VANADIUM

By Henry E. Hilliard

In 1996, vanadium (V) consumption was 4,650 metric tons of contained vanadium. The U.S. supply consisted of vanadium-bearing ferrophosphorus slag, iron slag, fly ash, petroleum residues, and spent catalysts. The United States imported 1,880 tons of ferrovanadium (V-content), 485 tons of vanadium pentoxide anhydride (V-content),and 2,610 tons (V-content) of other vanadium products valued at about \$50 million. The United States exported about 3,700 tons of vanadium products valued at about \$30 million. Total imports of vanadium materials in 1996 decreased about 5% from imports in 1995. Almost all of the decrease was due to lower vanadium-bearing slag imports from South Africa. The volume of exports of vanadium materials increased by about 41%.

Many uses of vanadium have been developed, including vanadium catalysts, pigments, electronics applications, and titanium-aluminum-vanadium aerospace alloys. About 90% of vanadium demand was for steel products, with titanium-aluminum-vanadium alloys and vanadium chemicals accounting for most of the remainder. Most vanadium is used in the form of ferrovanadium. Ferrovanadium is used as a means of introducing vanadium into steels, where it gives additional strength and toughness. In steels, the use can be subdivided into micro-alloyed or low-alloy steels, which generally contain less than 0.15% vanadium, and high-alloy steels. Ferrovanadium is available in alloys containing 45% to 50% and 80% vanadium. The 80% grade is mostly produced by the aluminothermic reduction of vanadium pentoxide in the presence of steel scrap or by direct reduction in an electric arc furnace. The 45% to 50% grade is produced from slag and other vanadium-containing materials by the silicothermic reduction of vanadium pentoxide. Vanadium addition to titanium alloys is made with aluminum-vanadium master alloys, which are also produced by the aluminothermic reduction of vanadium pentoxide followed by vacuum refining.

Legislation and Government Programs

The Strategic and Critical Materials Stock Piling Act mandates that a stock of strategic and critical materials be maintained to decrease and eliminate, where possible, dependence upon foreign sources of supplies in times of national emergency. The urgency surrounding the security of supply of strategic and critical materials faded away after the collapse of the Soviet Union and the end of the Cold War. The result has been that the U.S. Government stopped acquiring certain materials for the National Defense Stockpile (NDS) and began disposing of what it considered to be excess stockpile inventories. The Defense Logistics Agency (DLA), which has operational control of the NDS, identified vanadium as one of the materials for disposal. DLA cash disposals totaled \$427 million in fiscal year 1995 and \$391 million in fiscal year 1996. Vanadium pentoxide sales represented only about \$3 million of the total. Soon after the Defense Authorization Bill for fiscal year 1996 was signed into law, DLA introduced its Annual Materials Plan (AMP) for fiscal year 1997. The AMP spelled out the maximum allowable quantities of materials that could be sold during the year. Included were 200 short tons of vanadium pentoxide. No other laws directly affecting the stockpile were enacted during the reporting period.

Duty-free status under the Generalized System of Preferences was restored to vanadium pentoxide from South Africa, retroactive to October 1, 1996. A Presidential proclamation on October 17, 1996, included an annex that freed importers of South African V_2O_5 from paying a 13.0% duty on the material. The duty-free status was in effect through May 31, 1997. The change did not have an immediate impact on domestic ferrovanadium producers because most do not rely on South African vanadium pentoxide. However, there are some specialty-alloy producers who depend on imported material that may be affected by restoration of duty free status of vanadium pentoxide from South Africa.

Prices

For most of 1996, the European prices for vanadium pentoxide and ferrovanadium remained fairly stable in the ranges \$2.98 to \$3.10 per pound and \$15.00 to \$15.25 per kilogram of vanadium content respectively. Domestic vanadium pentoxide prices began 1996 in the range \$2.85 to \$3.00 per pound and continued at that level through the first quarter. Prices began to increase somewhat in the second quarter, rising to the \$3.05 to \$3.15 range by mid-April. Prices remained flat for most of the remainder of the year. Prices started to rise again in November, closing out the year in the \$3.28 to \$3.35 range. Unlike the price of pentoxide, the price of FeV was flat through the entire year. FeV prices began the year in the \$7.35 to \$7.45 pound range, fell to \$7.20 to \$7.40 in July and closed out 1996 at the \$7.40 to \$7.60 range.

