STRONTIUM

By Joyce A. Ober

Strontium occurs commonly in nature, averaging 0.034% of all igneous rock; however, only two minerals, celestite (strontium sulfate) and strontianite (strontium carbonate), contain strontium in sufficient quantities to make its recovery practical. Of the two, celestite occurs much more frequently in deposits of sufficient size to make development of mining facilities currently attractive. Strontianite would be the more useful of the two common minerals because strontium is used most commonly in the carbonate form, but few deposits have been discovered that are suitable for development. There is only one strontianite mine in the world.

Chemical Products Corp. (CPC) of Cartersville, GA, was the only U.S. producer of strontium compounds from celestite. CPC produced strontium carbonate from imported ore because there were no active celestite mines in the United States.

Legislation and Government Programs

Government stockpiling of celestite began in 1942 to provide a secure supply of celestite for the production of strontium compounds required for defense applications during World War II. Celestite purchase specifications issued in 1960 for the U.S. National Defense Stockpile established quality requirements at greater than 95% strontium sulfate content with less than 1.5% calcium sulfate and less than 2% barium sulfate.

In 1963, the stockpile was determined to be unnecessary, and the General Services Administration began selling stockpile material. All the stockpile-grade celestite was sold by 1973, with the remaining material grading less than 91% strontium sulfate and more than 4% calcium sulfate and some with more than 10% barium sulfate.

About 3,300 metric tons of celestite was offered for sale in 1994, the first time celestite from the stockpile had been offered since 1980; no bids were accepted. The stockpile currently contains approximately 12,000 tons of celestite. The low quality of the material remaining in the stockpile will make it difficult to dispose of; the stockpile reports issued by the Defense National Stockpile Center—the agency now responsible for managing stockpile sales—list the celestite as valueless.

Production

The sole U.S. strontium carbonate producer voluntarily provided domestic production and sales data to the U.S. Bureau of Mines. Production and stock data, however, were withheld from publication to avoid disclosing company proprietary data. *(See table 1.)*

Although there have been no active celestite mines in the United States since 1959, celestite deposits have been identified nationwide. During World War II, domestic mining of celestite resources was conducted in Texas and California. U.S. celestite mines had at that time been inactive since World War I, and strontium minerals were imported to satisfy domestic demand.

CPC is the only domestic company that produces strontium carbonate from celestite; the company also produces strontium nitrate. All the celestite CPC used in 1994 was imported from Mexico. CPC utilizes the black ash method of strontium carbonate production at its facility.

The black ash method and the soda ash method are the two most common recovery techniques. The black ash method, known alternatively as the calcining method, produces chemical-grade strontium carbonate, which contains at least 98% strontium carbonate. The soda ash or direct conversion method produces technical-grade strontium carbonate, containing at least 97% strontium carbonate.

The first step in the black ash process involves mixing the crushed and screened celestite with powdered coal. The mixture is then heated to about 1,100° C, expelling oxygen in the form of carbon dioxide from the insoluble strontium sulfate to form water-soluble strontium sulfide.

Strontium sulfide is dissolved in water and the resulting solution filtered. Carbon dioxide is then passed through the solution or soda ash is added, forming and precipitating strontium carbonate from solution. The precipitated strontium carbonate is then filtered, dried, ground, and packaged. The byproduct sulfur from the process is recovered as elemental sulfur or as other byproduct sulfur compounds.

In the soda ash method, ground celestite is washed and most of the water removed. The thickened mixture is combined with soda ash and treated with steam for 1 to 3 hours. During this time, celestite and soda ash react to form strontium carbonate and sodium sulfate. Sodium sulfate is water soluble, making it possible to separate the insoluble strontium carbonate by centrifuging. The black ash method is the preferred means of strontium carbonate production due to the higher grade product, and most new production facilities employ black ash technology.

Several U.S. companies produced strontium metal and compounds from strontium carbonate. Calstron Corp. of Memphis, TN, produced strontium metal, Mallinkrodt Inc. of St. Louis, MO, produced strontium chloride, and Mineral Pigments Corp. of Beltsville, MD, produced strontium chromate. A few other companies produced downstream strontium compounds, but on a very small scale.

