

VANADIUM

By Robert G. Reese Jr.

In 1997, U.S. vanadium production was limited to material recovered from various industrial waste streams. Eight firms in Arkansas, Idaho, Louisiana, Texas, and Utah processed material, such as vanadium-bearing ferrophosphorus slag, iron slag, fly ash, petroleum residues, and spent catalysts, to produce vanadium pentoxide, ferrovanadium, and vanadium metal. Recycling of vanadium is negligible; only small quantities of vanadium-based catalysts and vanadium-aluminum alloy are recycled.

Domestic vanadium consumption increased slightly in 1997. Metallurgical applications in which vanadium is used as a minor alloying element with iron, steel, and titanium remained the dominant use for vanadium, accounting for nearly all domestic consumption. The largest nonmetallurgical use for vanadium was in catalysts.

Including the United States, seven countries recovered vanadium from ores, concentrates, slag, or petroleum residues. South Africa, Russia, and China were the largest vanadium-producing nations. In five of the six foreign countries, vanadium production was primarily a byproduct of iron mining and processing.

The reserve base of vanadium is more than 27 million metric tons, a sufficiently large supply that by itself can satisfy the market for several hundred years at the present rate of consumption. Additionally, the probable increased recovery of vanadium from spent catalyst, fly ash, and other petroleum residues will extend the viability of the reserve base significantly.

Legislation and Government Programs

In 1994, the U.S. Department of Defense determined that vanadium pentoxide was no longer needed as a critical and strategic metal in the National Defense Stockpile (NDS) and authorized disposal of its entire holdings. On September 30, 1997, the Defense Logistics Agency, which had operational control of the NDS, completed the disposal of all the vanadium pentoxide.

Production

In October, International Uranium Corp. began initial ore production at its Sunday Mine in Colorado. Ore containing uranium and vanadium was shipped to the company's White Mesa mill in Utah for stockpiling. The White Mesa mill has a capacity of approximately 2,000 tons of ore per day and can produce uranium and vanadium. Production at the mine is expected to reach nearly 6,000 tons per month by mid-1998 (International Uranium Corp., 1997).

In April, Metallurg Inc. and its operating subsidiary, Shieldalloy Metallurgical Corp., reorganized and emerged from bankruptcy (Metallurg Inc., 1997). The two companies had sought protection from creditors in September 1993 under Chapter 11 of the U.S. Bankruptcy Code. Reportedly, the need to file under Chapter 11 was necessitated by a number of factors, including an economic recession that began in 1989, an increase in the supply of competing products

from the former Soviet Union, and a decrease in defense-related spending by the U.S. Government.

International Uranium Corp. completed acquisition of nearly all the uranium-producing assets and business of the Energy Fuels group of companies, including Energy Fuels, Ltd., Energy Fuels Exploration Co., and Energy Fuels Nuclear, Inc., in May. The Energy Fuels group had been in Chapter 11 bankruptcy proceedings.

Consumption

In 1997, domestic vanadium consumption was 4,730 metric tons. Although vanadium has many uses, metallurgical applications account for nearly all domestic consumption. 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. Ferrovanadium is available in alloys containing 45% to 50% and 80% vanadium. The 45% to 50% grade is produced from slag and other vanadium-containing materials by the silicothermic reduction of vanadium pentoxide. The 80% grade is produced mostly by the aluminothermic reduction of vanadium pentoxide in the presence of steel scrap or by direct reduction in an electric arc furnace. Vanadium steels can be subdivided into microalloyed or low-alloy steels, which generally contain less than 0.15% vanadium, and high-alloy steels, which contain as much as 5% vanadium.

Nonmetallurgical applications include catalysts, ceramics, vanadium chemicals, and electronics. The dominant nonmetallurgical use is in catalysts.

Consumption data for vanadium were collected by the U.S. Geological Survey (USGS) from a voluntary survey of all known domestic consumers. There were 46 respondents to the 1997 survey. These respondents represented about 61% of the total canvassed and were estimated to have accounted for about 60% of total consumption. Data for nonrespondents were derived by using past reported data and/or trends and data from nonsurvey sources.

Prices

In 1997, the domestic price for ferrovanadium, as published in Metal Bulletin, ranged between \$7.40 and \$11.00 per pound. The low price occurred in January and from there rose through the first third of the year before declining slightly. In September, the price resumed its upward trend, reaching its high in December. Similarly, the European ferrovanadium price recorded the low for the year in January and the high in December. The European price ranged between \$15.75 and \$27.80 per kilogram.