Production

The major marketplace vanadium materials are vanadium pentoxide, ferrovanadium, aluminum-vanadium alloys, vanadium chemicals, and vanadium-bearing iron slags. The United States produced all of these with the exception of vanadium-bearing iron slags.

Domestic production data for vanadium were developed by the U.S. Geological Survey (USGS) from a voluntary survey of all U.S. operations. All U.S. vanadium pentoxide producers responded to the survey. In addition to the vanadium pentoxide mills, the USGS canvassed three other companies which produce ferrovanadium, vanadium metal, vanadium chemicals, and other specialty vanadium alloys, e.g. aluminum-vanadium master alloys. These three companies also responded to the voluntary survey.

Consumption

Metallurgical applications continued to dominate vanadium use in 1997, accounting for more than 97% of total consumption. Nonmetallurgical applications included catalysts, ceramics, vanadium chemicals, and electronics. The dominant nonmetallurgical use was in catalysts. Much less was consumed for ceramic and electronics (batteries).

Consumption data for vanadium are developed by the USGS from a voluntary survey of all known domestic consumers. There were 61 respondents to the 1996 survey. The 61 respondents represented about 77% of the total canvassed and were estimated to have accounted for about 93% of total consumption, or about 4,325 metric tons. The consumption of nonrespondents, derived by using their past consumption relationships, trends, and data from nonsurvey sources, was estimated to be about 326 tons. The USGS estimate of total reported U.S. consumption of vanadium in 1996 was 4,650 tons as shown in table 1.

World Review

In South Africa, Highveld Steel & Vanadium Corporation's resumption of vanadium pentoxide and ferrovanadium production at its subsidiary, Transvaal Alloys, served notice to the rest of the vanadium industry of its intention to move aggressively into the production of down-stream value-added vanadium products. This development is in line with the trend at other South African producers toward the production of ferrovanadium. Highveld purchased Transvaal in 1994 with the intention of entering the vanadium chemical market. Transvaal's chemical operations were moved to Vanchem, Highveld's chemical division. Transvaal's vanadium mining operations were closed because Highveld did not need the pentoxide and ferrovanadium capacity. The reopening of the Transvaal plant expanded Highveld's FeV capacity from 1,000 to 4,000 tons per year. At about the same time that Highveld restarted FeV production at the Transvaal plant, it reduced sharply its exports of vanadium-bearing slag and began converting most of this material to ferrovanadium, most of which was exported. U.S. imports of ferrovanadium from South Africa increased from none in 1983 to 231 tons in 1996. U.S. imports of South African vanadium pentoxide during this same period increased from 121 to 769 tons. These developments occurred as the availability of V_2O_5 from China for sale on the spot market decreased sharply. China's short supply of raw materials was caused by a shortage of vanadium-bearing slag deliveries from New Zealand to China. Also, Highveld had not shipped slag to China since the first quarter of 1995. The net result has been higher vanadium pentoxide prices. Also, European converters who depended exclusively on South African vanadium-bearing slag have had to scramble to find another source of raw materials.

Current Research and Technology

Vanadium Pentoxide Recovery From Orimulsion Planned.—A German plant that recovers vanadium pentoxide from fly ash was set to open in 1997. The plant at Hennstedt, near the Danish border, will recover 2,000 tons of vanadium pentoxide, 250 tons of nickel, and 14,000 tons of magnesium sulfate per year. The metals will be recovered from ash produced at a powerplant in Denmark that imports 1 to 1.5 million tons per year of Venezuelan Orimulsion. The recovery plant will be owned by a joint venture in which Bitor Energy, which markets Orimulsion, has a 45% stake; Reakt of the United Kingdom will have 10%; and Strategic Minerals Corp. (Stratcor), a U.S. vanadium producer, 45%. There are plans for Britain to import 4 to 5 million tons per year of Orimulsion to be burned at a powerplant in Pembroke, south Wales, contingent on Government approval. Following Government approval, another metals recovery plant might eventually be built at Pembroke. Orimulsion consists of heavy crude oil mixed with 30% water. Venezuela plans to increase production of Orimulsion from 4.8 million tons in 1996 to 20 million tons by 2000 (Financial Times, 1996).

