VANADIUM

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In 1999, nearly all U.S. vanadium production was accounted for by materials recovered from various industrial waste streams. Fewer than 10 firms, primarily in Arkansas, Idaho, Louisiana, Texas, and Utah, processed such materials, mainly vanadium-bearing ferrophosphorus slag, iron slag, fly ash, petroleum residues, and spent catalysts, to produce vanadium pentoxide, ferrovanadium, and vanadium metal. Recycling of vanadium was negligible; only small quantities of vanadium-based catalysts and vanadium-aluminum alloy were recycled.

Domestic vanadium consumption decreased by more than 12% in 1999. Metallurgical applications in which vanadium was used as a minor alloying element with iron, steel, and titanium remained the dominant use, which accounted for nearly all domestic consumption. The largest nonmetallurgical use for vanadium was in catalysts.

Seven countries recovered vanadium from ores, concentrates, slag, or petroleum residues (table 7). 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 U.S. Geological Survey (USGS) estimates that the vanadium reserve base 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.

Legislation and Government Programs

The primary nonmetallurgical use for vanadium and only source of recycled material was as a catalyst. In December, the U.S. Environmental Protection Agency (EPA) provided clarification on the treatment of spent catalysts generated by the petroleum refining industry. In 1998, the EPA finalized a rule in which four wastes from the petroleum refining industry were added to its hazardous waste list. These wastes included spent hydrotreating and spent hydrorefining catalysts; hydrocracking operations were not mentioned in the rule. Thus, the rule appeared to allow dual-purpose facilities (those that use hydrotreating and hydrocracking) to declare their spent catalyst as nonhazardous and to permit disposal of the spent catalyst in standard landfills. Clarifying its position, the EPA stated that it considered spent catalyst from dual-purpose facilities as hazardous waste (American Metal Market, 1999).

Production

In mid-1999, continued weakness in the uranium and vanadium markets combined with the prospect that conditions in these markets would not improve for several years prompted International Uranium Corp. to suspend mining operations at its properties on the Colorado Plateau. Additionally, the company wrote off the value of these properties in its financial statements. Although mining was halted, some of the previously mined ore was processed by the company's White Mesa mill. During fiscal year 1999, the White Mesa mill produced more than 224 metric tons (t) of triuranium octoxide (yellow cake) and 375 t of vanadium pentoxide from stockpiled ore and alternate feed material (International Uranium Corp., 2000, p. 8).

Consumption

In 1999, domestic vanadium consumption was 3,830 t. Although vanadium has many uses, metallurgical applications account for essentially all domestic consumption. Most vanadium is used in the form of ferrovanadium, which 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. Most of the 80% grade is produced 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 (which is the dominant use), ceramics, vanadium chemicals, and electronics. Consumption data for vanadium were collected by the USGS from a voluntary survey of all known domestic consumers. The 69 respondents to the 1999 survey represented about 65% 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 1999, the domestic price for ferrovanadium, as published in Metal Bulletin, ranged from $4.35 to $6.25 per pound, a much narrower range than the $5.25 to $15.50 range reported for 1998. The price reached its high in January and declined steadily throughout the remainder of the year. The low price was reported in December. Similarly, the European ferrovanadium price recorded its high for the year in January and its low in December. The European price ranged from $7.45 to $13.70 per kilogram compared with $11.80 to $32.00 in 1998.

Metal Bulletin's published price for domestic vanadium pentoxide ranged between $1.25 and $2.90 per pound in 1999. The price peaked in January and, except for a slight rally during the summer, steadily declined throughout the year. In 1998, Metal Bulletin's vanadium pentoxide price ranged from $2.40 to $6.90 per pound.

World Review

As in the United States, nearly all the world's supply of vanadium is from primary sources. Seven countries recovered vanadium from ores, concentrates, slag or petroleum residues (table 7). The largest vanadium-producing nations remained China, Russia, and South Africa, with production primarily a byproduct of the iron and steel industry. Japan and the United States were believed to be the only countries to recover significant quantities of vanadium from petroleum residues.

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 Western Australia, construction of the Windimurra Mine was completed in 1999. By yearend, the pit was open to its full width, and no problems were reported with the milling circuit. Despite some delays with certification, the kiln began operation on December 24. The Windimurra Mine, a joint venture of Xstrata AG and Precious Metal Australia Ltd., produced its first vanadium pentoxide in January 2000 (Metal Bulletin, 1999).

Outlook

In the near term, the vanadium market will continue to follow the cyclical nature of the steel industry. The consumption of vanadium will probably continue to increase owing, in part, to the need for stronger and lighter steels and, in part, to 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.

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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)

	1995	1996	1997	1998	1999
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/	1,990	3,730	NA	NA	NA
Consumption	4,650	4,630	4,710 r/	4,380 r/	3,830
Exports:					
Ferrovanadium	340	479	446	579	213
Vanadium pentoxide (anhydride)	229	241	614	681	747
Other oxides and hydroxides of vanadium	1,010	2,670	385	232	70
Imports for consumption:					
Ferrovanadium	1,950	1,880	1,840	1,620	1,930
Vanadium pentoxide (anhydride)	547	485	711	847	208
Other oxides and hydroxides of vanadium	36	11	126	33	--
Ore, slag, ash, residues	2,530	2,270	2,950	2,400	1,650
Stocks:					
Ferrovanadium	355 r/	294 r/	311 r/	324 r/	354
Oxide	9 r/	7	8 r/	8	9
Other 5/	5 r/	4	4	4	5
World, production from ore, concentrate, slag 6/	42,100	40,900	40,700 r/	44,500 r/	42,000 e/

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data. -- Zero.

