SILICON

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Silicon (Si) is a light chemical element with metallic and nonmetallic characteristics. In nature, silicon combines with oxygen and other elements to form silicates. Silicon in the form of silicates constitutes more than 25% of the Earth's crust. Silica is a silicate consisting entirely of silicon and oxygen. Silica (SiO_2) as quartz or quartzite is used to produce silicon ferroalloys for the iron and steel industries, and silicon metal, for the aluminum and chemical industries. Ferrosilicon and silicon metal are referred to by the approximate percentage of silicon contained in the material and the maximum amount of trace impurities present.

Almost all ferrosilicon products are consumed by the iron and steel industries. In terms of their nominal silicon contents, the two standard grades of ferrosilicon are 50% ferrosilicon and 75% ferrosilicon.

Metallurgical-grade silicon metal is used by the primary and secondary aluminum industries and the chemical industry. The products sold to these industries vary considerably in their specifications. Specifications for silicon metal used by the primary aluminum and chemical industries generally are more stringent than those for metal used by the secondary aluminum industry. In addition, the chemical industry requires that the metal be ground into a fine powder rather than the lump form used by the aluminum industry. Silicon metal that is refined into semiconductor-grade metal for use in making computer chips is crucial to modern technology, but the quantities are quite small in relation to total silicon metal demand (Gill, 1997). This report contains no information about this highest purity silicon except as it appears in the foreign trade statistics.

On the basis of contained silicon, overall domestic silicon production of 429,000 metric tons (t) was marginally less than that of 1997, and apparent consumption of silicon decreased by about 2%, to 616,000 t from the revised figure of 628,000 t for 1997. (See table 1.) Year-average dealer import prices for standard grades of ferrosilicon and silicon metal decreased from those of 1997 by as much as 13% among ferrosilicon grades and 8% for metal.

Also on the basis of contained silicon, overall U.S. trade volume decreased by about 4% for exports and 5% for imports. U.S. net import reliance for silicon products was estimated to have decreased by 1% to 30%.

Legislation and Government Programs

The outcomes of criminal and civil price fixing suits stemming from allegations that certain domestic producers conspired to fix prices of ferrosilicon sold in the U.S. market from 1989 to 1991 tended to be settlements or penalties that were relatively small. In the criminal suit, sentences given out at the end of January were $150,000 for SKW Metals and Alloys Inc., $30,000 for a company vice president, and 18 months probation for both (Ryan's Notes, 1998g). Subsequently, the defendants appealed the convictions underlying the sentences, and the U.S. Department of Justice appealed the small size of the fines (Platt's Metals Week, 1998). In the civil suits, several settlements were worked out among the various producers and their class-action and steel company plaintiffs (American Metal Market, 1998; Ryan's Notes, 1998c, d). In November, a Federal jury ruled that five steelmakers had not been harmed by the alleged ferrosilicon price fixing of the three companies that had not made settlements (Ryan's Notes, 1998f). Certain class-action suits continued into 1999.

Production

Overall domestic gross production and net shipments of silicon products decreased by roughly 2% compared with those of 1997. For ferrosilicon, two of three production categories showed declines; the decrease in net shipments was about 10% for ferrosilicon containing 25% to 55% silicon, 3% for ferrosilicon containing 56% to 95% silicon, and 7% for miscellaneous silicon alloys. Production and net shipments, however, were up by about 4% for silicon metal. Overall producer stocks increased by about 14% mainly because of a rise of about one-fifth in combined stocks of standard grades of ferrosilicon. These comparisons are exclusive of silvery pig iron, statistics for which were not published to avoid disclosing proprietary data.

Domestic production data for silicon are derived from monthly and annual voluntary surveys and estimates for nonrespondents by the U.S. Geological Survey (USGS). The figures in table 2 represent 100% of the production and shipments from the operations listed in table 3 that are canvassed by means of the Silicon Alloys survey.