Vanadium Battery Under Development in Japan.—Companies affiliated with Mitsubishi of Japan are undertaking a project to incorporate vanadium secondary batteries into power generation plants by 2000. Kajima-Kita Kyodo Hatsudan, a power generation company, is in charge of the development of the battery. The vanadium secondary battery contains a vanadium pentoxide-sulfuric acid electrolyte and carbon electrodes. At the current state of development, the battery has a capacity of 10 kilowatts (kW). Beginning in October 1996, the Mitsubishi Companies will produce large batteries with a capacity of 200 kW per charge and will market the batteries as power sources in power generation plants, "intelligent" buildings, and related areas.

Small vanadium secondary batteries, with a capacity of 50 kW, are also under development as part of the Japanese Ministry of International Trade and Industry's 'New Sunshine Program.' Kajima-Kita is developing these small models for use as backup power sources for solar batteries. The possibility of using vanadium batteries in electric vehicles is also under investigation.

Kajima-Kita currently extracts vanadium pentoxide from petroleum residues. The company recovered 150 tons in 1994 and 200 tons in 1995 (Roskill's Letter From Japan, 1996).

Vanadium Oxides Toxicities Investigated.—The "in-vivo"-toxicity of vanadium pentoxide and vanadium trioxide (administered orally, dermally and by inhalation) has been reinvestigated with particular emphasis on the safety and handleability of vanadium oxides in the vanadium processing industry. Chemical thermodynamic properties of vanadium oxides make it likely that some earlier results of vanadium toxicities have introduced artifacts as a consequence of the administration techniques used. In this investigation, special precautions were taken to avoid any chemical changes or any artificial interactions during sample preparation to ensure that the results significantly reflect the toxicities of vanadium compounds as exposure to them might occur. In the industrial situation the most pertinent results are those from toxicity tests involving oral or inhalative administration. The results of this investigation indicate that, as far as these two parameters are concerned, vanadium pentoxide should be classified as "harmful" according to EEC Directive 83/467/EEC. Vanadium trioxide has a significantly lower toxicity and should be classified as "relatively non-toxic" if swallowed (Monatshefte für Chemie, 1994).

Vanadium Foil Selected For Use in Superconducting Cables.—A process has been proposed for the manufacture of cables that contain the ceramic high-temperature superconductor $YBa_2Cu_3O_{7-\alpha}$. The cables would carry electrical current with little or no loss of power when cooled to about -200°C. The process would begin with the mixing of oxides of yttrium, barium, and copper with water to form a slurry, followed by drying of the slurry, followed by calcining in a rotating kiln to obtain a stoichiometric precursor oxide. In the next few steps, a thin vanadium metal foil would be unspooled and formed into a V-channel, onto which the precursor powder would be metered. The foil is permeable to oxygen at high temperatures (850 to 950°C) to which the cable would be subsequently exposed, but is impervious to oxygen and other environmental contaminants at the lower temperatures at which the cable would be used. Vanadium was selected as the foil material because it exhibits the desired permeability-versus-temperature characteristics, plus a favorable thermal-expansion characteristic (NASA Tech Briefs, 1996).

