SILICON

By Thomas S. Jones

Silicon (Si) is a light chemical element having 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. The primary aluminum and chemical industries generally require more-stringent specifications than those of 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 current 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 occurs in the foreign trade statistics.

On the basis of contained silicon, overall domestic silicon production advanced for the fourth successive year to about 430,000 metric tons, and apparent consumption of silicon increased by about 5%, to 625,000 tons. *(See table 1.)* Year-average dealer import prices for standard grades of ferrosilicon and silicon metal decreased from those of 1996 by as much as 23% among ferrosilicon grades and 9% for metal.

Also on the basis of contained silicon, overall U.S. trade volume increased for exports and imports by about 13%. U.S. net import reliance for silicon products was estimated to have remained at about 31%.

Legislation and Government Programs

In March, SKW Metals & Alloys Inc. and its president were found guilty of conspiring to fix prices of ferrosilicon, but not silicon metal, sold in the U.S. market from 1989 to 1991 (Metal Bulletin, 1997d). SKW's subsequent appeal to the U.S. District Court in Buffalo, NY, which had heard the case, was rejected, but sentencing was delayed until 1998 (Ryan's Notes, 1997b). As an outgrowth of the Government's price-fixing suits, a variety of civil suits (including a class action suit) seeking damages from a number of U.S. producers of silicon products were progressing through the courts.

Production

Overall domestic gross production of silicon products increased by about 3% compared with that of 1996, and shipments were marginally greater. The advances were for ferrosilicon with 56% to 96% silicon content and silicon metal. Both categories were also principally responsible for an overall 17% increase in producer stocks. 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 "Silicon Alloys" survey canvasses the operations listed in table 3. The figures in table 2 represent 100% of the production and shipments from these operations.

Principal elements in the cost of silicon and ferrosilicon production are 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 alloys is extremely power intensive, requiring an input of as much as 14,000 kilowatt hours per ton of silicon content for some operations. 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 scrap metal, from which recovery of its contained silicon is incidental to recovery of the primary metal. Some silicon is recycled internally in smelters when fines or off-grade material are remelted.

Elkem Metals Co. and Globe Metallurgical Inc. acted to change their status with respect to production of ferrosilicon and silicon metal. Elkem Metals restarted production of ferrosilicon at Alloy, WV, in January via that plant's 20-megawatt furnace (Elkem ASA, 1998) and began reconstruction of an idle furnace that was projected to increase the plant's annual capacity for silicon metal by 20,000 tons by mid-1998 (Metal Bulletin, 1997b). In mid-1997, Globe completed conversion of a 22-megawatt furnace at its Niagara Falls, NY, plant from production of ferrosilicon to silicon metal (Ryan's Notes, 1997a). Later in the year, Globe acquired a one-third interest in Norway's FeSil ASA, whose products include ferrosilicon and silicon metal (Platt's Metals Week, 1997a).

Late in the year, Applied Industrial Materials Corp. (AIMCOR) was acquired by and became an independent subsidiary of Walter Industries Inc., headquartered in Tampa, FL. Included in the

acquisition was AIMCOR's metals group that operates a ferrosilicon smelter at Bridgeport, AL (Kelly, 1997).

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 1997, total U.S. apparent consumption of silicon metal and silicon-containing ferroalloys was estimated to have been about 625,000 tons of contained silicon; this was an increase of 5% compared with that of 1996. A decline of about 4% in apparent consumption of ferrosilicon and miscellaneous silicon alloys to 348,000 tons was more than offset by an increase in apparent consumption of silicon metal of about 18%, to 277,000 tons. Ferrosilicon and miscellaneous silicon alloys continued to account for a larger share (56%) of total demand than that for silicon metal, on the basis of silicon content. The year-to-year changes were in keeping with trends during the 1990's of a relatively steady demand for ferrosilicon and miscellaneous silicon alloys and an increasing demand for silicon metal.

