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STRONTIUM

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By Joyce A. Ober

Domestic survey data and tables were prepared by Virginia C. Harper, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Domestic strontium consumption continued to decrease for the seventh consecutive year because its major end use, color television faceplate glass production, had declined dramatically in the United States owing to the shift of production to Asia and increased popularity of new flat panel television displays that do not use strontium carbonate in their glass. The last television glass plant in the United States closed during the year. Worldwide, strontium ore production increased slightly as a result of expanded production in Mexico.

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.

Legislation and Government Programs

In 2006, the National Defense Stockpile contained approximately 12,000 metric tons (t) of celestite, which was authorized by the U.S. Congress for disposal. No bids were made on the material that was offered for sale. Celestite has been offered for sale from the stockpile every year since 1994; none has been sold. The low quality of the material that remains in the stockpile makes it undesirable as raw material for strontium carbonate production. Reports issued by the Defense National Stockpile Center of the Defense Logistics Agency, the agency responsible for managing stockpile sales, list the celestite as valueless.

Production

Chemical Products Corp. (CPC) of Cartersville, GA, voluntarily provided domestic production and sales data to the U.S. Geological Survey (USGS). These data, however, are withheld to avoid disclosing company proprietary data (table 1). CPC, the only domestic company that produced large quantities of strontium chemicals and for many years the sole U.S. producer of strontium compounds from celestite, discontinued manufacture of strontium compounds at its Georgia plant in April. CPC owned and operated a strontium compound plant in Reynosa, Mexico.

Consumption

The USGS estimated the distribution of strontium compounds by end use. The information collected from CPC and provided by the U.S. Census Bureau on strontium trade were the bases for the end-use estimates listed in table 2.

Although strontium consumption in ceramics and glass manufacture remained the leading end use, dramatic declines in strontium carbonate use in television faceplate glass continued. Its use in ceramic ferrite magnets and other ceramic and glass applications continued with a larger portion of market share, but based on a much smaller total market. The use of strontium nitrate in pyrotechnics was estimated to equal the use of strontium carbonate in televisions.

All color televisions and other devices that contain color cathode-ray tubes (CRTs) sold in the United States are required by law to contain strontium in the faceplate glass of the picture tube to block x-ray emissions. Major manufacturers of television picture tube glass incorporate, by weight, about 8% strontium oxide in their glass faceplate material. Added to the glass melt in the form of strontium carbonate, strontium is converted to strontium oxide. In addition to blocking x rays, strontium improves the appearance of the glass and the quality of the picture and increases the brilliance (Wagner, 1986). Domestic television glass production began a steep decline with the closure of one plant in 2003 and the closure of three in 2004. The remaining plant in Pennsylvania that produced television glass closed in May (Semmes, 2006). Although strontium compounds are used in some flat panel displays, consumption is much lower than what is used in CRT screens.

Permanent ceramic magnets are another end use for strontium compounds in the form of strontium ferrite. These 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 is 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 nonmilitary applications. Military pyrotechnic applications include marine distress signals, military flares, and tracer ammunition. Nonmilitary applications include fireworks and warning devices (Conkling, 1981).

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 used, to some degree, on aluminum packaging to prevent corrosion (Roskill Information Services Ltd., 1992, p. 76).

Strontium metal has become a more important part of total strontium consumption. Small amounts of strontium 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. The use of cast aluminum parts instead of steel has become common in the automotive industry because of the reduced weight, resulting improved gas mileage (Lidman, 1984).

Other end uses consumed only small amounts 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 phosphate is used in the manufacture of fluorescent lights, and the entire range of strontium chemicals is used in analytical chemistry laboratories.

Prices

According to 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 19% higher than that of 2005, although the quantity imported was 16% lower. The average unit customs value of imported strontium carbonate was $0.49 per kilogram, which was an increase of 27% from $0.39 per kilogram in 2005. In 2006, the unit value of imported strontium metal increased slightly to $2.94 per kilogram from $2.87 per kilogram. In 2006, the corresponding value for strontium nitrate was $0.87 per kilogram, which was slightly lower than in 2005.