Consumption

The U.S. Bureau of Mines estimated the distribution of strontium compounds by end use. Of the 11 operations to which a survey request was sent, all responded. The information collected from this survey and the information provided by the U.S. Bureau of the Census on strontium trade were the basis for the end-use estimates shown in table 2.

In 1994, approximately 80% of all strontium was consumed in ceramics and glass manufacture, primarily in television faceplate glass and ceramic ferrite magnets, and in smaller amounts in other ceramic and glass applications. Over the past 20 years, production of faceplate glass for color television picture tubes has become the major consumer of strontium.

All color televisions and other devices containing color cathode-ray tubes 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 about 8%, by weight, strontium oxide in their glass faceplate material. Added to the glass melt in the form of strontium carbonate, strontium carbonate is converted to strontium oxide. In addition to blocking X-rays, the strontium improves the appearance of the glass, increasing the brilliance and improving the quality of the picture.

Permanent ceramic magnets were another

large end use for strontium compounds, in the form of strontium ferrite. These magnets are used extensively in small direct current (dc) motors used in automobile windshield-wipers, loudspeakers, other electronic equipment, toys, and magnetically attached decorative items.

Strontium ferrite magnets have high coercive force, high thermal and electrical resistivity, 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, resist demagnetization and are low density.

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 has been found to be better in this application.

The strontium compound used most frequently in pyrotechnic devices was strontium nitrate. Strontium carbonate, strontium oxalate, strontium sulfate, and strontium chlorate can be used in pyrotechnic applications, but strontium nitrate is used in significantly larger quantities than any of these.

Pyrotechnic devices were used in military and nonmilitary applications. Military pyrotechnic applications that contained strontium included tracer ammunition, military flares, and marine distress signals. Nonmilitary applications included warning devices and fireworks.

Strontium is used to remove lead impurities during the electrolytic production of zinc. The addition of strontium carbonate in sulfuric acid to the electrolyte reduces the lead content of the electrolyte and of the zinc that is deposited on the cathode.

Strontium chromate is an additive to corrosion resistant paint. It is an effective coating for aluminum, most notably on aircraft fuselages and ships. These paints are used to some degree on aluminum packaging to prevent package corrosion.

Strontium metal is a very limited part of total strontium consumption. Small amounts of strontium are added to molten aluminum to improve the castability of the metal, making it more suitable for casting items that have been traditionally made from steel. The addition of strontium to the melt improves the machinability of the casting. The use of cast aluminum parts is currently gaining popularity in the automotive industry because the weight reduction of the automobile from using cast aluminum parts instead of steel improves energy efficiency.

Other end uses consume only small amounts of strontium and strontium compounds. As mentioned previously, the presence of strontium in glass applications improves the brilliance of the glass. It also improves the quality of certain ceramic glazes as well as eliminating the toxicity that may be present in glazes containing lead or barium. One high-tech strontium ceramic is strontium titanate, which is sometimes used as substrate material for semiconductors and also in some optical and piezoelectric applications.

Strontium chloride was used in toothpaste for temperature-sensitive teeth. For this application, impurities must be strictly controlled, with limits for some of them in the parts per million range.

Strontium phosphate was used in the manufacture of fluorescent lights, and the entire range of strontium chemicals was used in analytical chemistry laboratories. *(See table 2.)*

Prices

The average customs value for celestite imported from Mexico was about $68 per ton, 7% lower than the average value in 1993. Mexico was the source of nearly 100% of 1994 celestite imports.

The average unit customs value of imported strontium carbonate was $0.60 per kilogram and the average value for strontium nitrate was $0.97 per kilogram; the unit value for strontium carbonate was virtually the same as in 1993, and the strontium nitrate value was 15% higher.

Foreign Trade

According to reports from the U.S. Bureau of the Census, exports of strontium compounds increased more than 300% from the levels reported in 1993. Imports of celestite—all from Mexico—increased 35%.