A factor working against expansion of demand for ferrosilicon was the substitution of metallurgical-grade silicon carbide, U.S. imports of which came mostly from China. This substitution was made mainly by foundries (Ryan's Notes, 1998). Data for reported domestic consumption of silicon alloys appear to confirm the substitution; consumption of silicon carbide in production of cast iron was more than twice as great in 1997 as in 1996. *(See table 4.)* North American production and U.S. imports of silicon carbide are reported in the annual review for 1997 for Manufactured Abrasives in the Mineral Industry Surveys series of the USGS and in the Manufactured Abrasives chapter of the 1997 Minerals Yearbook.

Expansions at two plants of a specialty nature added to the trend for further growth in demand for silicon metal. Hemlock Semiconductor Corp., Hemlock, MI, completed a 2,000-ton expansion in its polysilicon annual capacity and stated that by the first part of 1998, it will make another similar expansion. The company expanded capacity to keep up with growing demand for computer chips (Chemical Week, 1997). In silicones, Rhone-Poulenc Inc. more than doubled its capacity for production of silanols, which are vulcanizers used mainly as moldmaking agents, at its Troy, NY, plant (Scheraga, 1997).

Prices

Demand for metallurgical-grade silicon alloys and metal is determined by the level of activity in the steel, ferrous foundry, aluminum, and chemical industries. Prices can fluctuate widely with changes in demand, supply, and other market factors. 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 54.8 for 50% ferrosilicon, 48.0 for 75% ferrosilicon, and 81.4 for silicon metal were about 14%, 23%, and 9% lower, respectively, than those in 1996, as given by Platt's Metals Week or as calculated from Platt's weekly listings. In 1997, yearend prices for these materials were about 17% lower than those at the beginning of the year.

Price trends generally were downward throughout 1997; for 75% ferrosilicon, the trend represented a continuation of a trailing off in the latter part of 1996, and for silicon metal, a further retreat from the mid-1996 peak. For 50% ferrosilicon, the price range in cents per pound, which began the year at 63 to 65, dropped as of the end of January to 53 to 56. The range remained at that level until early October when it decreased to 51 to 54, after which no further change took place. For 75% ferrosilicon, the price range, which began the year at 52 to 56, declined relatively sharply through mid-February to 47.75 to 49.75 and then generally declined at a slower rate to end the year at 44 to 47. For silicon metal, the price range, which began the year at 85 to 88, increased in February to 85 to 88.5 and then held steady until early June when the setting in of a strong downward trend led to a yearend range of 68 to 76.

Foreign Trade

On the basis of gross weight, U.S. exports of ferrosilicon were marginally greater overall than those in 1996, although total value of exports decreased about 8%. *(See table 5.)* Canada, Japan, and the United Kingdom together were the recipients of about 73% of total 1997 exports. Combined exports of silicon metal were up by about 35% in terms of gross weight and value. Combined shipments to Canada, Japan, the Republic of Korea, Mexico, and Taiwan accounted for more than 80% of total shipments. Although shipments of high-purity silicon containing more than 99.99% silicon constituted less than 20% of total volume, they accounted for about 90% of total value because of their high unit value.

U.S. imports of silicon ferroalloys decreased overall by about 8% in gross weight and 17% in value compared with those in 1996. *(See table 6.)* The total quantity of silicon imported as ferroalloys was the least since 1991. About 80% of total quantity and value was accounted for by imports in the ferrosilicon category of "55% to 80% silicon, other," imports of which decreased by about 12% on the basis of gross weight. Iceland, Norway, and South Africa were the leading suppliers for this category. Imports of magnesium ferrosilicon increased by more than 70%; those from Norway more than doubled, and those from Brazil rose more than 70%. Norway was again the leading source for ferrosilicon imports with almost one-half of the total.

Overall imports of silicon metal increased by about 49% in volume and 32% in value compared with those in 1996. Imports of high-value silicon metal containing more than 99.99% silicon were about 1% of total volume but about 35% of total value, thus representing the largest import category for value. Import volumes for the two other categories were up by roughly one-half. For the metal category of silicon content from 99.00% to 99.99%, about one-half of imports was from Canada and South Africa combined; for the category of a silicon content of less than 99%, about one-

half of imports was from Russia. The total quantity of silicon imported as metal was the greatest to date for the 1990's.