The private equity interests with which ownership of Simcala Inc. was shared with company management changed in April from Capital One Partners and Charter Oak Partners to Atlanta-based Cravey, Green & Whalen, Inc. (Ryan's Notes, 1998b). At the Alloy, WV, plant of Elkem Metals Co., reconstruction of an idle furnace into that plant's fifth silicon metal furnace was completed; the furnace was started up in the third quarter of the year. Reconstruction included new process computer control and electrical balancing systems that were expected to be applied to the plant's other silicon furnaces (Elkem ASA, 1999, p. 49).

Principal elements in the cost of silicon and ferrosilicon production are the delivered costs of the ore (quartz or quartzite) and costs of energy, reductant coke or low ash coal, iron in the form of steel scrap (if required), and labor. Production of silicon metal and silicon-containing alloys is extremely power intensive and can require up to 14,000 kilowatt-hours of electric energy per metric ton of silicon contained in the final product (Dosaj, 1997). This high-energy

demand can be offset somewhat by recovering heat energy from furnace off-gases. Locations of ferrosilicon and silicon metal smelters are usually determined by balancing marketing costs against processing costs.

Silicon is not generally recovered from secondary sources. The only secondary possibility is recovery from metallic scrap, such as aluminum alloys, cast iron, and steel, from which recovery of contained silicon is incidental to that of the primary metal. Some silicon is recycled internally in smelters when fines or off-grade material are remelted.

Consumption

Ferrosilicon was used primarily as a deoxidizing and alloying agent in the production of iron and steel products. Metallurgical-grade silicon metal was used by the aluminum industry in the production of wrought and cast products. It also served as the basic raw material in the manufacture of many chemical products and intermediates, such as silicones and silanes.

For 1998, total U.S. apparent consumption of silicon metal and silicon-containing ferroalloys was estimated to have been about 616,000 t of contained silicon, a slight decline of about 2% compared with the revised figure of 628,000 t for 1997. Apparent consumption of ferrosilicon and miscellaneous silicon alloys decreased marginally to 349,000 t from the revised figure of 351,000 t for 1997; apparent consumption of silicon metal decreased by 3.6%, to 267,000 t. The share of total demand accounted for by ferrosilicon and miscellaneous silicon alloys increased slightly to 57% on the basis of silicon content. Final data on U.S. consumption and stocks of silicon materials in 1998 were not available at the time this report was prepared.

Among factors tending to depress growth in demand of ferrosilicon was the use of metallurgical-grade silicon carbide as a substitute, as signified by continued growth in imports of silicon carbide (CRU International Ltd., 1998). North American production and U.S. imports of silicon carbide were reported in the 1998 annual review of Manufactured Abrasives in the Mineral Industry Surveys series of the USGS and in the Manufactured Abrasives chapter of the 1998 Minerals Yearbook.

For silicon metal, demand growth was adversely affected by a strike at a major domestic automobile manufacturer, which temporarily reduced demand for silicon in aluminum castings, and by financial problems in Asia that reduced demand for silicones and semiconductors (Ryan's Notes, 1998a). At the beginning of the year, expansions of capacity for production of polysilicon used in semiconductor applications were still underway, but later on, startup was deferred for at least one of them (Mitsubishi Polycyrstalline Silicon America, Mobile, AL) until 1999 (Chemical Week, 1998; Hunter, 1998). In the latter half of 1997, Dow Corning Corp. announced an expansion of capacity at its Midland, MI, plant for production of trichlorosilane, a primary ingredient for making polysilicon (Chemical Week, 1997). This expansion was completed in 1998, approximately 1 year later.

Prices

Demand for metallurgical-grade silicon alloys and metal is determined in the short term less by their prices than by the level of activity in the steel, ferrous foundry, aluminum, and chemical industries. As a result, prices tend to vary widely with changes in demand and supply. The basis for U.S. prices of silicon materials was cents per pound of contained silicon.

Year-average import prices, in cents per pound, of 52.1 for 50% ferrosilicon, 43.1 for 75% ferrosilicon, and 70.5 for silicon metal were about 2%, 13%, and 8% lower, respectively, than those of 1997, as given by Platt's Metals Week or as calculated from Platt's weekly listings. In 1998, yearend prices for these materials were lower than those at the beginning of the year by about 5% for 50% ferrosilicon, 10% for 75% ferrosilicon, and 13% for silicon metal.

