]	2002	2003	2004	2005	2006[e]
Belgium[e]	200,000	200,000	200,000	200,000	200,000
Canada[4]	175,000	253,000	277,000	300,000	300,000 p
Chile[e]	80,000	83,000	82,000	84,000 r	84,000
Finland	39,237	49,163	61,256	62,000	62,000
Germany[e]	16,000	14,000	14,000	12,000 r	12,000
India[e, 5]	11,500	12,000	12,000	13,000	13,000
Japan	752,099	733,973	599,170	624,630 r	735,000
Peru	49,700 r	47,800 r	51,900 r	48,800 r	49,800 p
Philippines[e]	55,000 r	45,000 r	48,000 r	68,000 r	65,000
Serbia and Montenegro[6]	15,000 e	10,000	5,000 e	--	--
Sweden[e]	20,000	20,000	20,000	20,000	20,000
United States	W	W	W	W	W
Total	1,410,000 r	1,470,000 r	1,370,000 r	1,430,000 r	1,540,000

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]World totals, U.S. data, and estimated data have been rounded to three significant digits; may not add to totals shown.

[2]Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in copper ores, copper concentrates, blister copper, and/or refinery residues but did not recover refined selenium from these materials indigenously were excluded to avoid double counting. Table includes data available through May 27, 2007.

[3]In addition to the countries listed, Australia, Iran, Kazakhstan, Mexico, Poland, Russia, and Uzbekistan, produced refined selenium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Australia is known to produce selenium in intermediate metallurgical products and has facilities to produce elemental selenium. In addition to having facilites for processing imported anode simes for the recovery of selenium and precoius metals the United Kingdom has facilities for processing selenium scrap.

[4]Excludes selenium intermediates exported for refining.

[5]Data are for Indian fiscal year beginning April 1 of year stated.

[6]In June 2006, Montenegro and Serbia formally declared independence from each other and dissolved their union. Mineral production data for 2006, however, still reflect the unified country.

TABLE 7

TELLURIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Kilograms, contained tellurium)

Country[3]	2002	2003	2004	2005	2006[e]
Canada[4]	39,000	40,000	69,000	75,000	75,000 p
Japan	28,656	33,154	32,703	22,623 r	24,000
Peru	21,600	22,000	22,000	32,880 r	33,000 p
United States	W	W	W	W	W

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

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

[2]Insofar as possible, data relate to refinery output only; thus, countries that produced tellurium contained in copper ores, copper concentrates, blister copper and/or refinery residues, but did not recover refined tellurium are excluded to avoid double counting. Table is not totaled because of exclusion of data from major world producers.

[3]Australia, Belgium, Chile, Colombia, Germany, Mexico, the Philippines, Poland, and some countries of the Commonwealth of Independent States, including Kazakhstan and Russia, are known to produce refined tellurium, but output is not reported; available information is inadequate for formulation of reliable estimates of output levels.

[4]Excludes tellurium intermediates exported for refining.