Imports of silicon metal reported as being from India, which accounted for about 6% of total U.S. imports of metal, were often mentioned in trade journals. In view of the seeming lack of production of silicon metal in India, these imports were suspected of being Chinese material that was repackaged and transhipped through India to avoid high antidumping duties (Kelly, 1998).

In 1997, U.S. net import reliances for ferrosilicon and silicon metal products were estimated to be 29% and 34%, respectively, compared with the corresponding figures of 33% and 26% for 1996. Overall import reliance for silicon products was estimated to be 31%, the same as for 1996.

The general rates of duty that applied to U.S. imports during 1997 were, on an ad valorem basis, 1.5% for standard 75% ferrosilicon, free for magnesium ferrosilicon and most other ferrosilicon, and 5.3% or 6.9% for metal exclusive of the high-purity grade (U.S. International Trade Commission, 1996). Congress allowed the Generalized System of Preferences (GSP) program to expire on May 31 but in August approved its retroactive extension through June 30, 1998. Reimbursement of duties paid during the period when the program was not in effect was approved also (U.S. Department of the Treasury, Customs Service, 1997). Under the GSP, the United States grants duty-free access to goods from qualifying developing countries and territories. The GSP treatment for standard 75% ferrosilicon from Argentina had been terminated as of mid-May because of considerations related to intellectual property rights (President of the United States of America, 1997).

The International Trade Administration of the U.S. Department of Commerce published the results of a number of antidumping duty administrative reviews in 1997 that affected antidumping margins on silicon metal and ferrosilicon from Brazil and silicon metal from Argentina.

For silicon metal from Brazil, for the period of review (POR) of July 1, 1992, through June 30, 1993, the results as amended in September were margins of 18.71% for Companhia Brasileira Carbureto de Calcio (CBCC), 25.46% for Eletroila S.A. (Eletrosilex), 0.00% for Companhia Ferroligas Minas Gerais—Minasligas (Minasligas), 31.60% for Rima Industrial S.A. (RIMA), and 91.06% for "all others" (U.S. Department of Commerce, 1997d); for the POR of July 1, 1993, through June 30, 1994, the results as amended in October were margins of 61.58% for CBCC, 35.23% for Camargo Corrêa Metais S.A. (CCM), 38.39% for Eletrosilex, 0.00% for Minasligas, and 91.06% for RIMA and "all others" (U.S. Department of Commerce, 1997f); for the POR of July 1, 1994, through June 30, 1995, the results as amended in October were margins of 0.37% for CBCC, 35.23% for CCM, 6.68% for Eletrosilex, 43.53% for Minasligas, 51.23% for RIMA, and 91.06% for "all others" (U.S. Department of Commerce, 1997e); and for the POR of July 1, 1995, through June 30, 1996, margins preliminarily determined in August were 0.00% for CBCC, 36.74% for Eletrosilex, 1.93% for Minasligas, 70.02% for RIMA, and 91.06% for "all others" (U.S. Department of Commerce, 1997g).

For ferrosilicon from Brazil, for the POR of March 1, 1995, through February 29, 1996, the results as amended in October were margins of 0.00% for CBCC, 2.54% for Minasligas, and 35.95% for "all others" (U.S. Department of Commerce, 1997a, b).

For silicon metal from Argentina, for the POR of September 1, 1992, through August 31, 1993, margins as finally determined in February were 13.80% for Electrometalurgica Andina S.A.I.C., 24.62% for Silarsa S.A., and 17.87% for "all others" (U.S. Department of Commerce, 1996c).

In addition to these actions of the United States affecting trade in silicon materials, the European Commission extended antidumping duties on imports of silicon metal from China and raised the duty rate to 49% in December (Metal Bulletin, 1997a).

World Review[1]

Data on annual world production of ferrosilicon and silicon metal by country during recent years are reported in the annual review for 1997 for Ferroalloys in the Mineral Industry Surveys series of the USGS and in the Ferroalloys chapter of the 1997 Minerals Yearbook. World production of ferrosilicon was estimated to have been about 4.1 million tons in 1997 compared with a revised total of about 4.4 million tons in 1996. The major producers of ferrosilicon in 1997 were, in decreasing order, China, Russia, Norway, the United States, Ukraine, Brazil, France, South Africa, and Kazakstan, and accounted for more than 80% of total production. World production of silicon metal was estimated to have been about 662,000 tons in 1997 compared with a revised total of about 649,000 tons in 1996. 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 1997 were, in decreasing order, the United States, Brazil, Norway, France, Russia, South Africa, and Australia and accounted for more than 90% of total production as listed in table 1.