Metal Bulletin's published price for domestic vanadium pentoxide ranged between \$3.28 and \$5.80 per pound in 1997. The price ranged from \$3.28 to \$3.35 per pound in early 1997, began rising near mid-January, and continued to increase through the end of March. In early April, the price gradually drifted lower to the

range of \$3.75 to \$3.80 per pound by mid-July. From this point, it rose through yearend, finishing the year in the range of \$5.50 to \$5.80 per pound.

World Review

The world supply of vanadium is almost all primary, essentially because vanadium is used as a minor alloying element in iron, steel, and titanium and is not extracted from those metals when they are recycled. Recycling of vanadium is negligible, with only small quantities of vanadium-based catalysts and vanadium-aluminum alloy processed. Including the United States, seven countries recovered vanadium from ores, concentrates, slag or petroleum residues. South Africa, Russia, and China were the largest vanadium-producing nations. Except in Japan and the United States, vanadium production was primarily a byproduct of iron mining and processing.

Outlook

In the near term, the vanadium market will continue to follow the cyclical nature of the steel industry. It is believed that the consumption of vanadium will continue to increase, owing in part to the need for stronger and lighter steels and in part from the demand created by new applications, such as the vanadium battery. As in the United States, worldwide demand for vanadium is expected to be closely and directly related to the demand for steel.

References Cited

International Uranium Corp., 1998, 1997 annual report: Denver, CO, International Uranium Corp., 36 p.
Metallurg Inc., 1998, 1997 10K report: New York, NY, Metallurg Inc., 89 p.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

International Strategic Minerals Inventory Summary
Report—Vanadium: U.S. Geological Survey Circular 930-K, 1992.
Vanadium. Ch. in United States Mineral Resources, U.S. Geological Survey Professional Paper 820, 1973.
Vanadium. Ch. in Mineral Commodity Summaries, 1998.¹
Vanadium. Mineral Industry Surveys, monthly.¹

Other

Chemical and Engineering News.
Engineering and Mining Journal.
Metal Bulletin Monthly [London].
Metalworking News.
Roskill Reports [London].

¹Prior 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)

	1993	1994	1995	1996	1997
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/	2,870	2,830	1,990	3,730	NA
Consumption	3,970	4,280	4,650	4,630	4,730
Exports:					
Ferrovandium	219	374	340	479	446
Vanadium pentoxide (anhydride)	126	335	229	241	614
Other oxides and hydroxides of vanadium	895	1,050	1,010	2,670	385
Imports for consumption:					
Ferrovandium	1,630	1,910	1,950	1,880	1,840
Vanadium pentoxide (anhydride)	70	294	547	485	711
Other oxides and hydroxides of vanadium	19	3	36	11	126
Ore, slag, ash, and residues	1,450	1,900	2,530	2,270	2,950
World: Production from ore, concentrate, slag 5/	37,000 r/	37,700 r/	44,400 r/	45,800 r/	NA

r/ Revised. NA Not available. 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)

Form	1996		1997	
	Consumption	Ending stocks	Consumption	Ending stocks
Ferrovandium 2/	4,220,000 r/	264,000 r/	4,320,000	290,000
Oxide	13,900 r/	6,610 r/	14,200	5,290
Ammonium metavanadate	W	W	W	W
Other 3/	393,000 r/	3,560 r/	402,000	2,630
Total	4,630,000 r/	274,000 r/	4,730,000	298,000

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, small quantities of other vanadium alloys, vanadium metal, and data represented by the symbol "W."

TABLE 4
U.S. CONSUMPTION OF VANADIUM IN 1997, BY END USE 1/

(Kilograms of contained vanadium)

End use	Quantity
Steel:	
Carbon	1,800,000
Stainless and heat resisting	20,100
Full alloy	908,000
High-strength low-alloy	944,000
Tool	481,000
Unspecified	W
Total	4,150,000
Cast irons	W
Superalloys	23,500
Alloys (excluding steels and superalloys):	
Cutting and wear-resistant materials	W
Welding and alloy hard-facing rods and materials	4,060
Other alloys 2/	506,000
Chemical and ceramic uses:	
Catalysts	W
Pigments	W
Miscellaneous and unspecified	46,000
Grand total	4,730,000

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.

