



2012 Minerals Yearbook

STRONTIUM

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Domestic apparent consumption of strontium decreased in 2012 as reflected by a decrease in net imports of strontium compounds. Apparent consumption of strontium, which peaked in 1997, has shown a downward trend since that time. At its peak, as much as 75% of strontium consumed in the United States was used in faceplate glass for color cathode ray tubes (CRTs). That market for strontium compounds collapsed when the last U.S. CRT glass plant closed in 2006, the same year that domestic strontium carbonate and strontium nitrate production ceased. Strontium minerals were not mined in the United States in 2012, although deposits have been identified and were mined in the past. World production of celestite decreased by about 4% to 254,000 metric tons (t) in 2012 from 264,000 t in 2011 (tables 1, 4).

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 is not found in nature in metallic form. 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 mining attractive.

Production

Although strontium carbonate was not produced in the United States in 2012, it was the principal strontium compound produced globally, 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.'s strontium carbonate and strontium nitrate operations in Cartersville, GA. A few companies produced small quantities of downstream strontium chemicals elsewhere in the United States.

Consumption

Strontium compounds were mostly consumed by the ceramics, glass, and pyrotechnics industries, with smaller amounts consumed by a multitude of other industries. Strontium carbonate is used directly in some applications and also is 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. Anecdotal reports, which have thus far been impossible to verify, indicate that increased imports of celestite since 2010 may have been the result of celestite being

substituted for barite in some drilling fluids used in natural gas and crude wells. Oil field service companies that produce drilling fluids do not specify the content of the fluids they sell and treat that information as proprietary; thus, celestite consumption in drilling fluids was not confirmed.

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 that are ideal for use in these applications, such as effectiveness at high temperatures, low densities, and resistance to corrosion and demagnetization. Strontium oxide and strontium carbonate are used as frits in ceramic glazes as a nontoxic alternative to barium and lead. Strontium oxide is used as a glass modifier to enhance optical glass properties, increase hardness and strength, and intensify light refraction. Strontium glass is colorless and absorbs ultraviolet and x-ray radiation, an ideal glass for CRT faceplates, although flat panel displays have replaced CRTs in most applications. 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, to produce a bright red and in combination with a copper compound to produce purple. 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.

In metallurgical applications, strontium metal is added to aluminum alloys to improve castings used in aerospace and automotive applications. 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. Strontium chromate, however, was classified as a carcinogen in humans because of its hexavalent chromium content, leading many in the paint industry to seek safer alternatives and the European Chemical Agency to propose strict regulations for its use. Although achieving comparable corrosion resistance proved difficult using more environmentally friendly materials, initial work resulted in the development of a calcium-strontium-phosphate complex on a silicate core that showed promise (Hodges and others, 2010; European Chemical Agency, 2012). Other strontium compounds were used as catalysts to accelerate the drying of oils, paints, and printing inks (Brezinski and others, 2011).

The prescription drug strontium ranelate has been shown to reduce the incidence of fractures in osteoporotic patients by promoting the uptake of calcium into bones. No rigorous clinical studies have been completed that prove whether strontium dietary supplements, such as strontium carbonate and strontium citrate, are effective treatments for osteoporosis (Johannes, 2013). 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 some toothpastes 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 may consume more strontium (McCoy, 2009; McIntosh, 2009; Physorg, 2010; Walter, 2010; Singh and others, 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 \$49.82 per metric ton, an 8% increase compared with that of 2011. The average unit customs value of imported strontium carbonate was \$0.82 per kilogram, a 19% decrease from \$1.01 per kilogram in 2011. In 2012, the unit value of imported strontium metal increased by 26% to \$9.03 per kilogram from \$7.14 per kilogram. In 2012, the corresponding value for strontium nitrate was \$1.19 per kilogram, which was 5% higher than that of 2011. Strontium compound and mineral prices can vary widely from year to year, and reasons for significant changes are difficult to determine.

Foreign Trade

With the changes in the domestic strontium market—strontium carbonate consumption for CRT production shifting to Asia (where CRTs continued to be produced) and the continued consumption of strontium compounds for ceramics, glass, and pyrotechnic—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 34,300 t in 2012, about the same as those of 2011 (table 3).

Total strontium exports by gross weight were 120 t in 2012—four times that in 2011. Exports to Canada, India, the Republic of Korea, and the United Kingdom accounted for 100% of total strontium exports (table 2).

Imports of celestite from Mexico were 19,700 t in 2012, 18% more than those in 2011 (table 3). Imports of all strontium compounds and metal decreased in 2012 compared with those of 2011. Strontium compounds imported from China, Germany, and Mexico accounted for nearly 99% of total strontium imports into the United States by gross weight, with Mexico representing 66%; Germany, 28%; and China, 5% of total imports.

