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SELENIUM AND TELLURIUM [ADVANCE RELEASE]

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Selenium and Tellurium

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In 2014, domestic production of selenium and tellurium decreased. Only one copper refinery in Texas reported production of primary refined selenium and tellurium. U.S. consumption of selenium and tellurium also decreased in 2014. The average U.S. dealers' price for selenium in 2014 decreased by 26% to $26.78 per pound from $36.17 per pound in 2013 and ended the year at an average of $24 per pound. The average Rotterdam (in warehouse, duties unpaid) price for tellurium in 2014 increased by 7% to $119 per kilogram from $112 per kilogram in 2013 but ended the year at a 7-year low price of $107 per kilogram. These yearend price decreases reflected a decrease in global consumption of selenium and tellurium and an overall decrease in mineral commodity prices during 2014.

Except for two mines in China that began mining tellurium as a principal product in 2010, selenium and tellurium were recovered as byproducts of nonferrous metal mining, principally from the anode slimes produced during the electrolytic refining of copper. Selenium and tellurium were also recovered as byproducts from gold, lead, nickel, platinum-group metals, and zinc mining.

First Solar, Inc. started a recycling program for tellurium. They expected a 25-year product life for recovering tellurium and cadmium in solar panels. Selenium and tellurium can also be recovered economically from industrial scrap and chemical process residues (First Solar, Inc., 2015, p. 29).

Production

The only U.S. producer of refined selenium and tellurium responded to an annual survey of production by the U.S. Geological Survey; however, to avoid disclosing company proprietary data, production data were withheld.

ASARCO LLC's (Tucson, AZ) copper refinery in Amarillo, TX, was the only U.S. producer of refined selenium and tellurium. One copper refinery produced and exported semirefined material containing 90% selenium plus tellurium for toll refining in Asia, and one U.S. refinery generated selenium- and tellurium-containing slimes that were exported for processing. Most of the selenium and tellurium contained in domestic anode slimes came from copper ores in Arizona and Utah. Domestic production of refined selenium and tellurium decreased in 2014 compared with production in 2013.

Consumption

Selenium.—In 2014, world consumption of selenium was estimated to have been slightly less than that in 2013. In 2010, the last year that data were available, global consumption of selenium by application was estimated, in descending order of consumption, as metallurgy, 40%; glass manufacturing, 25%; agriculture, chemicals/pigments, and electronics, 10% each; and other, 5% (Selenium Tellurium Development Association, 2010).

The main metallurgical end use for selenium was for the production of electrolytic manganese in China, where selenium dioxide (SeO_2) was substituted for sulfur dioxide to reduce the power required to operate electrolytic cells. In 2014, demand for selenium by electrolytic manganese producers in China decreased compared with that in 2013 owing to decreased consumption of manganese by steel producers. About 1.2 to 2 kilograms (kg) of SeO_2 was used per metric ton of electrolytic manganese produced (Chao, 2014b, c).

In other metallurgical applications, selenium was used with bismuth to substitute for lead as a free-machining agent in brass plumbing fixtures. The Safe Drinking Water Act Amendments of 1996 (Public Law 104–182) restrict the use of lead in any fixtures, fluxes, pipes, and solders used for the installation or repair of facilities that provide water for human consumption after August 1998. Metallurgical-grade selenium was also used as an additive to cast iron, copper, lead, and steel alloys.

In the glass industry, selenium was used to decolorize the green tint caused by iron impurities in container glass and other soda-lime silica glass. It was also used in art and other glass to produce a ruby red color and in architectural plate glass to reduce solar heat transmission through the glass.

Selenium is a micronutrient essential to human and animal health, and in areas with selenium-poor soils, selenium has been added to fertilizer and applied to acreage used to grow animal feed to increase selenium in the diet of animals and, in turn, the diet of humans. This practice was more common outside the United States, especially in countries with selenium-poor soils.

Cadmium sulfoselenide compounds were used as pigments in ceramics, glazes, paints, and plastics. Selenium pigments have good heat stability, react well to moisture, and are resistant to ultraviolet or chemical exposure. These pigments produce a wide range of red, orange, and maroon colors, but because of the relatively high cost and the toxicity of cadmium-based pigments, their use was limited to applications where cost was not the prevailing factor and human contact was limited, such as art pieces.

