

VANADIUM

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In 1998, U.S. vanadium production was limited to material recovered from various industrial waste streams. Fewer than 10 firms, primarily in Arkansas, Idaho, Louisiana, Texas, and Utah, processed such material, 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 decreased slightly in 1998. Metallurgical applications in which vanadium was used as a minor alloying element with iron, steel, and titanium remained the dominant use, 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. China, Russia, and South Africa were the leading nations in vanadium production. 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 petroleum residues will extend the viability of the reserve base significantly.

Production

In February, International Uranium Corp. began initial ore production at its Rim Mine in Colorado. As with the company's Sunday Mine, which began production in October 1997, ore containing uranium and vanadium was shipped to the company's White Mesa mill in Utah for stockpiling. The mill has a capacity of approximately 2,000 tons of ore per day and can produce uranium and vanadium. Production at the Rim Mine was expected to reach nearly 2,000 tons per month of ore by mid-1998; owing to declining prices, however, mining operations were suspended in December (International Uranium Corp., 1999, p. 10).

In July, Metallurg Inc. was acquired by a group of investors led by Safeguard International Fund L.P., an international equity fund that invests in process industries. Metallurg and its operating subsidiary, Shieldalloy Metallurgical Corp., produced ferrovanadium, vanadium chemicals, and vanadium aluminum alloy from various raw materials, including slag from steelmaking in South Africa, residues from the refining of

petrochemical products, and ash from the burning of fuel oil by electric utilities (Metallurg Inc., 1998, p. 9).

Consumption

In 1998, domestic vanadium consumption was 4,390 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 catalysts.

Consumption data for vanadium were collected by the U.S. Geological Survey from a voluntary survey of all known domestic consumers. The 60 respondents to the 1998 survey represented about 75% of the total canvassed and were estimated to have accounted for about 79% of total consumption. Data for nonrespondents were derived by using past reported data and/or trends and data from nonsurvey sources.

Prices

In 1998, the domestic price for ferrovanadium, as published in Metal Bulletin, ranged from \$5.25 to \$15.50 per pound, wider than the \$7.40-to-\$11.00 range reported for 1997. The price rose during the first quarter and declined steadily throughout the remainder of the year. The price reached its high in February and early March, while the low was reported in December. The European ferrovanadium price recorded its high for the year in January and February and its low in December. The European price ranged from \$11.80 to \$32.00 per kilogram, compared with \$15.75 to \$27.80 in 1997.

Metal Bulletin's published price for domestic vanadium pentoxide ranged between \$2.40 and \$6.90 per pound in 1998. The price peaked in January and, except for a slight rally

during the second quarter, steadily declined throughout the year. In 1997, Metal Bulletin's vanadium pentoxide price ranged from \$3.28 to \$5.80 per pound.

World Review

As with the United States, nearly all the world's supply of vanadium is from primary sources. Including the United States, seven countries recovered vanadium from ores, concentrates, slag or petroleum residues. China, Russia, and South Africa were the leading nations in vanadium production. Except in Japan and the United States, vanadium production was primarily a byproduct of iron mining and processing.

Recycling of vanadium was negligible. Its major use was as a minor alloying element in iron, steel, and titanium from which it is not extracted when those metals are recycled. Only small quantities of vanadium-based catalysts and vanadium-aluminum alloy were processed to recover vanadium.

In response to rising vanadium prices, slightly more than 67 tons of ferrovanadium was sold from the Government-sponsored rare metals stockpile in Japan near the end of April. Although the stockpile was started in 1983 to provide relief to metal consumers during periods of high prices, this sale was the first use of the stockpile for its intended purpose. The stockpile is funded by industry and Government sources and, at its peak in March, contained 486 tons of ferrovanadium (Metal Bulletin, 1998a). In June, an additional 30 tons of ferrovanadium was sold from the stockpile (Metal Bulletin, 1998b).

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

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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)

	1994	1995	1996	1997	1998
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/	2,830	1,990	3,730	NA	NA
Consumption	4,280	4,650	4,630	4,730	4,390
Exports:					
Ferrovandium	374	340	479	446	579
Vanadium pentoxide (anhydride)	335	229	241	614	681
Other oxides and hydroxides of vanadium	1,050	1,010	2,670	385	232
Imports for consumption:					
Ferrovandium	1,910	1,950	1,880	1,840	1,620
Vanadium pentoxide (anhydride)	294	547	485	711	847
Other oxides and hydroxides of vanadium	3	36	11	126	33
Ore, slag, ash, residues	1,900	2,530	2,270	2,950	2,400
Stocks:					
Ferrovandium	240 r/	299 r/	275 r/	297 r/	302
Oxide	6 r/	7 r/	7	7 r/	8
Other 5/	3 r/	4 r/	4	4 r/	4
World: Production from ore, concentrate, slag 6/	34,700	42,100	40,900 r/	40,200 r/	41,800 e/

e/ Estimated. 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/ Consists principally of vanadium-aluminum alloy, small quantities of other vanadium alloys, vanadium metal, and ammonium metavanadate.