Declining prices in 1998 thus continued the downward trend of prices in 1997. For 50% ferrosilicon, the price range, in cents per pound, changed only once, decreasing from 51 to 54 for January through early August to 50 to 53 for mid-August and thereafter. For 75% ferrosilicon, the price range, in cents per pound, decreased steadily in a stepwise fashion, beginning the year at 44 to 47 and ending the year at 39 to 40. For silicon metal, the price range, in cents per pound, began the year at 68 to 76, dipped to 64 to 76 late in January, recovered to 68 to 76 as of mid-March, held steady at that level until mid-September, and then declined as of late October to a final level of 63 to 70.

Foreign Trade

U.S. exports of ferrosilicon decreased about one-seventh overall in gross weight and value compared with those in 1997. Canada, Japan, the Republic of Korea, Mexico, and the United Kingdom together accounted for about 86% of total 1998 exports. (See table 4.) Combined exports of silicon metal increased by about 4% in gross weight but decreased by about 2% in value. Combined shipments to Canada, Japan, the Republic of Korea, Mexico, and Taiwan accounted for about 82% of total shipments. Shipments of high-purity silicon containing more than 99.99% silicon constituted only about 18% of total volume but about 90% of total value because of their high unit value.

U.S. imports of silicon ferroalloys increased overall by about 4% in gross weight but decreased by about 7% in value compared with those of 1997. Imports of material containing 55% to 80% silicon accounted for most of the increase. About four-fifths of total quantity and value were accounted for by imports in the ferrosilicon category of "55% to 80% silicon, other," of which Iceland, Norway, and South Africa were the leading suppliers. (See table 5.) Norway remained the leading source of ferrosilicon overall, although its share of the total declined to 40% as imports from Norway in the category of "ferrosilicon, other" fell to only 5% of those in 1997.

In decreasing order of silicon content, overall imports of silicon metal decreased by about 14% in volume, 18% in content, and 21% in value compared with those of 1997, and import volumes for the three import categories declined by 20%, 11%, and 16%, respectively. The total of silicon units imported as metal equaled the average for the preceding 4 years. Although imports of high-value silicon metal containing more than 99.99% silicon constituted not much more than 1% of total volume, they accounted for the largest share (38%) of total value. The main volume of imports was about equally divided between the other two silicon content categories. For the category of "silicon content from 99.00% to 99.99%,"

almost 60% was from Canada and South Africa combined; those from Canada decreased by 27%; and those from South Africa rose by 48%. For the category of "silicon content less than 99%," about 55% of imports was from Russia.

Trade journals continued to imply that silicon metal actually produced in China was being imported into the United States and Western Europe under the guise that it had come from such countries as Australia, Italy, the Philippines, and South Africa (Metal Bulletin, 1998a; Ryan's Notes, 1998e). Suspicions of this type had been directed at the 7,700 t of silicon metal imported into the United States from India in 1997; in 1998, only 84 t of U.S. imports of silicon metal were reported to have come from India.

In 1998, U.S. net import reliances for ferrosilicon and silicon metal products were estimated to be 32% and 29%, respectively, compared with 29% and 34% for 1997. Overall import reliance for silicon products was estimated to be 30%, or 1% less than that of 1997.

The general rates of duty that applied to U.S. imports during 1998 were, on an ad valorem basis, 1.5% for standard 75% ferrosilicon, free for magnesium ferrosilicon and most other ferrosilicon, and 5.3% or 6.2% for metal exclusive of the high-purity grade (U.S. International Trade Commission, 1997). Congress allowed the Generalized System of Preferences (GSP) program to expire after June 30 but in October approved its retroactive extension through June 30, 1999, as part of the Omnibus Budget Bill. Reimbursement of duties paid during the period when the program temporarily was not in effect was approved also (Customs Service, 1998). Under the GSP, the United States grants duty-free access to goods from qualifying developing countries and territories.