World Review

Large deposits of high-grade celestite have been discovered throughout the world, but active mines were primarily in China, Mexico, and Spain. These countries accounted for 89% of total celestite produced in 2012. Turkey was a leading celestite producer but has reported no celestite production since 2008. Smaller mines operated in Argentina, Iran, and Morocco. Many large deposits are not economic 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 have operated in Canada, China, Germany, Japan, Mexico, the Republic of Korea, and the United States, but the status of some of these operations was unclear in 2012, and some were thought to be idle.

Outlook

Improved economic conditions worldwide could spur increased demand for strontium carbonate in more traditional applications. Use of strontium by the ceramics, glass, and pyrotechnics industries is expected to continue, with continued demand for strontium used in ferrite magnets. With developments in advanced applications, consumption of strontium in new end uses may increase.

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GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Historical Statistics for Mineral and Material Commodities in the United States, Data Series 140.
Strontium. Ch. in Mineral Commodity Summaries, annual.

TABLE 1
SALIENT STRONTIUM STATISTICS¹

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

	2008	2009	2010	2011	2012
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption: ³					
Strontium compounds	9,420	5,860	8,640	10,000	8,150
Strontium minerals	2,030	6,420	2,370	7,320	8,660
Exports, carbonate ³	70	94	72	18	71
Shipments from Government stockpile excesses	--	--	--	--	--
Apparent consumption ⁴	11,400	12,200	10,900	17,300	16,700
Price, average value of mineral imports at port of exportation	64	47	45	46	50
World, production of celestite, gross weight	390,000 ^r	330,000 ^r	219,000 ^r	264,000 ^r	254,000 ^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 CARBONATE, BY COUNTRY¹

Country	2011		2012	
	Gross weight (kilograms)	Value ²	Gross weight (kilograms)	Value ²
Argentina	2,600	\$3,450	--	--
Brazil	600	5,030	--	--
Canada	14,300	17,900	20,700	\$24,300
Germany	12,200	11,500	--	--
India	--	--	2,950	2,800
Korea, Republic of	--	--	14,800	14,100
Saudi Arabia	650	3,360	--	--
United Kingdom	--	--	81,300	88,400
Total	30,300	41,300	120,000	130,000

-- 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

Compound and country	2011		2012	
	Gross weight (kilograms)	Value ²	Gross weight (kilograms)	Value ²
Celestite, Mexico	16,700,000	\$768,000	19,700,000	\$983,000
Strontium carbonate:				
China	2,740,000	6,290,000	152,000	529,000
Germany	4,480,000	3,360,000	4,060,000	3,190,000
Italy	13,400	76,200	6,000	40,700
Mexico	6,860,000	4,540,000	7,070,000	5,490,000
Spain	157,000	132,000	38,000	23,700
Total	14,200,000	14,400,000	11,300,000	9,270,000
Strontium metal:				
Canada	552	33,400	--	--
China	165,000	1,180,000	121,000	1,090,000
France	--	--	9,000	72,100
Germany	--	--	265	5,190
Korea, Republic of	--	--	3	3,480
Mexico	9,260	38,500	--	--
Russia	--	--	20	9,090
Total	175,000	1,250,000	130,000	1,180,000
Strontium nitrate:				
China	321,000	452,000	424,000	611,000
France	--	--	120	8,400
Hungary	--	--	300	6,630
India	--	--	600	5,400
Japan	108,000	379,000	--	--
Mexico	2,740,000	2,750,000	2,600,000	2,970,000
Spain	81,700	70,700	60,000	63,000
Total	3,250,000	3,660,000	3,090,000	3,670,000
Strontium oxide, hydroxide, peroxide:				
China	37,600	67,500	1,160	20,400
Hong Kong	--	--	20,000	19,000
Japan	1	2,030	172	12,300
Norway	--	--	1	3,050
Russia	10	6,500	--	--
Total	37,600	76,000	21,300	54,700

-- Zero.

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

²Customs value.

Source: U.S. Census Bureau.

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

(Metric tons)

Country ³	2008	2009	2010	2011	2012 ^c
Argentina	14,910	8,169	8,512	1,056 ^r	5,000
China ^c	200,000	210,000	94,000 ^r	100,000 ^r	100,000
Iran ^c	2,000	15,396 ^{r,4}	-- ^r	40,000 ^r	20,000
Mexico	29,621 ^r	36,127 ^r	31,429	40,669 ^r	46,192 ⁴
Morocco ^c	2,600 ^r	2,500 ^r	2,500	2,500	2,500
Pakistan ^c	1,000	--	--	--	--
Spain	138,590 ^r	57,466 ^r	83,035 ^r	80,000 ^{r,c}	80,000
Turkey	1,600	--	--	-- ^r	--
Total	390,000 ^r	330,000 ^r	219,000 ^r	264,000 ^r	254,000

^cEstimated. ^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 March 31, 2014.

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

⁴Reported figure.