Developments affecting production and producers of ferrosilicon and silicon metal during 1997 included cutbacks in production of silicon metal by some Brazilian firms. Late in the year, however, Eletrosiderúrgica Brasileira S.A. (Sibra), Bahia State, started up two furnaces for silicon metal that had been converted from production of silicomanganese. At full output, these furnaces made Sibra capable of producing silicon metal at the rate of 20,000 tons per year. Among the world's larger exporters of silicon materials, China saw its exports of ferrosilicon decrease in 1997 by 17%, to 210,000 tons. China's silicon metal producers were adopting technology that would allow them to produce metal that would meet the more-stringent composition standards for chemical-grade material. In 1996, China's export total for silicon metal of 276,000 tons was marginally greater than that for 1995. In 1996, Japan was the recipient of the majority of China's ferrosilicon exports and

[1]Discussions of the more significant developments during 1997 for specific countries were based in a number of instances on news items in such trade journals as American Metal Market, Metal Bulletin (London), Platt's Metals Week, Ryan's Notes, and TEX Report (Tokyo). These items have not been acknowledged individually because the information they conveyed often was aggregated, possibly with that from other sources.

roughly one-half of China's silicon metal exports.

Shortly after midyear, Norway's Elkem ASA increased its ownership interest in Icelandic Alloys, a ferrosilicon producer, from 30% to 51%; Icelandic was planning to add a third furnace that would increase its annual production capacity from 70,000 tons to 110,000 tons by 1999. Elkem signed a number of long-term contracts to supply silicon metal to European and Japanese customers. In support of this, a ferrosilicon furnace at the Thamshavn plant was to be converted to production of silicon metal. Fesil ASA, another Norwegian producer of silicon materials, sold its Hafslund Metall ferrosilicon plant to a subsidiary of the U.S.'s Globe Metallurgical as part of a transaction in which Globe acquired a one-third interest in Fesil.

In Kazakstan at the Aksu ferroalloy plant, a ferrosilicon furnace whose annual output was rated at 20,000 tons was recommissioned in September following its modernization. This was shortly before Kazakstani nationals began to dispute the control that the Trans-World Group had assumed over the Aksu plant.

In Saudi Arabia, the newly started production of silicon metal at the plant of Gulf Ferro Alloys Co. (SABAYEK) was limited to only part of 1997 by operational troubles. Some of SABAYEK'S output was exported to the United States.

Western consumption of ferrosilicon in 1997 was estimated by CRU International Ltd. to be 1.82 million tons of contained silicon on the basis of 75% silicon content in ferrosilicon. This was an increase of 3.5% compared with 1.76 million tons for 1996. Major consuming areas accounting for 70% of the total were, in decreasing order, Western Europe, Japan, and the United States. Western consumption of silicon metal was estimated to be 903,000 tons, which was almost 10% higher than the previous all-time high of 822,000 tons in 1996. Major consuming areas accounting for 84% of the total were, in decreasing order, Western Europe, the United States, and Japan (CRU International Ltd., 1998).

Current Research and Technology

Laboratory studies were made and model calculations performed on the rate and manner in which ferrosilicon (50% and 75% grades) and silicon metal dissolve in steel (Lee, Klevan, and Jensen, 1998). In other laboratory experiments, use of directionally solidified samples was tested as a means of designing and developing ferrosilicon-based treatment alloys for the making of cast irons (Onsøien and others, 1997).

Investigation of the effects of phosphorus in 75% ferrosilicon indicated the presence of phosphide inclusions in the microstructure that could react with moisture in the atmosphere to produce phosphine and lead to crumbling of the alloy (Horn, Heckel, and Nassaralla, 1997). Laboratory studies of the thermodynamics of the phosphorus content of liquid alloys of silicon and iron or manganese suggested calcium treatment as a way of dephosphorizing ferrosilicon and silicomanganese (Ueda, Morita, and Sano, 1997).