The Department of Commerce's Foreign-Trade Zones Board (F-TZB) granted authority for establishment of a foreign-trade subzone at the Beverly, OH, plant of Globe Metallurgical, Inc., where silicon ferroalloys and metal are produced. Zone procedures exempted Globe from paying duty on materials used in production for export. One of the conditions imposed by the F-TZB was that any imported merchandise subject to an antidumping or countervailing duty order must be exported (Foreign-Trade Zones Board, 1998).

The International Trade Administration of the U.S. Department of Commerce published the results of a number of final or amended final antidumping duty administrative reviews in 1998 that affected antidumping margins on ferrosilicon from Brazil and silicon metal from Brazil and China.

For ferrosilicon from Brazil for the period of review (POR) of August 15, 1993, through February 28, 1995, the results as amended in January were margins of 30.69% for Companhia de Ferro Ligas da Bahia (Ferbasa) and 35.95% for "all others" (International Trade Administration, 1998b). For the POR of March 1, 1996, through February 28, 1997, the result as finally determined in May was to lower the margin to zero for Ferbasa (International Trade Administration, 1998c). The "all others" rate subsequently was raised to 42.17% in July by another action of the International Trade Administration (International Trade Administration, 1998a).

For silicon metal from Brazil for the POR of July 1, 1995, through June 30, 1996, the results as finally determined in February were margins of 0.00% for Companhia Brasileira Carbureto de Calcio, 39.00% for Eletroila S.A., 1.67% for Companhia Ferroligas Minas Gerais—Minasligas, 3.08% for Rima Industrial S.A., and 91.06% for "all others" (International Trade Administration, 1998d).

For silicon metal from China for the POR of June 1, 1996, through May 31, 1997, the margin as finally determined in July was 139.49% for all shipments (International Trade Administration, 1998e).

In July, the U.S. International Trade Commission (USITC) initiated a review of the affirmative determinations that it previously had made for ferrosilicon in its investigations of countervailing duties on material from Venezuela and antidumping duties on material from Brazil, China, Kazakhstan, Russia, Ukraine, and Venezuela. This was in response to a request from Brazilian ferrosilicon producers that alleged changed circumstances (U.S. International Trade Commission, 1998a). In September, the USITC decided that it would not conduct a similar review of its earlier affirmative determinations for silicon metal from Argentina, Brazil, and China. A request for a changed-circumstances review for silicon metal had been made by General Motors Corp. (U.S. International Trade Commission, 1998b).

World Review[1]

Data on annual world production of ferrosilicon and silicon metal by country during recent years are given in the annual review for 1998 for Ferroalloys in the Mineral Industry Surveys series of the USGS and in the Ferroalloys chapter of the 1998 Minerals Yearbook. World production of ferrosilicon was estimated to have been about 3.9 million metric tons (Mt) in 1998 compared with about 4.1 Mt in 1997. The major producers of ferrosilicon in 1998 were, in decreasing order, China, Russia, Norway, the United States, Ukraine, Brazil, France, and South Africa and accounted for more than 80% of total production. World production of silicon metal was estimated to have been about 653,000 t in 1998 compared with a revised total of about 664,000 t in 1997. This is exclusive of China's production, which is believed to have been the world's largest but for which data are lacking. The other major producers of silicon metal in 1998 were, in deceasing order, the United States, Brazil, Norway, France, Russia, and South Africa and accounted for almost 90% of total production as listed in table 1.

Western consumption of ferrosilicon in 1998 was estimated by CRU International Ltd. (CRU) as 1.67 Mt of contained silicon. This was a decrease of 7.8% as compared with the revised figure of 1.81 Mt for 1997. Japan (-28%) and other Asian areas had the largest percentage declines in consumption. Western consumption of silicon metal was estimated to be 873,000 t, a decrease of 3.3% from the previous year's all-time high. As with ferrosilicon, Japan and other Asian areas (-24%) had the largest percentage declines. In decreasing order, Western Europe, the United States, and Japan accounted for 69% of the 1998 consumption total for ferrosilicon and 85% of that for silicon metal (CRU International Ltd., 1999).

