



2010 Minerals Yearbook

STRONTIUM

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Domestic apparent strontium consumption decreased in 2010, attributed primarily to a decrease in imported celestite. The 10,400 metric tons (t) of strontium content consumed in 2010 was dramatically lower than the nearly 38,000 t consumed at its peak in 1997. Strontium minerals were not mined in the United States in 2010, although deposits have been identified and were mined in the past. World production of celestite increased from 400,000 t in 2009 to 405,000 t in 2010.

Strontium composes about 0.04% of the Earth's crust, ranking 15th among elements in abundance (MacMillan and others, 2005). Owing to its high reactivity to air and water, strontium metal is not found in nature in its metallic form. The two strontium-bearing minerals, celestite (strontium sulfate) and strontianite (strontium carbonate), contain strontium in sufficient quantities to make recovery practical. Of the two, celestite occurs much more frequently in sedimentary deposits of sufficient size to make development of mining facilities attractive.

Legislation and Government Programs

Strontium may be found in trace amounts in drywall, but the occurrence of foul odor, electrical corrosion, and illness associated with homes fitted with Chinese-manufactured drywall led Florida State and Federal investigators to suspect the presence of elevated strontium sulfide levels. An initial study conducted by the Florida Department of Health found trace amounts of strontium sulfide in Chinese drywall and none in domestic drywall. The Environmental Protection Agency found elevated strontium and sulfur levels in Chinese drywall. A joint study conducted in 2010 by the U.S. Consumer Product Safety Commission and the U.S. Department of Housing and Urban Development concluded that strontium was not a good indicator for the identification of tainted Chinese drywall in a home and strontium did not play a causal role in the problems associated with the tainted drywall (Florida Department of Health, 2009; U.S. Environmental Protection Agency, 2009; Federal Interagency Task Force on Problem Drywall, 2010).

Production

Although strontium carbonate was not produced in the United States in 2010, strontium carbonate was the principal strontium compound produced globally in 2010, and most other strontium compounds were derived from strontium carbonate. Domestic production of strontium carbonate ceased in 2006 with the closure of the Chemical Products Corp. strontium carbonate and strontium nitrate operations. A few companies produced small quantities of downstream strontium chemicals elsewhere in the United States.

Consumption

Strontium compounds were mostly consumed by the ceramic, glass, and pyrotechnics industries, with smaller amounts consumed by a multitude of other industries. Strontium carbonate is used directly in some applications and is also converted into appropriate downstream chemicals such as strontium chloride, strontium hydroxide, or strontium nitrate. Celestite is typically used as the raw material in strontium carbonate production and is consumed directly in small quantities as an alternative to barium sulfate as white filler in industrial products.

Permanent ceramic ferrite magnets are used extensively in small direct current motors for automobile windshield wipers, loudspeakers, magnetically attached decorative items, toys, and other electronic equipment. Strontium ferrite magnets possess the chemical and physical properties ideal for use in these applications, such as resistance to corrosion and demagnetization, low densities, and effectiveness at high temperatures (Haberberger, 1971). Strontium oxide and strontium carbonate are used as frits in ceramic glazes as a nontoxic alternative to barium and lead (Yunpeng, 2009). Strontium oxide is used as a glass modifier to increase hardness and strength, enhance optical glass properties, and increase light refraction. Strontium glass is colorless and absorbs ultraviolet and x-ray radiation, an ideal glass for cathode ray tube (CRT) faceplates. The fiberglass, lab glass, and pharmaceutical glass industries consume strontium in smaller amounts.

Strontium nitrate is used most often as a coloring agent in pyrotechnic applications, but strontium carbonate, strontium chloride, strontium oxalate, and strontium sulfate can also be used. Strontium pyrotechnic applications include civilian and military flares, fireworks, and tracer ammunition (Conkling, 1981).

Strontium is used in a few metallurgical applications. Strontium metal is added to aluminum alloys to improve castings used in automotive and aerospace applications (Metallurg Aluminum, 2006). Strontium can be used to remove lead impurities during the electrolytic production of zinc. The addition of strontium carbonate dissolved in sulfuric acid reduces the lead content of the electrolyte and of the zinc deposited on the cathode.

Strontium chromate was incorporated into paints as a corrosion inhibitor, effectively coating aluminum used in the construction of aircraft fuselages and ships (Roskill Information Services Ltd., 1992, p. 76). Strontium chromate, however, was classified as a carcinogen in humans, leading many in the paint industry to seek safer alternatives and the European Chemical Agency to enact strict regulations for its use (Hodges and others, 2010; European Chemical Agency, 2011). Other strontium

compounds were used as catalysts to accelerate the drying of oils, paints, and printing inks (Brezinski and others, 2009).

The drug strontium ranelate, a strontium salt of ranelic acid, has been used to reduce the incidence of fractures in osteoporotic patients by promoting the uptake of calcium into bones (Nielsen, 2004). Medical trials demonstrated strontium ranelate drugs increased bone formation and decreased bone resorption, reducing both vertebral and nonvertebral fractures in patients with postmenopausal osteoporosis (Deeks and Dhillon, 2010). The isotope strontium-89 has been used successfully in medical trials for the treatment of pain associated with advanced metastatic cancer (Porter, 1994). Strontium chloride is used in toothpaste to treat tooth-sensitivity caused by temperature and pressure.