In 2014, conventional crystalline silicon-based cells remained the dominant photovoltaic (PV) technology and their production increased to 43.1 gigawatt-peak (GWp), or 91% of the market, whereas thin-film PV cells production remained at about 4.4 GWp, or 9% of the PV market. Three major types of thin-film PV cells were in commercial production—amorphous silicon and thin silicon, cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS). In 2014, CdTe solar cells accounted for 1.9 GWp, or 43%, of thin-film PV production, with First Solar in Arizona accounting for a majority of production. CIGS

made up 1.7 GWp, or 39%, of the thin-film market, with Japan-based Solar Frontier K.K. the leading CIGS producer (Fraunhofer-Institut für Solare Energiesysteme ISE, 2015).

Tellurium.—World consumption of tellurium was estimated to have decreased in 2014 owing to a continued decreasing demand for thermoelectrics in China. However, based on a 69% increase in U.S. imports, U.S. apparent consumption has increased.

As with selenium, tellurium used in solar cells was estimated to have decreased in 2014 because of the decreasing cost of conventional silicon-based cells. The trend toward reduced subsidies through government loans and increased tariffs continued to encourage use of the lower cost silicon cells over the more expensive CdTe technology. Federal Government subsidies and tax credits in the United States were to expire at the end of 2016.

Mercury cadmium telluride was used in thermal-imaging devices to convert the raw image into a crisp screen picture, for infrared sensors, and for heat-seeking missiles. Semiconducting bismuth telluride was used in thermoelectric cooling devices employed in electronics and consumer products. These devices consist of a series of semiconducting material couples that, when connected to a direct current, cause one side of the thermoelement to cool and the other side to heat. Thermoelectric coolers were used in electronics and military applications, such as the cooling of infrared detectors, integrated circuits, laser diodes, and medical instrumentation. In China, these devices were used in refrigerators, water dispensers, and other home appliances. The devices were also used in high-end automobiles to cool cup holders and seats.

In metallurgy, tellurium was used in steel as a free-machining additive, in copper to improve machinability without 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.

Consumption estimates of chemical, catalyst, and other uses of tellurium remained stable, owing to decreasing price volatility. Tellurium was used as a vulcanizing agent and as an accelerator in the processing of rubber and in catalysts for synthetic fiber production. Other applications included the use of tellurium as a pigment to produce blue and brown colors in ceramics and glass.

Prices

The Platts Metals Week annual average New York dealer price for selenium was $27 per pound in 2014, 26% less than the annual average price in 2013. The price range began the year at $25 to $32 per pound and remained relatively unchanged throughout the year.

The Metal-Pages-published Rotterdam 99.99%-pure tellurium price averaged $119 per kilogram in 2014, a 7% increase from the 2013 price. The price range began 2014 at $80 to $100 per kilogram, rose to a range of $128 to $144 in July, and decreased to a yearend range of $120 to $130 per kilogram. The price increase in the first half of the year was attributed to speculation by traders expecting a recovery in the solar sector. When the expected increase in demand failed to materialize, the price decreased (Smith, 2014).

Foreign Trade

Exports of selenium materials in 2014 decreased by 20% to 521 metric tons (t) from exports in 2013. In descending order, the Republic of Korea, Hong Kong, Latvia, France, Indonesia, Taiwan, China, and Venezuela, were the destinations for 87% of selenium exports in 2014. Based on unrounded data, the annual average value of exports in 2014 was $18.45 per kilogram ($40.46 per pound), 8% less than the 2013 annual average (table 2). Based on the low value, much of the material reported as selenium was thought to be unrefined metal, residues, and scrap.

In 2014, imports of selenium, including selenium dioxide, increased by 9% to 478 t. Japan, Germany, China, Belgium, Panama, Norway, the Philippines, and the United Kingdom, in descending order, accounted for 98% of the imports of selenium into the United States in 2014. Based on unrounded data, the annual average value of imported selenium in 2014 was $55.86 per kilogram ($123.15 per pound), 27% less than in 2013 (table 3).

Only three countries, Germany, Japan, and China, in decreasing order, supplied the United States with SeO_2 in 2014, with Germany accounting for 47% of the imports (table 3). In 2014, imports of SeO_2 decreased by 22% to 11 t from those in 2013. Based on unrounded data, the annual average value of imports of SeO_2 was $48.24 per kilogram ($106.35 per pound), about a 20% decrease compared with that of 2013.