[1]Discussions of the more-significant developments during 1998 for specific countries were based in a number of instances on news items in trade journals, such as American Metal Market, Metal Bulletin [London], Platt's Metals Week, Ryan's Notes, and The TEX Report [Tokyo]. These items have not been acknowledged individually because the information they conveyed often was aggregated, possibly with that from other sources.

China.—China's exports of 270,000 t of ferrosilicon were almost 30% greater than those for 1997. In 1997, approximately 70% and 20% of ferrosilicon exports had gone to Japan and the Republic of Korea, respectively. According to He and Yu (1998), China had more than 400 producers of silicon metal with a combined productive capacity as large as 400,000 metric tons per year (t/yr). Some silicon metal production was being moved from the Guangxi Zhuang Autonomous Region to Sichuan Province because of the availability of hydroelectric power at lower cost. In 1997, total exports of 290,000 t of silicon metal were 5% greater than those for 1996, and in both years, roughly one-half went to Japan.

European Union.—As of March, the European Commission removed antidumping duties on imports of silicon metal from Brazil. These duties had been in effect since 1992 and were renewed in 1997 at rates ranging from 18.3% to 34.6% for specific producers. Euroalliages, an association of European producers of ferroalloys, had withdrawn its request for such duties late in 1997.

Iceland.—In November, the two ferrosilicon furnaces of Icelandic Alloys Ltd. temporarily were closed down because of a shortage of hydroelectric power. The first shutdown was on November 1, and the second, on November 25. At a 1997 conference, reports on technology for production control of the company's furnaces had been given by Hauksdóttir, Gestsson, and Vésteinsson (1998) and Ingason and Jonsson (1998).

Norway.—Elkem ASA and Fesil ASA each converted a furnace from production of ferrosilicon to silicon metal. At Elkem's Thamshavn plant, the conversion was completed by midyear and replaced 20,000 t of annual capacity for ferrosilicon by 14,000 t for silicon metal. At Fesil's Holla Metall plant, the conversion of the plant's only remaining ferrosilicon furnace took place in the second half of the year. This replaced 30,000 t of annual capacity for special grades of ferrosilicon by 18,000 t for silicon metal.

Spain.—In December, Ferroatlántica SL started a new furnace with an annual capacity of 10,000 t for silicon metal at its plant at Sabon. This addition raised Ferroatlantica's silicon capacity from all three of its silicon metal furnaces to about 33,000 t/yr.

Venezuela.—The lengthy privatization process of C.V.G. Venezolana de Ferrosilicio C.A. (Fesilven) ended around the first of December when it was sold to Spain's Ferroatlántica. Fesilven's ferrosilicon operations were being hampered by quartz supply shortages and maintenance problems.

Current Research and Technology

Topics related to smelting included presentation of data on air emissions of carbon dioxide (Lindstad, 1998; Monsen, Lindstad, and Tuset, 1998) and of carbon dioxide and other substances (Nestaas, Lindstad, and Kolbeinsen, 1998) during smelting of ferrosilicon and silicon metal in Norway. Reports relating to electrodes for silicon smelting included technological developments for prebaked electrodes (Klotz and Boardwine, 1998) and Spanish experience with a compound electrode (Bullón, Garcia-Alba, and others, 1998; Bullon, Lage, and others, 1998).

Researchers with Michigan Technological University reported further on their investigations of phosphide inclusions in ferrosilicon (Horn, Heckel, and Nassaralla, 1998) and suppression of phosphine evolution from them by adding magnesium (Horn, Nassaralla, and Heckel, 1998). Researchers in Iceland suggested that disintegration of ferrosilicon could be reduced by raising its cooling rate during and after solidification (Johannesson and Sigfusson, 1998).

The effect of silicon content on the mechanical properties of steels with transformation induced plasticity was studied in the laboratory. Such so-called thin-sheet TRIP steels are of particular interest for automotive applications (Pichler and others, 1998).