Vanadium Alloys Under Consideration for Use in Fusion Applications.—Vanadium alloys hold the promise to fully exploit the environmental attractiveness of advanced fusion energy systems. Although a fusion powerplant does not generate fission products, its structural components can become radioactive as a result of nuclear transmutations within the component materials from exposure to neutrons. To fully exploit its environmental attractiveness, fusion energy systems will require low-activation structural materials, which have low levels of induced radioactivity. The U.S. Fusion Materials Program of the Department of Energy's Office of Fusion Energy Science is pursuing the development of low-activation materials, including vanadium alloys, ferritic-martensitic steels, and SiC/SiC composites. Vanadium alloys are under consideration because they have the potential for minimum environmental impact and provide properties superior to those of steels and other candidate materials. For example, vanadium alloys can accommodate high heat loads and can operate at temperatures up to 700 to 750° C (1,300 to 1,380°F). They can provide favorable safety and environmental features, such as low long-term activation, low decay heat and reduced contact dose, low helium and hydrogen generation rates from fusion neutrons, and a potential for recycling. They can be rolled into thin sheets, extruded into tubing, and welded by several methods. Recent investigations have included compositions (in weight-percent) of V, 0-15Cr, 1-20Ti, 0-1Si. Current emphasis is on a reference composition of V, 4Cr, 4Ti, 0.05Si, which appears to have the best combination of properties (Johnson and others, 1997).

Outlook

The vanadium market in the near term will continue to follow the cyclical nature of the steel industry. It is believed that the consumption of vanadium in steel will continue to increase, owing in part to the need for stronger and lighter steels. The demand for vanadium is also expected to increase as new applications are found (see current research and technology section). Promising work on the use of vanadium in new high-strength pipeline steels, thin slab castings, and stainless steels is being pursued. Also, a much talked about vanadium battery may become viable (Roskill's Letter From Japan, 1996). The International Iron and Steel Institute, at its annual conference in October, predicted a growth in apparent world steel consumption in 1997 of 3.4% above consumption in 1996 (Metal Bulletin, 1996). Despite a predicted 1% decline in steel consumption in the United States, an overall world growth is expected which will result in greater demand for vanadium.

The reserve base of vanadium is more than 27 million tons, a sufficiently large supply that will satisfy the market well into the 22d century. This does not take into account increased production of vanadium from spent catalyst, fly ash, and other petroleum residues.

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

TABLE 1
SALIENT VANADIUM STATISTICS 1/

(Metric tons of contained vanadium unless otherwise specified)

		1992	1993	1994	1995	1996
United States:						
Production:						
Ore and concentrate:						
Recoverable vanadium 2/		W	W	W	W	W
Value	thousands	W	W	W	W	W
Vanadium oxide recovered from ore 3/		W	W	W	W	W
Vanadium recovered from petroleum residues 4/		1,350	2,870	2,830	1,990	3,730
Consumption		4,080	3,970	4,280	4,650 r/	4,650
Exports:						
Ferrovanadium		213	219	374	340	479
Vanadium pentoxide (anhydride)		26	126	335	229	241
Other oxides and hydroxides of vanadium		1,110	895	1,050	1,010	2,670
Imports for consumption:						
Ferrovanadium		592	1,630	1,910	1,950	1,880
Vanadium pentoxide (anhydride)		206	70	294	547	485
Other oxides and hydroxides of vanadium		103	19	3	36	11
Ore, slag, ash, and residues		838	1,450	1,900	2,530 r/	2,270
World: Production from ore, concentrate, slag 5/		33,200 r/	34,600	34,700	37,700 r/	39,100 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

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

2/ Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mill, plus vanadium recovered from ferrophosphorus slag derived from domestic phosphate rock.

3/ Produced directly from all domestic ores and ferrophosphorus slag; includes metavanadates.

4/ Includes vanadium recovered from fly ash, petroleum residues, and spent catalysts.

5/ Excludes U.S. production.

TABLE 2
U.S. VANADIUM PENTOXIDE PRODUCERS

Producer	Plant location	Capacity (metric tons pentoxide per year)
AMAX Metals Recovery Inc.	Braithwaite, LA	1,800
Energy Fuels Nuclear Inc.	Blanding, UT	6,800
Gulf Chemical & Metallurgical Corp.	Freeport, TX	1,400
Kerr-McGee Chemical Corp.	Soda Springs, ID	2,000
U.S. Vanadium Corp.	Hot Springs, AR	6,800

TABLE 3
U.S. CONSUMPTION AND CONSUMER STOCKS OF VANADIUM MATERIALS 1/

(Kilograms of contained vanadium)

	1995		1996	
Form	Consumption	Ending stocks	Consumption	Ending stocks
Ferrovanadium 2/	4,320,000 r/	347,000 r/	4,240,000	279,000
Oxide	16,200	7,910	14,600	6,880
Ammonium metavanadate	W	W	W	W
Other 3/	315,000	14,000	394,000	14,700
Total	4,650,000 r/	369,000 r/	4,650,000	301,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

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

2/ Includes other vanadium-iron-carbon alloys as well as vanadium oxides added directly to steel.

