

2005 Minerals Yearbook

STRONTIUM

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Domestic strontium consumption decreased for the sixth 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. Worldwide, strontium ore production increased as a result of significantly expanded production in China and Mexico.

Strontium occurs commonly in nature; it averages 0.04% of the Earth's crust and is the 15th element 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 2005, 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, have been withheld from publication to avoid disclosing company proprietary data (table 1). CPC, the only domestic company that produced large quantities of strontium chemicals and the sole U.S. producer of strontium compounds from celestite, has been a long-term consumer of celestite from Mexico; CPC also owned and operated a strontium carbonate plant in Reynosa, Mexico.

Late in 2005, CPC finalized an agreement with Solvay S.A. of Belgium, the world's leading producer of strontium compounds, to form a joint venture. The new company, named Solvay & CPC Barium Strontium GmbH & Co. KG, will manage CPC's and Solvay's technical-grade barium and strontium carbonate,

sodium sulfide, sodium hydrosulfide, and strontium nitrate businesses. Aligning the two companies' operations in Germany, India, the Republic of Korea, and Mexico allowed them to compete more efficiently in the changing markets, especially in Asia (Solvay S.A., 2005).

Consumption

The USGS estimated the distribution of strontium compounds by end use. Of the six operations to which a survey request was sent, five responded. The information collected from this survey and the information provided by the U.S. Census Bureau on strontium trade were the bases for the end-use estimates listed in table 2.

In 2005, almost 70% of all strontium was consumed in ceramics and glass manufacture, primarily in television faceplate glass and secondarily in ceramic ferrite magnets and other ceramic and glass applications. Although consumption in television glass declined, it remained the predominant end use for strontium.

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. At the end of 2005, only one plant in Pennsylvania produced television glass.

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

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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 (Bratt and Smith, 1963).

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 was a very small 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 and 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 value for celestite imported from Mexico was about \$56 per metric ton, which was 5.7% higher than that of 2004. The average unit customs value of imported strontium carbonate was \$0.39 per kilogram, which was an increase of 8.4% from \$0.36 per kilogram in 2004. In 2005, the unit value of imported strontium metal decreased 42% in 2005 to \$2.87 per kilogram from \$4.94 per kilogram. In 2005, the corresponding value for strontium nitrate was \$0.89 per kilogram, which was a 41% decrease from \$1.52 per kilogram in 2004.

Foreign Trade

Exports of strontium chemicals were less than one-half what they were in 2004 (tables 1, 3). Imports of celestite from Mexico were 1,820 t, which was only 29% of the amount imported the previous year (table 4). Based on these data, it can be assumed that strontium carbonate production in the United States has decreased dramatically in recent years.

In 2005, Mexico continued to be the most important source for imported strontium chemicals with almost 82% of the total,

followed by Germany with 7%, although total imports declined compared with the previous year. Imports of strontium carbonate were 24% lower than those of 2004. Imports from Mexico accounted for 87% of total strontium carbonate imports. Imports of strontium metal were significantly higher in 2005, reaching 770,000 kilograms, more than three times what they were the previous year. Virtually all of the reported strontium metal imports were from Japan (63%), China (24%), and the Republic of Korea (13%). Imports of strontium nitrate, which until 2005 was the second ranked imported strontium compound, vary significantly from year to year but typically represent about 2% to 4% of total strontium imports. In 2005, imports of strontium nitrate were 36% higher than those of 2004.

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 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 2005. Turkey was another leading celestite producer. Significant quantities of celestite were believed 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. In developed countries, 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 for sale in the United States. These changes have resulted in plummeting domestic strontium carbonate production with little likelihood of recovery in the 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.

Ferrite magnet markets are expected to be strong, and demand for strontium is likely to continue. Growth in other markets will probably continue at the current slower rate. Improved economic conditions worldwide could spur growth in demand for strontium carbonate applications.