In 2014, tellurium exports decreased to 27.9 t, a 34% decrease compared with exports in 2013 (table 4). The main destinations were, in descending order, Canada, Hong Kong, Germany, China, and the Netherlands, which accounted for 95% of total tellurium exports. Imports of unwrought tellurium increased by 69% in 2014 compared with imports in 2013 (table 5). The leading suppliers, in descending order, Canada, China, Malaysia, Belgium, and Peru, accounted for 98% of the total imports of tellurium metal into the United States. Canada and China accounted for 93% of the total imports.

World Review

Global selenium and tellurium output cannot be determined easily because not all companies or countries report production, and trade in scrap and semirefined products may be included with refined metal trade data.

China.—In 2014, China's rare metals Fanya Metal Exchange began listing and trading selenium and tellurium. On April 21, 2014, it began trading 99.99% tellurium and 99.9% selenium powder with reported stocks of 20 t of tellurium and 30 t of selenium. By October, Fanya warehouses reportedly held 205 t of selenium and 135 t of tellurium (Chao, 2014a, d).

China had the first CdTe power station online in 2014 in Luquan city. The modules were provided by Longuan Cd-Te PV Module Co. CdTe modules were used instead of silicon-based panels, owing to their ability to generate electricity in dim light conditions, including fog and pollution (Chao, 2014e).

Peru.—Corporación Nacional del Cobre de Chile (Codelco) and LS Nikko Copper Inc. established a joint venture in Chile to recover precious and minor metals from copper slimes. Construction of the plant in Mejillones started in late

2014. Projected output estimates included 20 metric tons per year (t/yr) of tellurium, 200 t/yr of selenium, 5 t/yr of gold, 550 t/yr of silver, 140 kilograms per year (kg/yr) of palladium, and 7 kg/yr of platinum (Sparks, 2014).

Sweden.—Boliden Group announced that the expansion of the Garpenberg zinc mine was slightly ahead of schedule and within budget. The expansion was expected to produce more tellurium once the expansion was completed. In the second quarter of 2014, Boliden produced 30,900 kg of tellurium, up from 24,500 kg in the same quarter of 2013 (Dragomanovich, 2014).

Outlook

The supply of selenium and tellurium is directly affected by the production of the principal product from which it is derived—copper—and to a lesser extent, by the production of gold, lead, nickel, platinum-group metals, or zinc produced from sulfide ores. With decreasing metal prices throughout 2014, production rates from copper refineries are expected to fall. Recovery of selenium and tellurium from copier drums continues to fall, owing to reduced supplies. However, many high-grade tellurium producers and users were recovering much of the manufacturing scrap generated from the production of consumable goods. Solar-cell recycling plants have been built in the United States and around the world with the intent to capture selenium and tellurium from end-of-life CIGS and CdTe cells.

Demand for selenium for glassmaking and manganese production is expected to remain unchanged. The start of trading of selenium on the Fanya Metal Exchange appears to be having limited influence on the market (Chao, 2014b).

In 2015, the tellurium market is expected to be oversupplied owing to two factors: a halt to stockpiling by Chinese refrigeration producers, and a reduction of purchases by Fanya. The Chinese refrigeration industry stopped purchasing tellurium, as existing stocks are expected to satisfy their demand for 2015. Fanya stopped purchasing tellurium, owing to an estimated surplus of 300 t of tellurium in the market. One partially offsetting factor could be increased consumption of tellurium by First Solar, which is projected to sell 2.9 gigawatts of CdTe solar panels in 2015. The increased tellurium consumption estimate for First Solar, however, is not expected to completely offset the anticipated lower consumption in the rest of the world (Chao, 2015; First Solar, Inc., 2015; Smith, 2014).