3/ Consists principally of vanadium-aluminum alloy and small quantities of other vanadium alloys and vanadium metal.

TABLE 4
U.S. CONSUMPTION OF VANADIUM IN 1996, BY END USE 1/

(Kilograms of contained vanadium)

End use	Quantity
Steel:	
Carbon	1,820,000
Stainless and heat resisting	21,700
Full alloy	1,030,000
High-strength low-alloy	890,000
Tool	433,000
Unspecified	W
Total	4,200,000
Cast irons	W
Superalloys	16,000
Alloys (excluding steels and superalloys):	
Cutting and wear-resistant materials	259
Welding and alloy hard-facing rods and materials	3,240
Magnetic alloys	W
Other alloys	386,000
Chemical and ceramic uses:	
Catalysts	W
Pigments	W
Miscellaneous and unspecified	49,700
Grand total	4,650,000

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

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

TABLE 5
U.S. EXPORTS OF ALUMINUM-VANADIUM MASTER ALLOY, FERROVANADIUM, OXIDES AND HYDROXIDES OF VANADIUM, AND VANADIUM METAL 1/

(Kilograms, vanadium content unless otherwise specified)

	1995		1996	
Material and country	Quantity	Value	Quantity	Value
Aluminum-vanadium master alloy: 2/ (gross weight)				
Argentina	--	--	1,080	$14,000
Australia	336	$4,360	499	6,380
Austria	71,600	316,000	16,100	178,000
Barbados	--	--	18,900	237,000
Brazil	216	2,810	--	--
Canada	120,000	1,620,000	94,300	1,160,000
Chile	--	--	770	10,000
China	26,300	355,000	--	--
Ecuador	465	12,500	--	--
France	11,200	146,000	2,980	38,800
Germany	11,400	151,000	7,390	110,000
Honduras	5,450	68,800	--	--
India	1,440	18,700	--	--
Ireland	671	10,300	782	14,600
Japan	3,670	65,200	20,400	322,000
Korea, Republic of	6,420	84,200	3,270	42,500
Malaysia	--	--	897	11,700
Mexico	367,000	4,840,000	32,900	434,000
Netherlands	8,550	111,000	--	--
Philippines	535	7,000	409	5,310
Russia	--	--	15,200	274,000
Singapore	7,380	93,700	--	--
Suriname	--	--	139	6,460
Switzerland	--	--	571	7,420
Taiwan	--	--	20,700	291,000
United Kingdom	16,800	281,000	68,700	1,200,000
Venezuela	--	--	3,810	49,600
Total	660,000	8,190,000	310,000	4,410,000

See footnotes at end of table.

TABLE 5--Continued
U.S. EXPORTS OF ALUMINUM-VANADIUM MASTER ALLOY, FERROVANADIUM, OXIDES AND HYDROXIDES OF VANADIUM, AND VANADIUM METAL 1/

(Kilograms, vanadium content unless otherwise specified)