Strontium exhibits a high dielectric constant, making it an attractive material for use in wireless devices and memory chips. Strontium titanate is sometimes used as a substrate material for semiconductors and in some optical and piezoelectric applications. Research also was conducted into the use of strontium in superconductors and radiation detectors. As the technology improves and costs decrease, high-tech industries are likely to consume more strontium (McCoy, 2009; McIntosh, 2009; Physorg, 2010; Walter, 2010; Singh, 2011).

Strontium oxide aluminate is used as a phosphorescent (glow-in-the-dark) pigment in applications such as emergency exit signs that glow brighter and longer than those using more-common photoluminescent pigments (Merit Lighting, LLC, 2008). Strontium phosphate is used in the manufacture of fluorescent lights, and the entire range of strontium chemicals is used in analytical chemistry laboratories.

Prices

Based on data published by the U.S. Census Bureau, the average customs unit value for celestite imported from Mexico was \$45.41 per metric ton, a decrease of 3.6% compared with that of 2009. The average unit customs value of imported strontium carbonate was \$0.71 per kilogram, an 8.9% increase from \$0.65 per kilogram in 2009. In 2010, the unit value of imported strontium metal decreased to \$5.80 per kilogram from \$8.05 per kilogram. In 2010, the corresponding value for strontium nitrate was \$1.33 per kilogram, which was 33% higher than that of 2009. Turkish f.o.b. prices for celestite (96% strontium sulfate) ranged from \$90 per ton to \$100 per ton in December 2010, essentially unchanged from the price range of December 2009 (Industrial Minerals, 2009, 2010).

Foreign Trade

With the changes in the domestic strontium market—strontium carbonate consumption for CRT production shifting to Asia and the continued consumption of strontium compounds for ceramics, glass, and pyrotechnics—strontium exports from and imports into the United States have become erratic from year to year. Adequate information to explain the variations is unavailable. Total strontium imports by gross weight were 20,900 t in 2010, a 17% decrease from those of 2009 but a 29% increase from those of 2008 (table 1). Total strontium exports by

gross weight were 827 t in 2010—4.6% less than in 2008, but 7% more than in 2009.

Imports of celestite from Mexico were 5,400 t in 2009, a 63% decrease from the 14,600 t imported in 2009 and 17% more than those of 2008 (table 3). Imports of strontium metal and strontium nitrate increased from those of 2009 by 69% and 29%, respectively, spurred by increases in imports from China and Mexico. Strontium compounds imported from China, Germany, and Mexico represented about 99% of total strontium imports into the U.S. by gross weight, with Mexico representing 65%, Germany 21%, and China 14% of total imports.

Although strontium exports from the United States increased from 2009 to 2010, exports had been decreasing every year from 2006 to 2009, with 2010 exports 5% less than those of 2008. Exports to Belgium, the Republic of Korea, and Vietnam represented 67% of total strontium exports by gross weight (table 2).

World Review

Large deposits of high-grade celestite have been discovered throughout the world, but active mines are primarily in China, Mexico, and Spain. These countries represented 97% of total celestite produced in 2010. Turkey had been another leading celestite producer but has experienced significant declines in production in recent years, with no celestite production since 2008. Smaller operations are located in Argentina, Iran, Morocco, and Pakistan. Many large deposits are not economically feasible to mine owing to high levels of barium and calcium, impurities requiring energy-intensive and cost-prohibitive methods for separation. Most strontium producers require a minimum of 90% strontium sulfate content to achieve profitability. Hand sorting and some washing are all that are necessary at many strontium mines; a few operations use froth flotation, gravity separation, or other methods to beneficiate ore. Production facilities for strontium compounds and metal were located in Canada, China, Germany, Japan, the Republic of Korea, Mexico, and the United States, although the current status of some of these operations is unknown.

Owing to decreased demand for CRTs and increased competition for the Chinese market, the Montevive celestite mine in Granada, Spain, (operated by Bruno SA) closed in late 2009 after more than 50 years of operation. The Belgian chemical producer Solvay Minerales SA was the only remaining celestite producer in Spain (O'Driscoll, 2009). Spanish celestite production decreased significantly in 2009, but further production decreases did not materialize in 2010. Although, overall, the Spanish minerals industry suffered a 15% to 20% drop in demand in 2010, celestite production remained the same as in 2009 (Moore, 2010).

Outlook

Improved economic conditions worldwide could spur growth in demand for strontium carbonate in more traditional applications. Use of strontium by the ceramics, glass, and pyrotechnic industries is expected to continue, with solid demand for strontium used in ferrite magnets. With

improvements in advanced applications, consumption of strontium in new end uses may increase.