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 $\label{eq:table 1} \textbf{TABLE 1} \\ \textbf{SALIENT STRONTIUM STATISTICS}^1$

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

| | 2001 | 2002 | 2003 | 2004 | 2005 |
|--|-----------|---------|----------------------|----------------------|---------|
| United States: | | | | | |
| Production, strontium minerals | | | | | |
| Imports for consumption: ³ | | | | | |
| Strontium compounds | 26,500 | 25,400 | 23,300 | 14,500 | 11,700 |
| Strontium minerals | 5,640 | 1,150 | 1,020 | 2,760 | 799 |
| Exports, compounds ³ | 929 | 340 | 693 | 552 | 255 |
| Shipments from Government stockpile excesses | | | | | |
| Apparent consumption ⁴ | 31,200 | 26,200 | 23,600 | 16,700 | 12,200 |
| Price, average value of mineral imports at port | | | | | |
| of exportation | 63 | 60 | 57 | 53 | 56 |
| World, production of celestite, gross weight ^{e, 5} | 399,000 г | 435,000 | 471,000 ^r | 457,000 ^r | 494,000 |
| | | | | | |

^eEstimated. ^rRevised. -- Zero.

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

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

³Source: U.S. Census Bureau.

⁴Production plus imports minus exports.

⁵Excludes Tajikistan, which was believed 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)

| 2004 | 2005 |
|------|--------------------|
| 2 | 2 |
| 11 | 13 |
| 2 | 3 |
| 14 | 22 |
| 68 | 55 |
| 3 | 5 |
| 100 | 100 |
| | 2 11 2 14 |

 $\label{eq:table 3} \textbf{U.S. EXPORTS OF STRONTIUM COMPOUNDS, BY COUNTRY}^1$

| | 2004 | 1 | 2005 | | |
|---------------------------------------|--------------|--------------------|--------------|----------|--|
| | Gross weight | | Gross weight | | |
| | (kilograms) | Value ² | (kilograms) | Value | |
| Strontium carbonate, precipitated: | | | | | |
| Canada | 36,900 | \$27,600 | | - | |
| China | - | | 18,600 | \$17,700 | |
| Germany | 9,930 | 40,200 | 14,000 | 126,000 | |
| Hong Kong | 45,600 | 43,400 | 15,400 | 14,60 | |
| Japan | 55,400 | 31,100 | 5,200 | 5,97 | |
| Korea, Republic of | 5,000 | 4,750 | | - | |
| Malaysia | 80,000 | 32,000 | | - | |
| Mexico | 108,000 | 46,600 | 5,370 | 5,10 | |
| Singapore | 4,190 | 3,980 | | - | |
| United Kingdom | 14,700 | 36,100 | 2,010 | 9,24 | |
| Venezuela | | | 3,990 | 16,90 | |
| Total | 360,000 | 266,000 | 64,500 | 196,00 | |
| Strontium oxide, hydroxide, peroxide: | | | | | |
| Australia | 27,200 | 14,900 | | - | |
| Belgium | 57,600 | 37,500 | 103,000 | 62,70 | |
| Brazil | 12,600 | 6,930 | | - | |
| Canada | 67,200 | 34,400 | 44,100 | 17,20 | |
| China | | | 7,580 | 4,17 | |
| Denmark | | | 32,200 | 17,70 | |
| France | | | 26,200 | 14,40 | |
| Japan | 56,200 | 220,000 | 18,600 | 10,20 | |
| India | | | 1,020 | 5,80 | |
| Israel | 12,500 | 6,860 | | - | |
| Korea, Republic of | 146,000 | 80,400 | 41,100 | 22,60 | |
| Mexico | 28,400 | 43,000 | 2,000 | 6,82 | |
| Thailand | 10,800 | 5,940 | | - | |
| Sweden | 4,690 | 2,580 | 25,300 | 13,90 | |
| Switzerland | 16,200 | 8,920 | | - | |
| United Kingdom | 29,400 | 16,200 | | - | |
| Total | 469,000 | 477,000 | 301,000 | 176,00 | |

⁻⁻ Zero.

Source: U.S. Census Bureau.