6/ Excludes U.S. production.

TABLE 2
U.S. CONSUMPTION OF VANADIUM, BY END USE AND FORM 1/

(Kilograms of contained vanadium)

	1997	1998
End use:		
Steel:		
Carbon	1,800,000	1,650,000
Stainless and heat resisting	20,100	42,400
Full alloy	908,000	891,000
High-strength low-alloy	944,000	950,000
Tool	481,000	269,000
Unspecified	W	W
Total	4,150,000	3,800,000
Cast irons	W	W
Superalloys	23,500	19,900
Alloys (excluding steels and superalloys):		
Cutting and wear-resistant materials	W	W
Welding and alloy hard-facing rods and materials	4,060	2,000
Other alloys 2/	501,000 r/	506,000
Chemical and ceramic uses:		
Catalysts	W	W
Pigments	W	W
Miscellaneous and unspecified	45,700 r/	62,400
Total	4,730,000	4,390,000
Form:		
Ferrovanadium	4,310,000 r/	4,010,000
Oxide	14,200	13,200
Other 3/	402,000	373,000
Total	4,730,000	4,390,000

r/ Revised. 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.

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

TABLE 3
U.S. IMPORTS AND EXPORTS OF ALUMINUM-VANADIUM MASTER ALLOY AND VANADIUM
METAL, INCLUDING WASTE AND SCRAP 1/

(Kilograms, gross weight)

	Aluminum-vanadium master alloy		Vanadium metal, including waste and scrap	
	Quantity	Value	Quantity	Value
Imports for consumption:				
1997	11,300	\$19,800	564,000	\$1,470,000
1998:				
Argentina	298,000	484,000	--	--
Canada	437	12,300	--	--
Germany	--	--	6,460	184,000
Russia	--	--	5,760	300,000
United Kingdom	--	--	2	5,910
Total	298,000	496,000	12,200	491,000
Exports:				
1997	974,000	13,400,000	155,000	1,340,000
1998:				
Australia	140	4,130	--	--
Austria	2,940	38,200	--	--
Canada	26,000	418,000	1,710	37,700
China	15,900	280,000	--	--
France	--	--	44,900	920,000
Germany	13,600	179,000	2,320	212,000
Greece	--	--	1	8,180
Japan	150,000	2,070,000	--	--
Israel	40,900	542,000	--	--
Italy	--	--	9	2,630
Korea Republic	6,380	70,500	4	3,920
Malaysia	698	9,450	--	--
Martinique	3,920	51,000	--	--
Mexico	576,000	7,470,000	--	--
Poland	--	--	5	2,800
Romania	481	6,250	--	--
Singapore	369	4,800	--	--
South Africa	--	--	746	4,790
Spain	1,680	20,000	--	--
Sweden	3,570	56,300	--	--
Switzerland	--	--	28	5,760
Thailand	540	7,020	--	--
United Kingdom	12,300	227,000	296,000	5,970,000
Total	856,000	11,500,000	346,000	7,160,000

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

Source: Bureau of the Census.

TABLE 4
U. S. IMPORTS AND EXPORTS OF FERROVANADIUM, VANADIUM PENTOXIDE (ANHYDRIDE) AND
OTHER OXIDES AND HYDROXIDES OF VANADIUM 1/

(Kilograms, contained vanadium)