	1995		1996	
Material and country	Quantity	Value	Quantity	Value
Ferrovanadium:				
Australia	--	--	546	$6,830
Canada	225,000	$3,960,000	320,000	5,720,000
Guatemala	--	--	114	3,760
Japan	5,910	137,000	--	--
Mexico	109,000	2,460,000	156,000	3,020,000
Venezuela	--	--	2,300	76,800
Total	340,000	6,550,000	479,000	8,830,000
Vanadium pentoxide (anhydride): 3/				
Australia	839	10,500	--	--
Austria	--	--	19,100	99,400
Belgium	--	--	7,850	103,000
Chile	1,270	12,100	18	2,680
France	1,300	12,300	12,100	132,000
Germany	25,000	290,000	--	--
Italy	26,800	235,000	107,000	913,000
Japan	14,200	121,000	13,800	126,000
Kuwait	--	--	4,970	34,300
Mexico	29,500	314,000	6,370	62,500
Netherlands	95,200	594,000	16,300	116,000
Pakistan	5,170	76,100	6,040	83,600
Peru	--	--	2,260	10,400
Saudi Arabia	4,820	21,600	--	--
Singapore	--	--	962	14,600
Taiwan	21,000	105,000	632	6,000
United Kingdom	3,690	35,000	43,500	356,000
Venezuela	405	4,980	--	--
Total	229,000	1,830,000	241,000	2,060,000
Other oxides and hydroxides of vanadium:				
Argentina	--	--	1,360	7,600
Australia	1,860	16,500	675	6,000
Belgium	15,900	105,000	--	--
Brazil	1,810	3,670	--	--
Canada	810,000	5,430,000	327,000	2,360,000
France	45,000	343,000	15,200	128,000
Germany	61,500	708,000	6,290	67,300
Italy	--	--	17,200	137,000
Japan	37,100	271,000	100	3,610
Mexico	--	--	2,500	25,600
Netherlands	3,630	43,600	--	--
Russia	--	--	12,300	110,000
South Africa	20,000	168,000	61,100	474,000
Spain	--	--	2,210,000	9,030,000
Switzerland	--	--	13,800	74,100
Taiwan	42	5,820	--	--
Venezuela	11,300	101,000	--	--
Total	1,010,000	7,200,000	2,670,000	12,400,000

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

2/ Includes vanadium metal.

3/ May include catalysts containing vanadium pentoxide.

Source: Bureau of the Census.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM-VANADIUM MASTER ALLOY, FERROVANADIUM, OXIDES AND HYDROXIDES OF VANADIUM, AND VANADIUM METAL 1/

(Kilograms, vanadium content unless otherwise specified)

Material and country	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Aluminum-vanadium master alloy: (gross weight)				
Germany	36,300	$342,000	1,610	$16,500
Ferrovanadium:				
Austria	113,000	2,030,000	45,100	718,000
Belgium	345,000	6,270,000	62,700	947,000
Canada	724,000	10,200,000	685,000	10,700,000
China	226,000	4,300,000	251,000	3,520,000
Czech Republic	288,000	3,390,000	487,000	6,820,000
Germany	31,000	604,000	2,690	32,300
Korea, Republic of	18,200	363,000	--	--
Russia	160,000	1,950,000	70,400	1,440,000
South Africa	49,700	898,000	231,000	3,490,000
Tajikistan	--	--	40,500	626,000
Total	1,950,000	30,000,000	1,880,000	28,300,000
Vanadium pentoxide (anhydride): 2/				
China	92,500	945,000	27,400	329,000
France	5,830	384,000	9,470	223,000
Germany	4,790	23,400	494	21,700
Hong Kong	--	--	1,330	37,500
South Africa	444,000	5,690,000	446,000	5,540,000
Total	547,000	7,040,000	485,000	6,150,000
Other oxides and hydroxides of vanadium:				
Canada	153	2,600	--	--
France	26,100	442,000	304	48,600
Germany	4,660	86,500	5	4,490
South Africa	4,710	77,200	--	--
United Kingdom	--	--	10,500	152,000
Total	35,600	608,000	10,800	205,000
Vanadium metal, including waste and scrap: (gross weight)				
Dominican Republic	50,700	33,500	--	--
Estonia	2,910	29,000	--	--
France	--	--	138	8,500
Germany	20,300	839,000	56,300	588,000
Korea, Republic of	438	4,360	35,300	16,700
Russia	21,100	296,000	4,410	182,000
South Africa	700,000	13,000,000	--	--
United Kingdom	200	3,140	5	15,900
Total	796,000	14,200,000	96,100	811,000

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

2/ May include catalysts containing vanadium pentoxide.