Studies were made of the thermodynamics of phosphorus in binary alloys of silicon with phosphorus and in ternary alloys of silicon with phosphorus and iron or manganese to assist in understanding the removal of phosphorus from silicon and silicon-containing ferroalloys (Miki and others, 1998).

The possibility of forming bulk amorphous silicon from supercooled liquid was theoretically analyzed (Shao, Spaepen, and Turnbull, 1998). In China, a hydrothermal method was developed for preparing porous silicon powder, such as might be used in optical devices (Chen and others, 1998).

Outlook

Demand for ferrosilicon follows trends in the iron and steel industries, which use ferrosilicon for deoxidation of molten metal and as an alloying agent. Details of the outlook for the steel industry are discussed in the Outlook section of the annual review for 1998 for Iron and Steel in the Mineral Industry Surveys series of the USGS and in the Iron and Steel chapter of the 1998 Minerals Yearbook. Signifying uncertainties in the global economic outlook, the October 1998 forecast of the International Iron and Steel Institute (IISI) omitted a midterm outlook (Gavaghan, 1998). The IISI's broad estimate of steel demand for 2005 corresponded to an annual growth rate between 1998 and 2005 of about 1.5%. An analyst who reviewed the ferrosilicon market in November 1998 foresaw an oversupply of ferrosilicon at least through the first half of 2000 (Metal Bulletin, 1998b).

Demand for silicon metal comes mainly from the aluminum and chemical industries. During the period from 1980 to 1995, silicon consumption grew at an annual rate of about 3.5% for the aluminum industry and 8% for the chemical industry to give an overall annual growth rate for worldwide silicon metal consumption of about 5.5% (Dosaj, 1997, p. 1110). As of mid-1998, CRU projected that demand for chemical-grade silicon by Western countries would increase at an average rate of about 7% for the next 5 years, and that supplies would be adequate for most of that period (de Linde, 1998). Maintenance of a growth rate this large seemingly will be set back at least for some time in view of recent economic declines in the Far East, which particularly has affected silicones demand. In Japan, the economic decline also has affected demand for silicon metal by the aluminum industry, which accounts for about four-fifths of Japanese demand for silicon metal (TEX Report, 1999).

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TABLE 1
SALIENT SILICON STATISTICS 1/

(Thousand metric tons of silicon content unless otherwise specified)

	1994	1995	1996	1997	1998
United States:					
Production	390	396	412	430	429
Exports:					
Ferrosilicon	20	22	27	27	24
Silicon metal	12	25	17	22	23
Imports for consumption:					
Ferrosilicon	147	158	148	135	142
Silicon metal	108	92	79	121	99
Apparent consumption:					
Ferrosilicon	360	381	361	351 r/	349
Silicon metal	256	228	233	277	267
Price, average, cents per pound Si: 2/					
Ferrosilicon, 50% Si	43.9	57.9	64.0	54.8	52.1
Ferrosilicon, 75% Si	40.8	58.1	62.2	48.0	43.1
Silicon metal	64.1	69.5	89.7	81.4	70.5
World: Production (gross weight): e/					
Ferrosilicon	3,800	4,000 r/	4,300 r/	4,100	3,900
Silicon metal	560	590	650	660	650

e/ Estimated. r/ Revised.
1/ Data are rounded to three significant digits.
2/ Platt's Metals Week dealer import prices.

TABLE 2
PRODUCTION, SHIPMENTS, AND STOCKS OF SILICON ALLOYS AND METAL,
IN THE UNITED STATES IN 1998 1/

(Metric tons, gross weight, unless otherwise specified)

Material	Silicon content (percentage)		Producers' stocks December 31, 1997	Gross production 2/	Net shipments	Producers' stocks December 31, 1998
	Range	Typical				
Silvery pig iron	5-24	18	W	W	W	W
Ferrosilicon	25-55	48	23,200	162,000	98,100	26,200
Do.	56-95	76	21,500	147,000	142,000	28,300
Silicon metal (excluding semiconductor grades)	96-99	98	10,600	195,000	188,000	10,500
Miscellaneous silicon alloys (excluding silicomanganese)	32-65	--	12,600	99,800	85,500	12,400

W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits.
2/ Ferrosilicon production includes material consumed in the production of miscellaneous silicon alloys.