Research and development work aimed at improving the physical properties of aluminum-silicon alloys by reinforcing them with particles of such materials as alumina, graphite, silicon carbide, and zircon was reviewed (Ejiofor and Reddy, 1997).

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 1997 for Iron and Steel in the Mineral Industry Surveys series of the USGS and in the Iron and Steel chapter of the 1997 Minerals Yearbook. The October 1997 forecast of the International Iron and Steel Institute (IISI) implied that domestic steel output was likely to be relatively steady throughout the remainder of the 1990's (Gavaghan, 1997). For world steel demand during the same period, the IISI forecast suggested an annual growth rate in the vicinity of 2%. Demand was expected to be the greatest in such areas as China and Latin America and relatively static in traditional industrialized countries. An analyst has projected that for the next few years, ferrosilicon consumption in the West will grow at an average annual rate of 1% (Metal Bulletin, 1997c).

Demand for silicon metal comes mainly from the aluminum and chemical industries. For the last decade or so, silicon consumption has grown at an annual rate of about 3.5% for the aluminum industry and 8% for the chemical industry to give an overall growth rate for worldwide silicon metal consumption of about 5.5% (Dosaj, 1997, p. 1110). Whether these growth rates can be sustained for another decade remains to be seen, but with silicon demand growing, a shortfall in silicon metal supply within the next few years has been projected (Platt's Metals Week, 1997b). The expectation is that at least part of the growing demand for silicon will be met by converting some furnaces from production of ferrosilicon to production of silicon metal. Such conversions would, in turn, have a positive effect on capacity use by ferrosilicon producers.

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[2]Prior to January 1996, published by the U.S. Bureau of Mines

TABLE 1
SALIENT SILICON STATISTICS 1/

(Thousand metric tons of silicon content unless otherwise specified)

	1993	1994	1995	1996	1997
United States:					
Production	367	390	396	412	430
Exports:					
Ferrosilicon	21	20	22	27	27
Silicon metal	10	12	25	17	22
Imports for consumption:					
Ferrosilicon	141	147	158	148	135
Silicon metal	71	108	92	79	121
Apparent consumption:					
Ferrosilicon	335	360	381	361	348
Silicon metal	222	256	228	233	277
Price, average, cents per pound Si: 2/					
Ferrosilicon, 50% Si	40.8	43.9	57.9	64.0	54.8
Ferrosilicon, 75% Si	40.6	40.8	58.1	62.2	48.0
Silicon metal	66.4	64.1	69.5	89.7	81.4
World: Production (gross weight): e/					
Ferrosilicon	4,000	3,800	4,100 r/	4,400	4,100
Silicon metal	560	560	590 r/	650	660

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 SILVERY PIG IRON,
FERROSILICON, AND SILICON METAL IN THE UNITED STATES IN 1997 1/

(Metric tons, gross weight, unless otherwise specified)

Material	Silicon content (percentage)		Producers' stocks, December 31, 1996	Gross production 2/	Net shipments	Producers' stocks, December 31, 1996
	Range	Typical				
Silvery pig iron	5-24	18	W	W	W	W
Ferrosilicon	25-55	48	22,700	175,000	109,000	23,200
Do.	56-95	76	16,900	147,000	146,000	21,500
Silicon metal (excluding semiconductor grades)	96-99	98	5,590	187,000	180,000	10,600
Miscellaneous silicon alloys (excluding silicomanganese)	32-65	--	13,000	106,000	91,800	12,600

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 1997

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	FeSi and Si.
Do.	Niagara Falls, NY	FeSi and Si.
Do.	Selma, AL	Si.
Do.	Springfield, OR	Si.
Keokuk Ferro-Sil Inc.	Keokuk, IA	FeSi and silvery pig iron.
Simcala Inc.	Mt. Meigs (Montgomery), AL	Si.
SKW Metals and Alloys Inc.	Calvert City, KY	FeSi.

1/ FeSi, ferrosilicon; Si, silicon metal.