Foreign Trade

Exports of strontium chemicals increased significantly in 2006, the first increase since 2003 (tables 1, 3). Imports of celestite from Mexico were 1,530 t, which was 16% lower than the amount imported in 2005 (table 4). In 2006, celestite imports represented only 3% of the 48,700 t of celestite that the United States imported in 1990, the peak year for celestite imports.

In 2006, Mexico continued to be the most important source for imported strontium chemicals with almost 78% of the total, followed by Germany with 11%. Several other countries were the source for the remainder of imported material. Imports of strontium carbonate were 27% lower than those of 2005, continuing a steep decline. Imports from Mexico accounted for 86% of total strontium carbonate imports. Imports of strontium metal were 20% lower than in 2005, but strontium metal imports tripled that year compared with those of 2004. Virtually all the reported strontium metal imports were from Japan (65%), China (21%), and the Republic of Korea (13%). Imports of strontium nitrate, which was the second ranked imported strontium compound, vary significantly from year to year but typically represent about 2% to 4% of total strontium chemical imports. In 2006, imports of strontium nitrate were nearly 7% of the total. Imports of strontium nitrate increased 43% compared with those of 2005. The increase was probably the direct result of the discontinuation of strontium nitrate production in Georgia in April because, although production ceased, demand continued.

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, thus 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.

The leading celestite producing countries were, in decreasing order of output, Spain, China, and Mexico, all with more than 100,000 t of production in 2006. Turkey was another leading celestite producer. Significant quantities of celestite were thought to have been produced in Tajikistan, but not enough information was available to make an estimate on the level of production. Celestite was produced in smaller quantities in Argentina, Iran, Morocco, and Pakistan (table 5). Production facilities for strontium compounds and metal were located in Canada, China, Germany, Japan, the Republic of Korea, Mexico, and the United States.

Detailed information on 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 increasing numbers of these devices are being produced and purchased. For that reason, strontium consumption has shifted to that region also. Globally, flat panel display technology that requires little or no strontium continues to gain market share, as the market prices decrease as a result of increased production capacity. Market economics have shifted the production of faceplate glass and smaller televisions to Asia and Mexico, where they now are being built, even for those

sold in the United States. These changes have resulted in the cessation of domestic 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 television technology could possibly replace CRTs in those markets as well.

Without domestic strontium carbonate to use as feedstock for strontium nitrate, the cost of domestic production became prohibitive. Strontium nitrate production shifted to other countries with lower costs of production, however strontium use in pyrotechnics is expected to continue.

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 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]

	2002	2003	2004	2005	2006
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption:[3]					
Strontium compounds	25,400	23,300	14,500	11,700	8,860
Strontium minerals	1,150	1,020	2,760	799	671
Exports, compounds[3]	340	693	552	255	716
Shipments from Government stockpile excesses	--	--	--	--	--
Apparent consumption[4]	26,200	26,600	16,700	12,200	8,820
Price, average value of mineral imports at port of exportation	60	57	53	56	64
World, production of celestite, gross weight[5]	444,000 r	492,000 r	521,000 r	570,000 r	585,000 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 to 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. ESTIMATED DISTRIBUTION OF PRIMARY
STRONTIUM COMPOUNDS, BY END USE

(Percent)

End use	2005	2006
Electrolytic production of zinc	2	4
Ferrite ceramic magnets	13	18
Master Alloys	6	7
Pigments and fillers	3	5
Pyrotechnics and signals	22	30
Television picture tubes	50 r	30
Other	4 r	6
Total	100	100

rRevised.

