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STRONTIUM [ADVANCE RELEASE]

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STRONTIUM

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Domestic apparent strontium consumption increased for the first time in 8 years. Strontium consumption in the United States has declined dramatically since 1997 when it peaked at nearly 38,000 metric tons (t) of strontium contained in various strontium compounds. This decline in consumption was caused by color television faceplate glass production, strontium's major end use since the early 1970s, shifting away from the United States to mostly Asia. Consumption shifted because cathode-ray tubes (CRTs) for television displays were replaced by flat panel technology that does not require strontium carbonate. The last television glass plant in the United States closed in 2006, eliminating all demand for strontium in its leading end use. Worldwide, strontium ore production decreased by about 4% as a result of reduced production in Mexico and Turkey.

Strontium occurs commonly in nature; it averages 0.04% of the Earth's crust and ranks 15th among elements in abundance (MacMillan and others, 1994). Only two minerals, celestite (strontium sulfate) and strontianite (strontium carbonate), however, contain strontium in sufficient quantities to make its recovery practical. Of the two, celestite occurs much more frequently in sedimentary deposits of sufficient size to make development of mining facilities attractive. Neither mineral is mined in the United States, although deposits have been identified and were mined in the past.

Production

More strontium carbonate was produced than any other strontium compound, and most other strontium compounds were derived from strontium carbonate. Domestic production of strontium carbonate ceased in 2006 when Chemical Products Corp. (CPC) of Cartersville, GA, closed its strontium carbonate and strontium nitrate operations. A few companies produced small quantities of downstream strontium chemicals elsewhere in the United States.

Consumption

It has become impossible to accurately estimate the end uses for strontium without basic information, which formerly had been provided by CPC. The entire strontium consumption scenario has been reconfigured because television faceplate glass is no longer produced in the United States; thus, what was once the dominant end use is no longer a factor. At its peak, as much as 75% of all strontium consumption in the United States was used in faceplate glass for CRTs to block x-ray emissions from the devices. Modern television technology has replaced CRTs with flat-panel display systems almost entirely in the United States, and the CRTs that are still sold domestically are produced elsewhere.

Even without strontium carbonate consumption in television glass, estimated strontium consumption in ceramics and glass manufacture remained one of the top end-use industries through its use in ceramic ferrite magnets and other ceramic and glass applications. These applications gained market share, but the new consumption patterns were based on a much smaller total market. Although strontium compounds were used in some flat panel displays, consumption was much lower than the amount used in CRT screens, and these devices were not produced domestically. The use of strontium nitrate in pyrotechnics was estimated to be about the same as the use of strontium carbonate in ferrite magnets.

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 have high coercive force and high thermal and electrical resistivities and are chemically inert. They retain their magnetism well, are not adversely affected by electrical currents or high temperatures, do not react with most chemical solvents, and have a low density (Haberberger, 1971).

One of the most consistent and continuing applications for strontium has been in pyrotechnic devices. Strontium burns with a brilliant red flame, and no other material is known to perform better in this application. The compound used most frequently in these devices is strontium nitrate, although strontium carbonate, strontium chlorate, strontium oxalate, and strontium sulfate may also be used. Pyrotechnic devices are used in military and civilian applications. Military pyrotechnic applications include marine distress signals, military flares, and tracer ammunition. Civilian applications include fireworks and warning devices (Conkling, 1981).

Scientists found that using nitrogen-base explosives instead of carbon-base compounds in pyrotechnics reduced the amount of smoke emitted during fireworks shows. The new formulations burn cleaner, requiring significantly lower quantities of coloring chemicals to achieve the desired brilliant displays. Although the cost of the new technology was too high for widespread use, as costs decline, the quantity of strontium consumed in pyrotechnics was likely to decline as well (Halford, 2008).

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 (Solvay S.A., 2007).

Strontium chromate is used as an additive in corrosion-resistant paint to effectively coat aluminum, most notably on aircraft fuselages and ships. These paints are also used on aluminum packaging to prevent corrosion (Roskill Information Services Ltd., 1992, p. 76). Strontium oxide aluminate was developed as a new type of phosphorescent (glow-in-the-dark) pigment and was being used in applications such as exit signs

that glow brighter and longer than those using more-common photoluminescent pigments (Merit Lighting, LLC, 2008).

The use of cast aluminum parts instead of steel has become common in the automotive industry because of the reduced weight, resulting in improved gas mileage. Small quantities of strontium metal added to molten aluminum make it more suitable for casting such items as engine blocks and wheels. The addition of strontium to the melt also improves the machinability of the casting (Lidman, 2002).