TABLE 4
REPORTED CONSUMPTION, BY MAJOR END USE, AND STOCKS OF SILICON ALLOYS
AND METALS IN THE UNITED STATES IN 1997 1/ 2/

(Metric tons, gross weight, unless otherwise specified)

Silicon content (percentage)	Silvery pig iron	Ferrosilicon 3/		Silicon metal	Miscellaneous silicon alloys 4/	Silicon carbide 5/
Range	5-24	25-55	56-95	96-99	--	63-70
Typical	18	48	76	98	48	64
End use						
Steel:						
Carbon	--	15,300	23,400	--	1,280	(6/)
Stainless and heat-resisting	--	75	50,600	218	(6/)	--
Other alloy	(6/)	(6/)	39,500	--	(6/)	--
Tool	--	--	2,440	--	(6/)	--
Unspecified	22	12,100	--	--	992	384
Total	22	27,500	116,000	218	2,280	384
Cast irons	21,500	66,000	28,900	(7/)	22,400	65,600
Superalloys	--	(7/)	(7/)	135	--	--
Alloys (excluding superalloys and alloy steel)	--	(7/)	--	(7/)	--	--
Miscellaneous and unspecified	(8/)	5,060	549	237,000 9/	(8/)	(8/)
Grand total	21,500	98,500	145,000	237,000	24,700	65,900
Consumers' stocks, December 31	1,100	12,000	9,890	2,140	W	2,210

W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes U.S. Geological Survey estimates.
3/ Includes briquets.
4/ Primarily magnesium-ferrsilicon but also includes other silicon alloys.
5/ Does not include silicon carbide for abrasive or refractory uses.
6/ Included with "Steel: Unspecified."
7/ Included with "Miscellaneous and unspecified."
8/ Included with "Cast irons."
9/ Includes silicones, silanes, fumed silica, and other chemicals.

TABLE 5
U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 1997 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Ferrosilicon:			
More than 55% silicon:			
Australia	75	48	$132,000
Brazil	58	35	75,800
Canada	8,820	5,290	6,370,000
Germany	102	74	164,000
Japan	27	16	21,200
Korea, Republic of	1,710	1,030	1,450,000
Malaysia	34	25	59,200
Mexico	1,850	1,180	1,960,000
Taiwan	58	35	46,500
Venezuela	8	5	12,800
Other	14	8	18,400
Total	12,800	7,750	10,300,000
Other ferrosilicon:			
Australia	1,690	845	1,630,000
Canada	9,130	4,560	6,510,000
Hong Kong	363	181	287,000
India	880	440	1,330,000
Japan	8,840	4,420	7,120,000
Korea, Republic of	1,070	535	1,690,000
Mexico	2,780	1,390	2,480,000
Singapore	466	233	378,000
Taiwan	805	403	727,000
United Kingdom	11,200	5,610	7,570,000
Other	2,000	992	2,420,000
Total	39,200	19,600	32,100,000
Total ferrosilicon	52,000	27,400	42,400,000
Metal:			
More than 99.99 % silicon:			
China	71	71	$3,130,000
Czech Republic	48	48	2,570,000
Denmark	49	49	3,740,000
Germany	90	90	5,250,000
Japan	2,480	2,480	144,000,000
Korea, Republic of	694	694	30,300,000
Malaysia	154	154	41,700,000
Mexico	35	35	1,350,000
Netherlands	41	41	1,280,000
Taiwan	162	162	5,020,000
Other	186	186	14,500,000
Total	4,010	4,010	253,000,000
99.00% - 99.99% silicon:			
Brazil	33	33	67,200
Germany	30	30	60,000
Ghana	182	180	395,000
Ireland	12	12	34,600
Japan	105	104	142,000
Korea, Republic of	828	821	1,290,000
Malaysia	833	824	1,620,000
Mexico	167	166	363,000
Singapore	14	14	18,200
United Kingdom	17	17	23,500
Other	26	26	42,500
Total	2,250	2,230	4,050,000
Other silicon:			
Belgium	91	89	128,000
Canada	3,530	3,430	3,440,000
China	415	403	740,000
Germany	830	806	1,540,000

See footnotes at end of table.