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GENERAL SOURCES OF INFORMATION

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TABLE 1
SALIENT STRONTIUM STATISTICS¹

(Metric tons of contained strontium and dollars per metric ton unless otherwise noted)²

	2006	2007	2008	2009	2010
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption: ³					
Strontium compounds	8,860	8,550	9,420	5,860	8,640
Strontium minerals	671	541	2,030	6,420	2,370
Exports, compounds ³	699	688	594	532	566
Apparent consumption ⁴	8,830	8,400	10,900	11,800	10,400
Price, average value of mineral imports at port of exportation	64	67	64	47	45
World, production of celestite, gross weight	524,000	518,000	656,000	400,000 ^r	405,000 ^e

^eEstimated. ^rRevised. -- Zero.

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

²The strontium content of celestite is 43.88%, which was used to convert units of celestite.

³Source: U.S. Census Bureau.

⁴Production plus imports minus exports.

TABLE 2
U.S. EXPORTS OF STRONTIUM COMPOUNDS, BY COUNTRY¹

	2009		2010	
	Gross weight (kilograms)	Value ²	Gross weight (kilograms)	Value ²
Strontium carbonate, precipitated:				
Austria	--	--	2,690	\$2,550
Canada	30,900	\$32,200	7,500	10,200
Germany	3,840	3,650	--	--
Japan	13,100	21,800	30,000	39,400
Mexico	102,000	41,100	73,100	45,800
Netherlands	6,320	6,000	--	--
Spain	--	--	7,530	7,150
United Kingdom	2,780	2,640	--	--
Total	159,000	107,000	121,000	105,000
Strontium oxide, hydroxide, peroxide:				
Argentina	--	--	25,100	13,800
Belgium	215,000	121,000	215,000	121,000
Brazil	--	--	21,600	11,900
Canada	--	--	62,600	30,100
Colombia	--	--	20,000	10,600
Germany	176,000	97,000	--	--
Israel	11,000	6,070	--	--
Japan	25,600	14,100	--	--
Korea, Republic of	102,000	56,100	264,000	148,000
Sweden	18,400	10,100	2,250	2,530
Switzerland	27,900	15,300	--	--
Taiwan	38,000	34,700	20,000	10,600
Trinidad and Tobago	-- ^r	-- ^r	--	--
Vietnam	--	--	76,000	46,400
Total	614,000^r	355,000^r	707,000	395,000

^rRevised. -- Zero.

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

²Free alongside ship value.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS, BY COUNTRY¹

	2009		2010	
	Gross weight		Gross weight	
	(kilograms)	Value ²	(kilograms)	Value ²
Celestite, Mexico	14,600,000	\$690,000	5,400,000	\$245,000
Strontium carbonate:				
China	600,000	693,000	2,380,000	2,320,000
Germany	1,240,000	703,000	4,290,000	2,880,000
Italy	20,400	124,000	14,000	82,300
Mexico	5,890,000	3,500,000	5,000,000	2,990,000
Spain	72,600	64,900	26,000	29,200
United Kingdom	25	9,720	10	4,430
Total	7,820,000	5,090,000	11,700,000	8,310,000
Strontium metal:				
China	20,200	149,000	118,000	682,000
Germany	--	--	21	3,500
Japan	30,400	71,200	--	--
Switzerland	19,500	344,000	--	--
Total	70,100	564,000	118,000	686,000
Strontium nitrate:				
Canada	1,700	5,700	--	--
China	93,600	115,000	231,000	273,000
France	--	--	1,600	16,100
Israel	--	--	9,600	9,070
Japan	58,000	178,000	181,000	1,540,000
Mexico	2,550,000	2,410,000	3,160,000	2,920,000
Spain	68,500	59,900	--	--
Total	2,770,000	2,770,000	3,580,000	4,760,000
Strontium oxide, hydroxide, peroxide:				
China	5,450	36,000	122,000	163,000
Japan	300	9,400	7,000	22,700
Korea, Republic of	974	5,370	--	--
Total	6,720	50,800	129,000	185,000

-- Zero.

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

²Free alongside ship value.

Source: U.S. Census Bureau.

TABLE 4
CELESTITE: WORLD PRODUCTION, BY COUNTRY^{1,2}

(Metric tons)

Country ³	2006	2007	2008	2009	2010 ^e
Argentina	19,822	4,904	14,910	8,169 ^r	7,000
China ^e	180,000	190,000	200,000	210,000	220,000
Iran ^{e,4}	1,000	2,000	2,000	2,000	2,000
Mexico	125,000	125,000 ^e	96,902	37,601	31,429 ⁵
Morocco ^e	2,700	2,700	2,700	2,600	2,500
Pakistan	1,466	1,476 ^r	1,500 ^{r,e}	1,600 ^{r,e}	1,600
Spain ^e	188,000	188,000	336,000 ⁵	138,000 ⁵	140,000 ^p
Turkey ^e	6,300	4,200	1,600	--	--
Total	524,000	518,000	656,000	400,000 ^r	405,000

^eEstimated. ^pPreliminary. ^rRevised. -- Zero.

¹World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Table includes data available through May 11, 2011.

³In addition to the countries listed, Tajikistan was thought to produce celestite, but information was not available to make reliable estimates.

⁴Data are for year beginning March 21 of that stated.

⁵Reported figure.