Other end uses consumed only small quantities of strontium and strontium compounds. Strontium improves the quality of certain ceramic glazes and eliminates the toxicity that may be present in glazes that contain barium or lead. Strontium titanate is sometimes used as a substrate material for semiconductors and in some optical and piezoelectric applications. Strontium chloride is used in toothpaste for temperature-sensitive teeth. For this application, impurities must be strictly controlled; some limits are in the parts-per-million range. Strontium also appears to be one of the most effective substances yet found for the prevention and treatment of osteoporosis and other bone-related conditions. 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 about $64 per metric ton, which was about 5% lower than that of 2007. The average unit customs value of imported strontium carbonate was $0.67 per kilogram, which was an increase of 17% from $0.57 per kilogram in 2007. In 2008, the unit value of imported strontium metal increased by 48% to $4.66 per kilogram from $3.15 per kilogram. In 2007, the corresponding value for strontium nitrate was $1.14 per kilogram, which was 10% higher than in 2007.

Foreign Trade

Strontium exports from and imports into the United States have become erratic from year to year as domestic consumption has declined. Adequate information to explain the variations is unavailable. In 2008, exports of strontium chemicals were about 7% higher than those of 2007 (tables 1, 2).

Imports of celestite from Mexico were 4,620 t, which was nearly four times the amount imported in 2007 (table 3). This figure, however, was less than one-tenth what it was in 1981 when celestite imports peaked at 49,699 t (U.S. Bureau of Mines, 1983, p. 956–959).

In 2008, Mexico continued to be the most important source for imported strontium compounds with almost 73% of the total, followed by China with nearly 15% and Germany with 9%. Several other countries were the source for the remainder of imported material. Imports of strontium carbonate were 12% higher than those of 2007. Imports from Mexico accounted for 73% of total strontium carbonate imports, and 16% came from China. Imports of strontium metal, declining for the third consecutive year, were 63% lower than in 2007. Nearly all strontium metal imports were from Japan (60%) and China (36%). Imports of strontium nitrate, which was the second ranked imported strontium compound, increased by 23% in 2008. Prior to 2006, strontium nitrate imports typically represented between 2% and 4% of total strontium chemical imports. Starting in 2006, imports of strontium nitrate became a larger portion of total strontium imports and represented 23% of imported strontium chemicals in 2008. The increases were the result of the discontinuation of strontium nitrate production in Georgia in April 2006 and declines in strontium carbonate imports and consumption. Unlike the decline in strontium carbonate use, domestic consumption of strontium nitrate has remained relatively stable.

World Review

In most instances, celestite deposits occur in remote, undeveloped locations far from population centers and in areas where inexpensive labor is available for mining. Huge deposits of high-grade celestite have been discovered throughout the world. Strontium commonly occurs along with barium and calcium, which have chemical properties very similar to those of strontium, making separation difficult. Because removing many impurities from celestite is difficult and energy-intensive, strontium chemical producers require that raw materials contain at least 90% strontium sulfate. Most operating celestite facilities produce sufficient supplies with only minimal processing necessary to achieve acceptable specifications. 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.

In 2008, the leading celestite producing countries were, in decreasing order of output, China, Spain, and Mexico. Turkey had been another leading celestite producer, but has experienced significant declines in production in recent years. Celestite was produced in small quantities in Argentina, Morocco, and Pakistan (table 4). 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.

Detailed information about most world resources was not readily available because very little information on exploration results has been published. Other deposits may be well identified but are in countries from which specific minerals information was not easily obtained.

Outlook

Major production of faceplate glass for CRT televisions and computer monitors has shifted to the Far East, especially China, where production of these devices continued. Globally, flat panel display technology that requires little or no strontium continues to gain market share, as consumer prices for this technology decrease. Market economics have shifted the production of faceplate glass and smaller televisions with CRTs to Asia and Mexico, where they now are being built for local consumption and export, including those for the U.S. market. These changes have resulted in the cessation of U.S. production of strontium carbonate with little likelihood of recovery in the foreseeable future. Television glass production also has declined

in Europe and Japan. Strontium demand for CRTs continues to be strong in Asia and Mexico, but newer display technology is likely to eventually replace CRTs in those markets as well.

Strontium use in pyrotechnics is expected to continue; however, the strontium consumption in pyrotechnics is likely to decline slowly as substitutes are developed that enable less strontium nitrate to be used to achieve the same colorful displays. Ferrite magnet markets are expected to be strong, and demand for strontium is likely to continue. Growth in other markets will probably continue at current slower rates. Improved economic conditions worldwide could spur growth in demand for strontium carbonate in some of these applications, but it is unlikely that television and monitor glass will ever represent the dominant end use for strontium that it once did.

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TABLE 1

SALIENT STRONTIUM STATISTICS[1]

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

	2004	2005	2006	2007	2008
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption:[3]					
Strontium compounds	14,500	11,700	8,860	8,550	9,420
Strontium minerals	2,760	799	671	541	2,030
Exports, compounds[3]	552	255	716	697 r	745
Shipments from Government stockpile excesses	--	--	--	--	--
Apparent consumption[4]	16,700	12,200	8,820	8,390 r	10,700
Price, average value of mineral imports at port of exportation	53	56	64	67	64
World, production of celestite, gross weight [5]	525,000 r	509,000 r	523,000 r	516,000 r	496,000 e

eEstimated. rRevised. -- Zero.