Mexico was once again the most important source for imported strontium compounds; Germany was second. Imports of strontium carbonate in 1994 were 34% higher than those in 1993, with imports from Mexico comprising 85% of total carbonate imports. Imports of strontium nitrate were 94% lower than in 1993. *(See tables 3, 4, and 5.)*

World Review

In almost all instances, celestite deposits occur in remote, undeveloped locations far from population centers 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, two elements with chemical properties very similar to strontium, thus making separation difficult. Because removing many impurities from celestite is difficult and energy intensive, current strontium chemical producers require material to contain at least 90% strontium sulfate. Most of the currently operating celestite facilities can 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 gravity separation, froth flotation, or other methods to beneficiate ore.

Detailed information on most world resources is not readily available. Many of the large deposits are in remote, sparsely inhabited areas, and very little formal exploration has been done. Other deposits may be well identified but are located in countries from which specific mineral information is not easily obtained.

Leading celestite producers are Mexico, Turkey, Iran, and Spain, in decreasing order of importance. Significant quantities of celestite are produced in China and the former U.S.S.R.; however, not enough information is available to make any estimate of location, number, or size of mines. Celestite is produced in smaller quantities in Algeria, Argentina, and Pakistan.

Until World War II, practically all celestite produced worldwide was from the United Kingdom; for several years following the end of the war the United Kingdom maintained its importance. Depleted reserves, encroaching civilization, and the discovery of vast deposits in other countries, resulted in the cessation of production in the United Kingdom. Any reported U.K. celestite production since 1992, was due to the reprocessing of mine tailings from the exhausted mine. *(See table 6.)*

Strontium compounds and/or metal production facilities are found in Canada, China, Germany, Japan, the Republic of Korea, Mexico, the United States, and the former U.S.S.R.

Outlook

Sales of televisions in the United States were at record high levels in 1994. In fact, sales and production were so high that faceplate glass was in short supply, and imports of glass were increasing. Because U.S. TV glass producers are operating at capacity, domestic consumption of strontium carbonate for this end use will remain at current levels until additional capacity is installed. However, worldwide demand for strontium carbonate will increase to meet the demand for U.S. glass imports.

Growth in television sales is expected to continue and larger screens are expected to increase in popularity, and so demand for strontium carbonate for television application

should expand. Other markets will probably continue at their current, slower rate.

Development of a technology to produce an affordable flat television display could severely reduce the demand for strontium carbonate, but this is not expected in the near future. Although a high-quality, large, flat screen is not yet available, small models are, and research continued to improve the technology. The question remains whether a new display system can be developed that will be economically attractive to the general public. Initial devices are expected to find application in military hardware and other sophisticated medical and scientific instrumentation. Flat screen display systems may eventually replace cathode-ray tubes, and, at that point, strontium producers may experience a serious setback.

OTHER SOURCES OF INFORMATION

U.S. Bureau of Mines Publications

Strontium. Ch. in Mineral Commodity Summaries, annual.

Strontium—Supply, Demand, and Technology, IC 9213.

Other Sources

American Ceramic Society Bulletin, monthly.
Chemical Marketing Reporter, weekly.
Engineering and Mining Journal, monthly.
Industrial Minerals (London), monthly.
Mining Annual Review (London).
Mining Engineering, monthly.
Mining Journal (London).
Mining Magazine (London).
Roskill Information Services Ltd. (London).
World Mining, monthly.

TABLE 1
SALIENT STRONTIUM STATISTICS 1/

(Metric tons of contained strontium unless otherwise noted 2/)

	1990	1991	1992	1993	1994
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption: 3/					
Strontium minerals	21,500	14,600	19,700	11,600	16,000
Strontium compounds	11,800	9,550	13,000	15,300	20,000
Exports (compounds) 3/	700	1,080	650	260	110
Shipments from Government stockpile excesses	--	--	--	--	--
Price, average value of mineral imports at port of exportation, dollars per ton	86	77	68	73	68
World production 4/ (celestite)	240,000	199,000	139,000	156,000 r/	150,000

e/ Estimated. r/ Revised.
1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits.
2/ The strontium content of celestite is 43.88%, which was used to convert units to celestite.
3/ Source: Bureau of the Census.
4/ Excludes China and the former U.S.S.R.