TABLE 3
PRINCIPAL PRODUCERS OF SILICON ALLOYS AND/OR SILICON METAL
IN THE UNITED STATES IN 1998

Producer	Plant location	Product 1/
American Alloys Inc.	New Haven, WV	FeSi and Si.
American Silicon Technologies	Rock Island, WA	Si.
Applied Industrial Minerals Corp.	Bridgeport, AL	FeSi.
Elkem Metals Co.	Alloy, WV	FeSi and Si.
Globe Metallurgical, Inc.	Beverly, OH	Do.
Do.	Niagara Falls, NY	Si.
Do.	Selma, AL	Do.
Do.	Springfield, OR	Do.
Keokuk Ferro-Sil Inc.	Keokuk, IA	FeSi and silvery pig iron.
Simcala Inc.	Mount Meigs (Montgomery), AL	Si.
SKW Metals and Alloys Inc.	Calvert City, KY	FeSi.

1/ FeSi, ferrosilicon; Si, silicon metal.

TABLE 4
U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 1998 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Ferrosilicon:			
More than 55% silicon:			
Brazil	3	2	$2,690
Canada	10,100	6,060	6,500,000
Chile	20	12	16,200
Costa Rica	8	5	8,260
Japan	30	18	23,700
Korea, Republic of	1,610	967	1,400,000
Malaysia	16	13	28,800
Mexico	3,000	1,930	2,940,000
Netherlands	18	11	45,000
Pakistan	84	51	67,400
United Kingdom	18	11	14,500
Total	14,900	9,080	11,100,000
Other ferrosilicon:			
Australia	1,410	705	1,130,000
Canada	8,210	4,100	5,720,000
China	630	315	617,000
Egypt	356	178	281,000
India	1,690	784	2,630,000
Japan	8,070	4,030	6,480,000
Korea, Republic of	1,160	578	942,000
Mexico	2,280	1,140	2,350,000
Taiwan	855	428	676,000
United Kingdom	3,850	1,930	2,660,000
Other	1,400	699	1,380,000
Total	29,900	14,900	24,900,000
Total ferrosilicon	44,800	24,000	35,900,000
Metal:			
More than 99.99% silicon:			
China	147	XX	$3,940,000
Czech Republic	53	XX	2,540,000
Denmark	41	XX	3,070,000
France	131	XX	3,730,000
Germany	137	XX	5,950,000
Japan	3,260	XX	179,000,000
Korea, Republic of	270	XX	13,200,000
Malaysia	65	XX	16,300,000
Taiwan	53	XX	3,940,000
United Kingdom	58	XX	10,200,000
Other	134	XX	9,190,000
Total	4,350	4,350 e/	251,000,000
99.00% - 99.99% silicon:			
Australia	525	520	740,000
Belgium	31	30	43,100
Brazil	63	63	119,000
Ghana	38	37	71,300
Hong Kong	44	44	44,100
Japan	54	53	78,500
Korea, Republic of	1,180	1,170	1,660,000
Mexico	32	32	44,300
New Caledonia	29	29	40,300
Ukraine	80	79	113,000
Other	80	80	133,000
Total	2,160	2,140	3,090,000
Other silicon:			
Australia	112	109	160,000
Canada	5,880	5,710	5,950,000
China	872	847	1,930,000
Germany	906	880	1,230,000

See footnotes at end of table.