TABLE 5--Continued
U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 1997 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Metal--Continued:			
Other silicon--Continued:			
Japan	1,380	1,340	$4,840,000
Korea, Republic of	117	114	316,000
Mexico	7,900	7,670	10,900,000
Taiwan	1,300	1,270	1,870,000
Thailand	215	209	284,000
United Kingdom	192	186	282,000
Other	611	594	1,300,000
Total	16,600	16,100	25,700,000
Total silicon metal	22,800	22,300	283,000,000

1/ Data are rounded to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 1997 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Ferrosilicon:			
55% - 80% silicon, over 3% Ca:			
Argentina	737	541	$722,000
Brazil	100	75	90,000
France	225	148	328,000
Germany	4	3	8,650
Norway	746	557	563,000
United Kingdom	91	68	479,000
Total	1,900	1,390	2,190,000
55% - 80% silicon, other:			
Argentina	5,000	3,740	3,820,000
Brazil	5,240	3,930	3,770,000
Canada	2,930	2,220	2,510,000
Egypt	5,960	4,280	4,210,000
Iceland	25,300	19,200	21,700,000
India	5,780	4,390	3,960,000
Macedonia	3,090	2,340	2,120,000
Norway	82,000	61,800	61,900,000
Poland	5,910	4,440	3,980,000
South Africa	14,600	11,100	10,300,000
Other	3,180	2,350	5,150,000
Total	159,000	120,000	123,000,000
80% - 90% silicon: Argentina	495	403	458,000
More than 90% silicon:			
Brazil	3	3	5,090
Canada	270	265	440,000
France	(2/)	(2/)	1,650
Total	273	268	447,000
Magnesium ferrosilicon:			
Argentina	300	151	330,000
Bosnia and Herzegovina	40	19	37,000
Brazil	8,670	4,030	8,330,000
Canada	290	139	351,000
China	523	251	441,000
Germany	40	22	184,000
Japan	132	59	285,000
Norway	5,180	2,680	5,750,000
Total	15,200	7,340	15,700,000
Other ferrosilicon:			
Brazil	1	1	1,970
Canada	9,870	2,930	7,450,000
China	54	28	23,200
France	118	51	297,000
India	4	(2/)	13,000
Norway	4,710	2,110	1,710,000
Poland	1,680	802	823,000
South Africa	80	12	76,800
United Kingdom	(2/)	(2/)	5,060
Total	16,500	5,930	10,400,000
Total ferrosilicon	193,000	135,000	153,000,000
Metal:			
More than 99.99% silicon:			
Australia	80	80	$144,000
Canada	86	86	214,000
China	63	63	2,620,000
Germany	541	541	50,300,000
Italy	376	376	20,500,000
Japan	346	346	15,300,000
Korea, Republic of	149	149	4,510,000
Taiwan	53	53	684,000

See footnotes at end of table.

TABLE 6--Continued
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 1997 1/

(Metric tons)

Country	Gross weight	Contained weight	Value
Metal--Continued:			
More than 99.99% silicon--Continued:			
Ukraine	15	15	$1,650,000
United Kingdom	20	20	1,290,000
Other	21	21	2,090,000
Total	1,750	1,750	99,300,000
99.00% - 99.99% silicon:			
Australia	4,290	4,190	7,240,000
Brazil	6,320	6,270	10,400,000
Canada	17,200	17,100	27,800,000
China	242	240	277,000
France	5,760	5,490	9,340,000
India	4,430	4,400	6,530,000
Norway	6,720	6,560	13,300,000
Russia	383	381	612,000
South Africa	11,200	10,700	19,000,000
Spain	800	792	1,260,000
Other	311	308	829,000
Total	57,600	56,500	96,500,000
Other silicon:			
Brazil	3,480	3,400	5,120,000
Canada	4,520	4,690	7,190,000
China	2,670	2,340	2,890,000
India	3,300	3,260	4,860,000
Macedonia	3,600	3,470	4,720,000
Norway	1,470	1,270	2,340,000
Russia	31,100	30,400	41,700,000
Saudi Arabia	2,050	2,010	2,620,000
South Africa	3,360	3,200	4,310,000
Ukraine	3,010	2,930	4,250,000
Other	3,880	5,610	5,830,000
Total	62,400	62,500	85,800,000
Total silicon metal	122,000	121,000	282,000,000

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.