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TABLE 1
SALIENT SELENIUM AND TELLURIUM STATISTICS[1]

(Kilograms, contained metal, unless otherwise specified)

	2010	2011	2012	2013	2014
Selenium:					
United States:					
Production, primary refined	W	W	W	W	W
Exports	857,000	1,350,000	952,000	648,000	521,000
Imports for consumption, total	480,000	601,000	460,000	439,000 r	441,000
Dealers' price, average, commercial grade,[2] dollars per pound	37.83	66.35	54.47	36.17	26.78
World, refinery production	2,150,000 r	2,170,000 r	2,250,000 r	2,250,000 r, e	2,310,000 e
Tellurium, United States:					
Production, primary refined	W	W	W	W	W
Exports	59,000	38,600	47,400	42,300	27,900
Imports for consumption	41,600	70,800	36,100	65,300 r	111,000
Price, commercial grade,[3] dollars per kilogram	221.25	349.35	149.66	111.95	119.47

eEstimated. rRevised. NA Not available. 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]The price is the annual average price published by the Metal-Pages for duties unpaid in warehouse (IWH) Rotterdam, 99.99% tellurium.

TABLE 2
U.S. EXPORTS OF SELENIUM[1]

	2013		2014	
Country	Quantity (kilograms, contained Se)	Value	Quantity (kilograms, contained Se)	Value
Australia	25,200	$748,000	--	--
Brazil	1,180	18,300	8,490	$132,000
Canada	71,800	2,010,000	4,620	138,000
China	15,100	131,000	23,100	359,000
Colombia	--	--	1,380	21,400
Dominican Republic	--	--	3,890	60,300
Ecuador	--	--	110	7,880
Egypt	2,640	22,200	--	--
France	--	--	33,100	550,000
Germany	56,400	861,000	226	3,500
Gibraltar	1,460	5,170	--	--
Hong Kong	115,000	2,270,000	97,900	1,710,000
India	--	--	184	2,860
Indonesia	43,900	681,000	29,200	452,000
Israel	300	4,650	--	--
Japan	53,400	1,570,000	32,200	868,000
Korea, Republic of	206,000	3,760,000	190,000	3,910,000
Latvia	--	--	34,000	181,000
Mexico	20,500	353,000	7,910	160,000
Panama	--	--	1,090	16,900
Peru	1,530	23,600	654	10,100
Philippines	1,600	27,200	2,720	24,100
South Africa	3,180	41,000	679	10,500
Taiwan	18,600	289,000	25,200	391,000
Thailand	--	--	177	2,740
United Kingdom	--	--	3,000	69,000
Venezuela	10,600	169,000	21,100	536,000
Total	648,000	13,000,000	521,000	9,620,000

-- 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	2013		2014	
	Quantity (kilograms, contained Se)	Value	Quantity (kilograms, contained Se)	Value
Selenium:				
Australia	3,310	$25,400	3,000	$22,100
Belgium	67,800 r	5,810,000 r	48,000	2,140,000
Canada	28,600	2,000,000	18,400	972,000
China	64,300	4,870,000	58,600	3,370,000
Germany	45,000	4,060,000	71,500	4,570,000
Israel	--	--	1	3,600
Italy	2,480	74,200	--	--
Japan	90,700	5,980,000	102,000	5,490,000
Korea, Republic of	12,400	796,000	4,170	227,000
Mexico	36,500 r	2,660,000 r	14,700	693,000
Netherlands	--	--	5	13,500
Norway	18,100	1,360,000	38,400	1,800,000
Panama	--	--	45,000	2,430,000
Peru	240	12,600	120	6,660
Philippines	28,100	2,730,000	33,400	3,010,000
Russia	--	--	1	3,420
Spain	5	5,920	--	--
Thailand	1,200	63,600	6,980	308,000
United Kingdom	26,500	2,340,000	22,900	1,130,000
Total	425,000 r	32,800,000 r	467,000	26,200,000
Selenium dioxide:[2]				
China	7,790	582,000	2,680	158,000
Germany	2,360	162,000	5,140	311,000
Japan	3,880	97,400	3,130	59,100
Total	14,000	841,000	10,900	528,000
Grand total	439,000 r	33,600,000 r	478,000	26,700,000

rRevised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Selenium content calculated as 71% of gross weight of material.

Source: U.S. Census Bureau.