2/ Includes magnetic alloys.

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)

Material and country	1996		1997	
	Quantity	Value	Quantity	Value
Aluminum-vanadium master alloy: 2/ (gross weight)				
Argentina	1,080	\$14,000	--	--
Australia	499	6,380	--	--
Austria	16,100	178,000	14,700	\$173,000
Barbados	18,900	237,000	--	--
Canada	94,300	1,160,000	29,800	382,000
Chile	770	10,000	--	--
China	--	--	78,700	1,090,000
France	2,980	38,800	--	--
Germany	7,390	110,000	33,800	475,000
India	--	--	105	3,060
Ireland	782	14,600	--	--
Israel	--	--	8,150	105,000
Japan	20,400	322,000	13,600	221,000
Korea, Republic of	3,270	42,500	1,330	18,900
Malaysia	897	11,700	212	2,750
Mexico	32,900	434,000	543,000	6,770,000
Netherlands Antilles	--	--	2,010	26,200
Philippines	409	5,310	--	--
Russia	15,200	274,000	1,910	24,000
Spain	--	--	625	8,130
Suriname	139	6,460	--	--
Switzerland	571	7,420	--	--
Taiwan	20,700	291,000	--	--
United Kingdom	68,700	1,200,000	245,000	4,070,000
Venezuela	3,810	49,600	--	--
Total	310,000	4,410,000	974,000	13,400,000
Ferrovandium:				
Australia	546	6,830	--	--
Canada	320,000	5,720,000	287,000	6,420,000
Guatemala	114	3,760	--	--
Mexico	156,000	3,020,000	159,000	3,350,000
Singapore	--	--	301	8,640
Venezuela	2,300	76,800	--	--
Total	479,000	8,830,000	446,000	9,780,000
Vanadium pentoxide (anhydride): 3/				
Australia	--	--	581	7,680
Austria	19,100	99,400	110,000	501,000
Belgium	7,850	103,000	155,000	1,490,000
Brazil	--	--	21,000	168,000
Chile	18	2,680	--	--
Czech Republic	--	--	57,200	461,000
France	12,100	132,000	52,900	526,000
Germany	--	--	39,200	330,000
Italy	107,000	913,000	109,000	873,000
Japan	13,800	126,000	--	--
Korea, Republic of	--	--	32,400	256,000
Kuwait	4,970	34,300	--	--
Mexico	6,370	62,500	1,130	10,800
Netherlands	16,300	116,000	32,800	328,000
Pakistan	6,040	83,600	--	--
Peru	2,260	10,400	--	--
Singapore	962	14,600	--	--
Spain	--	--	4,070	43,200
Taiwan	632	6,000	--	--
United Kingdom	43,500	356,000	--	--
Total	241,000	2,060,000	614,000	4,990,000

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)

Material and country	1996		1997	
	Quantity	Value	Quantity	Value
Other oxides and hydroxides of vanadium:				
Argentina	1,360	\$7,600	5,790	\$56,700
Australia	675	6,000	--	--
Canada	327,000	2,360,000	202,000	1,750,000
Colombia	--	--	14,900	121,000
Czech Republic	--	--	3,510	54,900
France	15,200	128,000	4,810	50,700
Germany	6,290	67,300	11,500	102,000
Indonesia	--	--	4,000	51,900
Israel	--	--	1,260	11,200
Italy	17,200	137,000	--	--
Japan	100	3,610	15,700	139,000
Korea, Republic of	--	--	788	7,010
Luxembourg	--	--	512	4,550
Mexico	2,500	25,600	4,020	34,900
Netherlands	--	--	15,600	45,000
Russia	12,300	110,000	--	--
South Africa	61,100	474,000	95,400	1,250,000
Spain	2,210,000	9,030,000	--	--
Switzerland	13,800	74,100	2,860	33,300
United Kingdom	--	--	1,560	6,040
Total	2,670,000	12,400,000	385,000	3,720,000