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

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

[3]Source: U.S. Census Bureau.

[4]Production plus imports minus exports.

[5]Excludes Tajikistan, which was thought to produce significant quantities of celestite, but information was not available to make reliable estimates.

TABLE 2

U.S. EXPORTS OF STRONTIUM COMPOUNDS, BY COUNTRY[1]

	2007		2008	
	Gross weight (kilograms)	Value[2]	Gross weight (kilograms)	Value[2]
Strontium carbonate, precipitated:				
Canada	64,800	$63,100	37,400	$40,100
Germany	6,450	56,800	--	--
Italy	5,420	5,150	--	--
Japan	11,500	14,700	--	--
Korea, Republic of	10,400	9,900	62,600	59,500
Mexico	17,300	23,700	18,100	14,100
Total	116,000	173,000	118,000	114,000
Strontium oxide, hydroxide, peroxide:				
Argentina	25,100	13,800	117,000	64,400
Belgium	13,900	7,660	29,300	16,100
Brazil	39,000	35,100	7,570	11,900
Canada	86,100 r	42,000 r	161,000	76,300
China	--	--	1,000	5,260
Colombia	76,000	52,800	30,700	16,900
France	222,000	217,000	189,000	297,000
Germany	99,400	55,500	139,000	63,900
Israel	55,600	30,600	63,300	34,800
Italy	43,100	177,000	37,000	42,400
Japan	19,000	11,200	12,100	6,630
Korea, Republic of	44,200	24,300	28,400	15,600
Mexico	99,800	64,800	--	--
Norway	--	--	4,550	2,500
Spain	--	--	95,000	53,100
Sweden	7,850	4,320	22,900	12,600
Switzerland	13,500	7,430	--	--
Taiwan	40,000	51,800	18,000	24,100
United Kingdom	11,800	13,700	7,640	4,200
Total	897,000 r	809,000 r	964,000	748,000

rRevised. -- Zero.

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

[2]Free 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 COUNTRY[1]

	2007		2008	
	Gross weight (kilograms)	Value[2]	Gross weight (kilograms)	Value[2]
Celestite, Mexico	1,230,000	$82,900	4,620,000	$295,000
Strontium carbonate:				
China	636,000	968,000	2,000,000	2,890,000
Germany	1,730,000	878,000	1,490,000	877,000
Italy	6,000	28,800	7,000	34,900
Mexico	8,960,000	4,610,000	9,240,000	4,750,000
United Kingdom	--	--	25	13,400
Total	11,300,000	6,480,000	12,700,000	8,560,000
Strontium metal:				
Brazil	--	--	4,090	22,100
Canada	19,800	82,100	47	2,200
China	94,300	369,000	60,700	326,000
Germany	13	2,140	--	--
Japan	309,000	843,000	103,000	410,000
Korea, Republic of	28,200	79,000	2,340	22,500
Netherlands	2,000	53,200	--	--
Switzerland	--	--	16	8,660
Total	454,000	1,430,000	170,000	791,000
Strontium nitrate:				
China	256,000	220,000	312,000	310,000
Germany	20,000	19,600	--	--
Japan	175,000	451,000	256,000	726,000
Mexico	2,640,000	2,510,000	3,130,000	3,230,000
Spain	79,400	77,700	170,000	152,000
Taiwan	--	--	16,700	15,200
Total	3,170,000	3,280,000	3,890,000	4,430,000
Strontium oxide, hydroxide, peroxide:				
China	85,700	105,000	104,000	103,000
Germany	--	--	1,400	23,500
Japan	600	17,200	601	20,700
Korea, Republic of	--	--	200	5,150
Total	86,300	122,000	106,000	152,000

-- Zero.

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

[2]Free alongside ship value.

Source: U.S. Census Bureau.

TABLE 4
CELESTITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2004	2005	2006	2007	2008[e]
Argentina	6,727	7,233	19,822	4,904 [r]	5,000
China[e]	150,000	180,000	180,000	190,000	200,000
Iran[4]	7,500	672	-- [e]	-- [e]	--
Mexico	87,609	110,833	125,000	125,000 [e]	96,902 [5]
Morocco[e]	2,700	2,700	2,700	2,700	2,700
Pakistan	570	1,855	1,466 [r]	1,600 [r]	1,700
Spain[e]	192,942 [5]	188,000	188,000	188,000 [r]	188,000
Turkey[e]	77,000 [r]	18,000 [r]	6,300 [r]	4,200 [r]	1,600
Total	525,000 [r]	509,000 [r]	523,000 [r]	516,000 [r]	496,000

[e]Estimated. [r]Revised. -- Zero.

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

[2]Table includes data available through May 12, 2009.

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

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

[5]Reported figure.