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

²Free alongside ship value.

 $\label{eq:table 4} \textbf{U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS, BY COUNTRY}^{1}$

| | 200 | 14 | 2005 | | |
|---------------------------------------|--------------|--------------------|--------------|--------------------|--|
| | Gross weight | | Gross weight | | |
| | (kilograms) | Value ² | (kilograms) | Value ² | |
| Celestite, Mexico | 6,290,000 | \$332,000 | 1,820,000 | \$98,400 | |
| Strontium carbonate: | | | | | |
| Belgium | 161,000 | 63,800 | 279,000 | 117,000 | |
| China | 77,000 | 30,000 | 46,000 | 47,700 | |
| Germany | 1,680,000 | 723,000 | 1,340,000 | 661,000 | |
| Italy | 2,000 | 8,720 | 5,000 | 20,700 | |
| Japan | | | 4,630 | 70,600 | |
| Mexico | 21,700,000 | 7,580,000 | 15,600,000 | 5,620,000 | |
| Spain | | | 602,000 | 353,000 | |
| United Kingdom | 11,000 | 22,200 | 960 | 40,200 | |
| Total | 23,600,000 | 8,430,000 | 17,900,000 | 6,930,000 | |
| Strontium metal: | | | | | |
| Canada | 10,400 | 74,300 | 3,140 | 51,800 | |
| China | 42,800 | 205,000 | 181,000 | 712,000 | |
| France | 18,000 | 121,000 | | | |
| Japan | 144,000 | 667,000 | 484,000 | 1,270,000 | |
| Korea, Republic of | 1,840 | 2,840 | 101,000 | 173,000 | |
| Total | 217,000 | 1,070,000 | 770,000 | 2,210,000 | |
| Strontium nitrate: | | | | | |
| China | 226,000 | 204,000 | 386,000 | 300,000 | |
| Japan | 69,200 | 426,000 | 31,000 | 80,900 | |
| Mexico | 231,000 | 169,000 | 292,000 | 212,000 | |
| Other | | | 5,350 | 44,800 | |
| Total | 527,000 | 798,000 | 714,000 | 637,000 | |
| Strontium oxide, hydroxide, peroxide: | | | | | |
| China | 83,000 | 52,900 | 8,110 | 18,000 | |
| Japan | 15,000 | 22,700 | 570 | 17,000 | |
| Russia | | | 5 | 2,750 | |
| Total | 98,000 | 75,600 | 8,690 | 37,700 | |

⁻⁻ Zero.

Source: U.S. Census Bureau.

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

²Free alongside ship value.

 ${\it TABLE~5}$ CELESTITE: ESTIMATED WORLD PRODUCTION, BY COUNTRY $^{1,\,2}$

(Metric tons)

| Country ³ | 2001 | 2002 | 2003 | 2004 | 2005 |
|----------------------|-----------------------|----------------------|----------------------|-----------------------|----------------------|
| Argentina | 3,566 ^{r, 4} | 2,595 r, 4 | 4,300 r, 4 | 6,727 ^{r, 4} | 6,700 |
| China | 50,000 | 100,000 | 100,000 | 130,000 | 140,000 |
| Iran ⁵ | 2,000 | 2,000 | 2,100 r, 4 | 7,500 ^{r, 4} | 7,500 |
| Mexico | 145,789 4 | 94,015 4 | 130,329 4 | 87,609 r, 4 | 115,214 ^p |
| Morocco | 1,879 4 | 3,780 4 | 2,700 | 2,700 | 2,700 |
| Pakistan | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 |
| Spain | 129,794 4 | 160,519 ⁴ | 160,000 | 160,000 | 160,000 |
| Turkey | 63,635 4 | 70,000 | 70,000 | 60,000 ^r | 60,000 |
| Total | 399,000 ^r | 435,000 | 471,000 ^r | 457,000 ^r | 494,000 |

^pPreliminary. ^rRevised.

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 20, 2006.

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

⁴Reported figure.

⁵Data are for year beginning March 21 of that stated.