Source: Bureau of the Census.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF VANADIUM-BEARING ASH, RESIDUES AND SLAG 1/

(Kilograms, vanadium pentoxide content)

Material and country	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Ash and residues:				
Argentina	5,290	$2,910	--	--
Canada	610,000 r/	573,000 r/	1,650,000	$1,010,000
Dominican Republic	--	--	23,100	16,600
France	849	6,840	--	--
Germany	328,000	107,000	5,150	3,960
Italy	122,000	69,300	--	--
Korea, Republic of	7,890	1,580	--	--
Kuwait	--	--	3,640	22,700
Mexico	997,000	4,690,000	781,000	2,560,000
Netherlands	3,530	18,800	13,000	7,050
Netherlands Antilles	381,000	136,000	87,900	168,000
Portugal	--	--	7,130	6,470
Spain	13,000	8,890	--	--
United Kingdom	237,000	311,000	14,800	3,260
Venezuela	35,800 r/	17,600 r/	--	--
Total	2,750,000 r/	5,940,000 r/	2,590,000	3,810,000
Slag, from the manufacture of iron and steel: 2/				
South Africa	1,770,000 r/	5,850,000	1,470,000	5,670,000

r/ Revised.

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

2/ As adjusted by the U.S. Geological Survey.

Source: Bureau of the Census.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS VANADIUM CHEMICALS 1/ 2/

(Kilograms, vanadium content)

Material and country	1995 Quantity	1995 Value	1996 Quantity	1996 Value
Sulfates	--	--	25	$14,900
Vanadates:				
Germany	576	$28,200	3,360	76,500
Japan	131	7,890	--	--
South Africa	43,100	246,000	73,900	553,000
Switzerland	--	--	8	5,240
United Kingdom	300	94,800	--	--
Total	44,100	376,000	77,200	634,000
Hydrides and nitrides:				
Canada	2,910	65,000	--	--
Japan	1	2,500	--	--
South Africa	--	--	255,000	4,630,000
Total	2,910	67,500	255,000	4,630,000

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

2/ Comprises vanadium ore and miscellaneous vanadium chemicals.

Source: Bureau of the Census.

TABLE 9
WORLD VANADIUM PENTOXIDE ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 1996 1/ 2/

(Metric tons of contained vanadium)

Country	Rated capacity 3/
Austria	1,500
Canada	770
Chile	2,300
China	8,200
Russia	9,500
South Africa	27,200
United States	11,000
Venezuela	2,500
Other	550
Total	63,500

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

2/ Includes vanadium pentoxide in vanadiferous iron slags and petroleum refinery residues.

3/ Includes capacity of operating plants as well as plants on standby status.

TABLE 10
VANADIUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of contained vanadium)

Country	1992	1993	1994	1995	1996 e/
Production from ores, concentrates, slag: 3/					
China (in vanadiferous slag product) e/	4,700	5,000	5,400 r/	7,000 r/	7,000
Hungary e/	200	200	200	200	200
Kazakstan e/	1,400	1,200	878 4/	924 4/	900
Russia e/	11,000	10,000	10,000	11,000	11,000
South Africa	14,285 r/	15,051	15,229 r/	16,297 r/	16,000
United States (recoverable vanadium)	W	W	W	W	W
Total	31,600 r/	31,500	31,700	35,400 r/	35,100
Production from petroleum residues, ash, and spent catalysts: 5/					
Japan e/	245	252	252	245	245
United States	1,350	2,870	2,740	1,990	3,730 4/
Total	1,590	3,120	2,990	2,240	3,980
Grand total	33,200 r/	34,600	34,700	37,700 r/	39,100

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ In addition to the countries listed, vanadium is also recovered from petroleum residues in Germany and several other European countries, but available information is insufficient to make reliable estimates. Table includes data through June 13, 1997.

3/ Production in this section is credited to the country that was the origin of the vanadiferous raw material.

4/ Reported figure.

5/ Production in this section is credited to the country where the vanadiferous product is extracted; available information is inadequate to permit crediting this output back to the country of origin of the vanadiferous raw material.