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	1996		1997	
	Quantity	Value	Quantity	Value
Aluminum-vanadium master alloy: (gross weight)				
Germany	1,610	\$16,500	11,300	\$19,800
Ferrovandium:				
Austria	45,100	718,000	34,600	595,000
Belgium	62,700	947,000	--	--
Canada	685,000	10,700,000	956,000	17,400,000
Chile	--	--	1,590	30,900
China	251,000	3,520,000	420,000	7,000,000
Czech Republic	487,000	6,820,000	63,800	947,000
France	--	--	4,060	85,900
Germany	2,690	32,300	7,050	145,000
Japan	--	--	465	26,100
Russia	70,400	1,440,000	--	--
South Africa	231,000	3,490,000	352,000	6,190,000
Tajikistan	40,500	626,000	--	--
Venezuela	--	--	1,620	5,190
Total	1,880,000	28,300,000	1,840,000	32,400,000
Vanadium pentoxide (anhydride): 2/				
China	27,400	329,000	--	--
France	9,470	223,000	--	--
Germany	494	21,700	516	21,900
Hong Kong	1,330	37,500	--	--
South Africa	446,000	5,540,000	711,000	9,280,000
Total	485,000	6,150,000	711,000	9,310,000
Other oxides and hydroxides of vanadium:				
China	--	--	3,830	36,500
France	304	48,600	--	--
Germany	5	4,490	1	2,070
South Africa	--	--	118,000	1,750,000
United Kingdom	10,500	152,000	4,510	81,000
Total	10,800	205,000	126,000	1,870,000
Vanadium metal, including waste and scrap: (gross weight)				
Austria	--	--	38	3,160
France	138	8,500	--	--
Germany	56,300	588,000	277,000 3/	724,000
Italy	--	--	88,600 3/	45,300
Korea, Republic of	35,300	16,700	46	6,450
Russia	4,410	182,000	19,900	612,000
Spain	--	--	24	2,000
Switzerland	--	--	15	7,900
United Kingdom	5	15,900	178,000	72,800
Total	96,100	811,000	564,000	1,470,000

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

2/ May include catalysts containing vanadium pentoxide.

3/ All or part of these data have been referred to the Bureau of the Census for verification.

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	1996		1997	
	Quantity	Value	Quantity	Value
Ash and residues:				
Canada	1,650,000	\$1,010,000	2,160,000	\$1,310,000
Dominican Republic	23,100	16,600	--	--
Germany	5,150	3,960	--	--
Italy	--	--	48,900	34,700
Korea, Republic of	--	--	20,500	6,830
Kuwait	3,640	22,700	467,000	630,000
Mexico	781,000	2,560,000	671,000	1,820,000
Netherlands	13,000	7,050	3,990	3,530
Netherlands Antilles	87,900	168,000	262	2,110
Portugal	7,130	6,470	--	--
United Kingdom	14,800	3,260	62,200	103,000
Venezuela	--	--	26,500	88,900
Total	2,590,000	3,810,000	3,460,000	4,000,000
Slag, from the manufacture of iron and steel: 2/ South Africa	1,470,000	5,670,000	1,800,000	7,990,000

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	1996		1997	
	Quantity	Value	Quantity	Value
Sulfates:				
Germany	--	--	12,600	\$97,000
India	25	\$14,900	15	5,610
Total	25	14,900	12,600	103,000
Vanadates:				
Belgium	--	--	28,500	76,800
Germany	3,360	76,500	17,300	302,000
Japan	--	--	28	14,900
South Africa	73,900	553,000	91,700	647,000
Switzerland	8	5,240	--	--
Total	77,200	634,000	137,000	1,040,000
Hydrides and nitrides: South Africa	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, 1997 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	1993	1994	1995	1996	1997 e/
Production from ores, concentrates, and slag: 3/					
China (in vanadiferous slag product) e/	5,000	5,400	13,700 r/	14,000 r/	8,000
Hungary e/	200	200	200	200	200
Kazakstan	800 r/	878	924	900 e/	900
Russia e/	12,800 r/	11,900 r/	11,000	11,000	11,000
South Africa	15,051	16,350 r/	16,297	15,685 r/	17,000
United States (recoverable vanadium)	W	W	W	W	W
Total	33,900 r/	34,700 r/	42,100 r/	41,800 r/	37,100
Production from petroleum residues, ash, and spent catalysts: 4/					
Japan e/	252	252	245	245	245
United States	2,870	2,740	1,990	3,730	NA
Total	3,120	2,990	2,240	3,980	NA
Grand total	37,000 r/	37,700 r/	44,400 r/	45,800 r/	NA

e/ Estimated. r/ Revised. NA Not available. 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 available through June 12, 1998.

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

4/ 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.