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

Country	2013 Quantity (kilograms, contained Te)	2013 Value	2014 Quantity (kilograms, contained Te)	2014 Value
Australia	369	$29,200	4	$5,450
Brazil	118	16,300	--	--
Canada	34,300	1,220,000	16,400	690,000
China	481	79,500	1,280	53,600
Germany	2,590	768,000	2,090	749,000
Hong Kong	--	--	5,670	126,000
India	--	--	11	2,800
Japan	380	35,300	221	7,710
Jordan	242	36,300	141	21,200
Korea, Republic of	1,760	267,000	240	8,870
Mexico	1,910	201,000	258	24,000
Netherlands	--	--	1,190	172,000
Panama	--	--	21	3,110
Switzerland	140	21,700	--	--
Taiwan	24	3,250	360	54,000
Total	42,300	2,670,000	27,900	1,920,000

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

Source: U.S. Census Bureau.

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

Country	2013 Quantity (kilograms, contained Te)	2013 Value	2014 Quantity (kilograms, contained Te)	2014 Value
Belgium	17,900	$907,000	1,970	$278,000
Canada	15,100 [r]	1,320,000 [r]	83,000	2,190,000
China	21,200	3,220,000	20,300	3,320,000
Germany	32	26,200	487	44,600
Japan	263	55,400	605	80,500
Malaysia	--	--	2,190	221,000
Peru	979	92,000	1,390	125,000
Philippines	9,840	1,230,000	587	27,100
United Kingdom	--	--	25	4,380
Total	65,300 [r]	6,860,000 [r]	111,000	6,290,000

[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 6
SELENIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Kilograms, contained selenium)

Country[3]	2010	2011	2012	2013[e]	2014[e]
Belgium[e]	200,000	200,000	200,000	200,000	200,000
Canada[4]	79,000 [r]	35,000 [r]	144,000 [r, e]	159,000	159,000
Chile[e, 5]	70,000 [r]	75,000 [r]	75,000 [r]	41,200	41,200
Finland	73,100	85,700	92,800	75,000	93,700
Germany[e, 6]	650,000	700,000	650,000	700,000	700,000
India[e, 7]	15,000	16,000	16,000	17,000	17,000
Japan	754,000 [r]	750,000 [e]	755,000 [e]	741,000	783,000
Peru	59,000	54,000	50,000 [e]	40,000	49,000
Poland	79,000	85,000 [r]	90,000 [r]	90,000	90,000
Russia[e]	140,000	140,000	145,000	150,000	145,000
Serbia	10,600	12,900	13,200 [e]	13,000	13,000
Sweden[e]	20,000	20,000	20,000	20,000	20,000
United States	W	W	W	W	W
Total	2,150,000 [r]	2,170,000 [r]	2,250,000 [r]	2,250,000 [r]	2,310,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in total.

[1]World totals and estimated data are rounded to no more than 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. Includes data available through September 30, 2015.

[3]In addition to the countries listed, Australia, China, Iran, Kazakhstan, Mexico, the Philippines, and Uzbekistan produced refined selenium, but output was not reported, because available information was inadequate for the 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 facilities for processing imported anode slimes for the recovery of selenium and precious metal, the United States has facilities for processing selenium scrap.

[4]Excludes selenium intermediates exported for refining.

[5]In 2012, the noble metals plant at Ventanas temporarily stopped production for limited periods of time during the fourth quarter of 2012 and planned to continue to limit production during the first quarter of 2013.

[6]In 2010, RETORTE GmbH substantially increased its production capacity for high-purity selenium, but actual production appeared to decrease in 2012 (in response to decreased demand).

[7]Data are for the fiscal year beginning April 1 of the year stated.

TABLE 7
TELLURIUM: ESTIMATED WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2, 3]

(Kilograms, contained tellurium)

Country[4]	2010	2011	2012	2013	2014
Canada[5]	8,000	6,000	11,000 r	12,000 p	9,000
Japan	47,000	47,000 r	43,000 r	31,000 r	32,000
Russia	31,000 r	30,000 r	30,000 r	31,000 r	32,500
United States	W	W	W	W	W

pPreliminary. rRevised. W Withheld to avoid disclosing company proprietary data.

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

[2]Includes data available through March 2, 2015.

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

[4]In addition to the countries listed, Australia, Belgium, Chile, China, Colombia, Germany, Kazakhstan, Mexico, the Philippines, Poland, and Sweden were known to produce refined tellurium, but output is not reported; available information was inadequate for the formulation of reliable estimates of the output levels.

[5]Excludes tellurium intermediates exported for refining.