TABLE 4--Continued
U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 1998 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Other silicon--Continued:			
Japan	2,790	2,710	$5,500,000
Korea, Republic of	218	211	313,000
Mexico	4,520	4,380	6,200,000
Switzerland	130	127	172,000
Taiwan	1,100	1,070	1,570,000
Ukraine	85	83	113,000
Other	592	575	1,280,000
Total	17,200	16,700	24,400,000
Total silicon metal	23,700	23,200	278,000,000

e/ Estimated. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL,
BY GRADE AND COUNTRY, IN 1998 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Ferrosilicon:			
55% - 80% silicon, over 3% Ca:			
Argentina	112	68	$142,000
Brazil	20	13	23,600
Canada	20	15	13,600
Egypt	267	177	122,000
India	216	156	246,000
Macedonia	6,040	4,400	3,590,000
United Kingdom	18	13	89,100
Total	6,700	4,850	4,220,000
55% - 80% silicon, other:			
Brazil	1,400	1,070	997,000
Canada	3,980	3,030	2,760,000
Egypt	2,350	1,740	1,520,000
France	1,230	847	2,390,000
Iceland	21,400	16,300	13,500,000
India	6,770	5,120	4,260,000
Macedonia	14,600	11,000	8,840,000
Norway	75,500	57,400	52,600,000
Poland	10,300	8,330	6,120,000
South Africa	26,000	19,800	16,000,000
Other	2,130	1,640	4,100,000
Total	166,000	126,000	113,000,000
80% - 90% silicon:			
Canada	16	13	7,790
South Africa	21	18	14,700
Total	37	31	22,500
Magnesium ferrosilicon:			
Argentina	740	352	743,000
Brazil	6,660	3,020	5,940,000
Canada	329	157	363,000
China	2,410	1,030	2,260,000
Germany	33	11	89,400
Japan	122	59	273,000
Netherlands	143	66	153,000
New Caledonia	60	29	56,400
Norway	4,870	2,280	5,360,000
Slovakia	21	10	4,650
Total	15,400	7,010	15,200,000
Other ferrosilicon:			
Brazil	451	43	317,000
Canada	10,600	3,410	7,860,000
China	399	162	218,000
France	734	357	1,730,000
India	43	7	28,700
Japan	(2/)	(2/)	6,650
Norway	249	47	272,000
Russia	403	193	256,000
South Africa	176	26	119,000
Total	13,100	4,250	10,800,000
Total ferrosilicon	201,000	142,000	143,000,000

See footnotes at end of table.

TABLE 5--CONTINUED
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL,
BY GRADE AND COUNTRY, IN 1998 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Metal:			
More than 99.99% silicon:			
Brazil	56	XX	$108,000
China	5	XX	40,800
France	7	XX	90,000
Germany	392	XX	44,700,000
Israel	3	XX	6,770
Italy	377	XX	17,800,000
Japan	358	XX	16,300,000
Korea, Republic of	132	XX	3,340,000
Taiwan	23	XX	400,000
United Kingdom	35	XX	1,970,000
Other	7	XX	577,000
Total	1,400	1,400 e/	85,300,000
99.00% - 99.99% silicon:			
Australia	1,240	1,230	2,070,000
Brazil	4,050	4,010	5,440,000
Canada	12,500	12,400	20,100,000
France	1,080	1,070	1,570,000
Norway	5,850	5,940	10,100,000
Philippines	522	518	547,000
Russia	7,530	6,300	10,400,000
South Africa	16,600	16,500	25,100,000
Spain	240	238	376,000
Ukraine	1,060	1,050	1,200,000
Other	314	310	881,000
Total	51,000	49,600	77,700,000
Other silicon:			
Brazil	1,710	1,680	2,070,000
Canada	4,790	4,740	7,530,000
China	2,660	2,620	2,300,000
Norway	1,620	1,120	2,580,000
Russia	28,900	27,100	32,100,000
Saudi Arabia	810	809	913,000
Slovenia	682	663	840,000
South Africa	6,950	6,430	6,630,000
Ukraine	1,980	1,940	2,380,000
United Kingdom	529	520	896,000
Other	1,640	913	2,170,000
Total	52,300	48,500	60,400,000
Total silicon metal	105,000	99,500	223,000,000

e/ Estimated. XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

Source: Bureau of the Census.