TABLE 2
U.S. ESTIMATED DISTRIBUTION OF PRIMARY
STRONTIUM COMPOUNDS, BY END USE

(Percent)

End use	1993	1994
Electrolytic production of zinc	2	2
Ferrite ceramic magnets	13	11
Pigments and fillers	5	6
Pyrotechnics and signals	11	9
Television picture tubes	66	69
Other	3	3
Total	100	100

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

	1993		1994	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Strontium carbonate precipitated:				
Brazil	--	--	(3/)	$6
Canada	365	$302	381	354
Germany	1	3	--	--
India	--	--	(3/)	3
Japan	--	--	14	13
Malaysia	--	--	1,220	402
Mexico	--	--	1	4
United Kingdom	9	69	2	16
Total	375 r/	374	1,620	798
Strontium oxide, hydroxide, and peroxide:				
Argentina	--	--	19	30
Belgium	36	37	177	18
Canada	--	--	40	26
Germany	--	--	1	8
Iceland	(3/)	4	--	--
Japan	1	9	--	--
Korea, Republic of	--	--	1	8
Norway	--	--	1	16
Thailand	16	12	--	--
Turkey	1	15	--	--
United Kingdom	--	--	4	4
Total	54	77	243	110

r/ Revised.
1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM MINERALS, 1/ 2/ 3/
BY COUNTRY

Country	1993		1994	
	Quantity (metric tons)	Value 3/ (thousands)	Quantity (metric tons)	Value 3/ (thousands)
Mexico	26,400	$1,920	35,500	$2,420
Other	(4/)	12 r/	(4/)	6
Total	26,400	1,930	35,500	2,420

r/ Revised.
1/ Celestite (strontium sulfate).
2/ Customs value.
3/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
4/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS, BY COUNTRY 1/

	1993		1994	
	Quantity (metric tons)	Value 2/ (thousands)	Quantity (metric tons)	Value 2/ (thousands)
Strontium carbonate:				
China	176	$84	101	$44
Germany	3,110	1,960	4,880	2,920
Italy	2	6	6	13
Japan	(3/)	7	(3/)	8
Mexico	21,500	12,500	28,100	16,900
Total	24,800	14,500	33,100	19,900
Strontium nitrate:				
China	4	3	4	5
Cote d' Ivoire	--	--	1	13
Germany	--	--	(3/)	3
Japan	(3/)	5	--	--
Mexico	1,530	1,280	84	65
Total	1,530	1,290	89	86

1/ Previously published and 1994 data rounded by the U.S. Bureau of Mines to three significant digits; may not add to toals shown.
2/ Customs value.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 6
STRONTIUM MINERALS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1990	1991	1992	1993	1994 e/
Algeria (celestite) e/	5,400	5,400	5,400	5,400	5,400
Argentina	3,110	1,200	1,200 e/	-- r/	--
Iran (celestite) 4/	34,100	28,500	13,100	20,000 e/	20,000
Mexico (celestite)	66,300	62,200	61,100	71,900 r/	70,000
Pakistan	1,800	1,470	1,450	1,680 r/	1,500
Spain e/ 5/	31,000	28,000	18,000	12,000	12,000
Turkey (celestite)	73,800	70,000	37,900	43,700 r/	40,000
United Kingdom e/	24,700 6/	2,000	1,000	1,000	1,000
Total	240,000	199,000	139,000	156,000 r/	150,000

e/ Estimated. r/ Revised.
1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
2/ Table includes data available through May 5, 1995.
3/ In addition to the countries listed, China and Poland produce strontium minerals, but output is not reported quantitatively, and available information is inadequate to make reliable estimates of output levels.
4/ Data are for year beginning Mar. 21 of that stated.
5/ Sr_2O_4 content.
6/ Reported figure.