	Ferrovanadium		Vanadium pentoxide (anhydride) 2/		Other oxides and hydroxides of vanadium	
	Quantity	Value	Quantity	Value	Quantity	Value
Imports for consumption:						
1997	1,840,000	\$32,400,000	711,000	\$9,310,000	126,000	\$1,870,000
1998:						
Argentina	1,570	41,800	--	--	--	--
Austria	143,000	3,280,000	--	--	--	--
Belgium	13,700	386,000	--	--	--	--
Canada	1,030,000	25,800,000	--	--	--	--
China	197,000	4,240,000	2,730	22,200	--	--
Czech Republic	20,500	530,000	--	--	--	--
France	10,000	131,000	--	--	--	--
Germany	5,750	132,000	1,140	43,800	--	--
Japan	--	--	1,400	22,300	--	--
Mexico	18,900	334,000	--	--	--	--
South Africa	188,000	4,350,000	839,000	12,200,000	28,500	497,000
United Kingdom	--	--	2,400	14,100	4,490	76,000
Total	1,620,000	39,300,000	847,000	12,300,000	33,000	574,000
Exports:						
1997	446,000	9,780,000	614,000	4,990,000	385,000	3,720,000
1998:						
Australia	273	4,540	1,460	9,090	--	--
Austria	--	--	100,000	986,000	--	--
Belgium	--	--	287,000	2,460,000	--	--
Brazil	15,000	369,000	7,480	56,500	--	--
Canada	363,000	6,950,000	--	--	53,900	528,000
China	--	--	--	--	47,100	419,000
Colombia	--	--	--	--	709	16,900
France	--	--	53,700	644,000	1,020	9,100
Germany	--	--	19,000	181,000	--	--
Ireland	--	--	--	--	2,980	26,500
Italy	--	--	147,000	1,930,000	--	--
Japan	--	--	--	--	1,840	16,400
Korea, Republic of	12,800	425,000	--	--	--	--
Luxembourg	--	--	--	--	433	3,850
Mexico	131,000	4,460,000	3,090	36,200	9,200	91,000
Netherlands	41,500	1,040,000	60,000	519,000	5,450	48,500
Saudi Arabia	301	9,980	416	4,160	--	--
Singapore	--	--	--	--	314	2,790
Switzerland	--	--	--	--	2,100	35,200
South Africa	--	--	--	--	104,000	1,600,000
Taiwan	--	--	--	--	742	6,600
Trinidad and Tobago	--	--	1,020	20,200	--	--
United Kingdom	--	--	--	--	2,260	20,100
Venezuela	15,300	424,000	--	--	310	2,750
Total	579,000	13,700,000	681,000	6,850,000	232,000	2,830,000

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 5
U.S. IMPORTS FOR CONSUMPTION OF VANADIUM-BEARING ASH, RESIDUES AND SLAG 1/

(Kilograms, vanadium pentoxide content)

Material and country	1997		1998	
	Quantity	Value	Quantity	Value
Ash and residues:				
Canada	2,160,000	\$1,310,000	250,000	\$1,770,000
Germany	--	--	7,000	48,800
Italy	48,900	34,700	352,000	161,000
Korea, Republic of	20,500	6,830	9,720	3,530
Kuwait	467,000	630,000	336,000	478,000
Mexico	671,000	1,820,000	1,240,000	3,420,000
Netherlands	3,990	3,530	82,300	145,000
Netherlands Antilles	262	2,110	21,300	122,000
Taiwan	--	--	2,330	2,600
United Kingdom	62,200	103,000	708,000	3,760,000
Venezuela	26,500	88,900	19,700	60,800
Total	3,460,000	4,000,000	3,030,000	9,960,000
Slag, from the manufacture of iron and steel: South Africa 2/	1,800,000	7,990,000	1,250,000	10,500,000

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 6
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS VANADIUM CHEMICALS 1/ 2/

(Kilograms, vanadium content)

Material and country	1997		1998	
	Quantity	Value	Quantity	Value
Sulfates:				
Germany	12,600	\$97,000	--	--
India	15	5,610	350	\$19,300
Total	12,600	103,000	350	19,300
Vanadates:				
Belgium	28,500	76,800	14,400	37,400
Chile	--	--	695	259,000
Germany	17,300	302,000	4,680	75,900
Japan	28	14,900	99	10,100
Mexico	--	--	3,400	8,550
South Africa	91,700	647,000	106,000	1,020,000
Total	137,000	1,040,000	129,000	1,410,000

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 7
VANADIUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons of contained vanadium)

Country	1994	1995	1996	1997	1998 e/
Production from ores, concentrates, slag: 3/					
China (in vanadiferous slag product) e/	5,400	13,700	14,000	14,500 r/	14,700
Hungary e/	200	200	200	200	100
Kazakhstan	878	924	900 e/	900 e/	1,000
Russia e/	11,900	11,000	11,000	9,000 r/	9,000
South Africa	16,350	16,297	14,770 r/	15,590 r/	17,000
United States (recoverable vanadium)	W	W	W	W	W
Total	34,700	42,100	40,900 r/	40,200 r/	41,800
Production from petroleum residues, ash spent catalysts: 4/					
Japan e/	252	245	245	245	245
United States	2,830 r/	1,990	3,730	NA	NA
Total	3,080 r/	2,240	3,980	NA	NA
Grand total	37,800 r/	44,400	44,800 r/	NA	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 7, 1999.

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.