TABLE 3
U.S. EXPORTS OF STRONTIUM COMPOUNDS, BY COUNTRY[1]

	2005		2006	
	Gross weight (kilograms)	Value[2]	Gross weight (kilograms)	Value[2]
Strontium carbonate, precipitated:				
Canada	--	--	7,490	$8,450
China	18,600	$17,700	--	--
Germany	14,000	126,000	8,890	57,700
Hong Kong	15,400	14,600	30,100	28,600
Japan	5,200	5,970	--	--
Korea, Republic of	--	--	626	13,000
Mexico	5,370	5,100	102,000	44,000
Panama	--	--	929	5,360
United Kingdom	2,010	9,240	--	--
Venezuela	3,990	16,900	--	--
Total	64,500	196,000	150,000	157,000
Strontium oxide, hydroxide, peroxide:				
Australia	--	--	16,900	9,280
Belgium	103,000	62,700	166,000	91,400
Canada	44,100	17,200	126,000	54,200
China	7,580	4,170	4,570	2,510
Denmark	32,200	18,000	21,000	11,600
France	26,200	14,400	113,000	177,000
Germany	--	--	9,640	5,300
Jamaica	--	--	4,590	2,520
Japan	18,600	10,200	--	--
India	1,020	5,800	--	--
Israel	--	--	19,200	10,600
Korea, Republic of	41,100	22,600	353,000	194,000
Mexico	2,000	6,820	4,920	4,330
Sweden	25,300	13,900	12,500	6,850
Switzerland	--	--	12,900	20,200
United Kingdom	--	--	7,310	4,020
Total	301,000	176,000	871,000	594,000

-- 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.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS, BY COUNTRY[1]

	2005		2006	
	Gross weight (kilograms)	Value[2]	Gross weight (kilograms)	Value[2]
Celestite, Mexico	1,820,000	$98,400	1,530,000	$98,400
Strontium carbonate:				
Belgium	279,000	117,000	119,000	49,400
China	46,000	47,700	86,300	196,000
Germany	1,340,000	661,000	1,580,000	766,000
Italy	5,000	20,700	11,000	51,900
Japan	4,630	70,600	2,000	2,350
Mexico	15,600,000	5,620,000	11,300,000	5,360,000
Spain	602,000	353,000	20,400	14,200
United Kingdom	960	40,200	9	3,470
Total	17,900,000	6,930,000	13,200,000	6,440,000
Strontium metal:				
Canada	3,140	51,800	--	--
China	181,000	712,000	131,000	548,000
Japan	484,000	1,270,000	400,000	1,020,000
Korea, Republic of	101,000	173,000	77,300	239,000
South Africa	--	--	8,000	10,000
Total	770,000	2,210,000	617,000	1,820,000
Strontium nitrate:				
China	386,000	300,000	339,000	293,000
France	1,080	10,100	--	--
Germany	456	20,800	78,800	73,800
India	3,810	13,900	1,850	6,220
Japan	31,000	80,900	25,000	65,500
Mexico	292,000	212,000	160,000	117,000
Spain	--	--	414,000	327,000
Total	714,000	637,000	1,020,000	883,000
Strontium oxide, hydroxide, peroxide:				
China	8,110	18,000	12,800	30,600
Germany	--	--	2,500	3,750
Japan	570	17,000	600	17,300
Russia	5	2,750	--	--
Total	8,690	37,700	15,900	51,600

-- 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 5
CELESTITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2002	2003	2004	2005	2006[e]
Argentina	2,595	4,300	6,727	7,233 [r]	7,500
China[e]	100,000	130,000 [r]	150,000 [r]	180,000 [r]	180,000
Iran[e, 4]	2,000	2,100 [5]	7,500 [5]	7,500	7,500
Mexico	94,015	130,329	87,609	110,833 [r]	125,000
Morocco[e]	3,780 [5]	2,700	2,700	2,700	2,700
Pakistan	382 [r]	402 [r]	570 [r]	1,855 [r]	1,900
Spain	171,293 [r]	152,383 [r]	206,001 [r]	200,000 [r, e]	200,000
Turkey[e]	70,000	70,000	60,000	60,000	60,000
Total	444,000 [r]	492,000 [r]	521,000 [r]	570,000 [r]	585,000

[e]Estimated. [r]Revised.

[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 20, 2007.

[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.