1/ Data are rounded to no more than three significant digits.

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)

	1998	1999
End use:		
Steel:		
Carbon	1,650,000	1,240,000
Stainless and heat resisting	42,400	81,600
Full alloy	891,000	802,000
High-strength low-alloy	950,000	868,000
Tool	269,000	344,000
Unspecified	W	W
Total	3,800,000	3,330,000
Cast irons	W	W
Superalloys	19,900	13,500
Alloys (excluding steels and superalloys):		
Cutting and wear-resistant materials	W	W
Welding and alloy hard-facing rods and materials	2,020 r/	1,940
Other alloys 2/	506,000 r/	402,000
Chemical and ceramic uses:		
Catalysts	W	W
Pigments	W	W
Miscellaneous and unspecified	47,500 r/	77,700
Total	4,380,000 r/	3,830,000
Form:		
Ferrovanadium	3,990,000 r/	3,490,000
Oxide	13,100 r/	11,500
Other 3/	372,000 r/	325,000
Total	4,380,000 r/	3,830,000

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

1/ Data are rounded to no more than three significant digits; may not add to totals 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:				
1998	298,000	$496,000	12,200	$491,000
1999:				
Argentina	1,110,000	1,550,000	--	--
China	--	--	8,000	71,400
Germany	3,550	10,600	11,400	400,000
Mexico	800	3,430	--	--
Philippines	--	--	33	26,000
Russia	98,400	117,000	11,000	282,000
Total	1,210,000	1,680,000	30,400	779,000
Exports:				
1998	856,000	11,500,000	346,000	7,160,000
1999:				
Australia	--	--	8,540	147,000
Austria	--	--	7	46,600
Bahamas, The	260	3,380	--	--
Belgium	18,100	532,000	--	--
Canada	234,000	2,240,000	1,270	28,500
Costa Rica	1,380	14,100	--	--
Finland	--	--	9	9,500
France	--	--	39,000	432,000
Germany	8,710	135,000	43	60,700
Guatemala	230	2,980	--	--
Hong Kong	8,920	116,000	--	--
India	2,000	36,500	--	--
Israel	20,100	261,000	5	5,830
Italy	245	7,200	2	5,860
Japan	9,800	219,000	385	49,400
Korea, Republic of	1,530	19,900	12	5,910
Mexico	204,000	2,770,000	--	--
New Guinea	1,640	48,300	--	--
Philippines	659	8,570	--	--
South Africa	--	--	8	4,300
Taiwan	--	--	848	78,800
United Kingdom	2,100	29,200	127,000	2,320,000
Total	514,000	6,440,000	177,000	3,200,000

-- Zero.

1/ Data are rounded to no more than 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:						
1998	1,620,000	$39,300,000	847,000	$12,300,000	33,000	$574,000
1999:						
Austria	279,000	2,970,000	--	--	--	--
Belgium	74,600	613,000	--	--	--	--
Canada	470,000	6,190,000	814	13,500	--	--
China	375,000	3,660,000	--	--	--	--
Czech Republic	32,400	343,000	--	--	--	--
Germany	--	--	2,210	113,000	--	--
Japan	293	15,000	1,000	12,200	--	--
Korea, Republic of	7,990	85,900	--	--	--	--
South Africa	673,000	6,620,000	204,000	1,780,000	--	--
United Kingdom	16,000	157,000	--	--	--	--
Total	1,930,000	20,700,000	208,000	1,920,000	--	--
Exports:						
1998	579,000	13,700,000	681,000	6,850,000	232,000	2,830,000
1999:						
Argentina	15,300	166,000	--	--	--	--
Austrailia	--	--	333	3,150	--	--
Austria	--	--	--	--	4,050	51,500
Belgium	--	--	434,000	2,540,000	6,910	70,000
Brazil	--	--	6,980	27,700	3,090	20,400
Canada	159,000	2,360,000	--	--	47,600	437,000
Colombia	--	--	--	--	747	6,640
France	--	--	38,800	231,000	843	7,500
Germany	--	--	137,000	678,000	--	--
Italy	--	--	88,400	467,000	--	--
Japan	1,580	52,600	16,200	96,400	4,330	38,500
Kuwait	--	--	9,980	72,000	--	--
Mexico	36,800	584,000	2,590	15,600	--	--
New Zealand	--	--	961	13,900	--	--
Pakistan	--	--	3,870	47,800	--	--
Saudi Arabia	--	--	527	5,000	--	--
Singapore	378	18,600	--	--	--	--
Switzerland	--	--	18	3,010	2,100	24,400
South Africa	--	--	607	5,760	--	--
Spain	--	--	4,500	33,900	--	--
Thailand	--	--	100	2,540	--	--
Trinidad and Tobago	--	--	1,970	14,900	--	--
Venezuela	--	--	632	6,000	--	--
Total	213,000	3,180,000	747,000	4,270,000	69,700	656,000

-- Zero.

1/ Data are rounded to no more than 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	1998		1999	
	Quantity	Value	Quantity	Value
Ash and residues:				
Canada	250,000	$1,770,000	146,000	$101,000
Germany	7,000	48,800	--	--
Hungary	--	--	44,700	44,500
Italy	352,000	161,000	519,000	319,000
Korea, Republic of	9,720	3,530	--	--
Kuwait	336,000	478,000	--	--
Mexico	1,240,000	3,420,000	856,000	5,740,000
Netherlands	82,300	145,000	--	--
Netherlands Antilles	21,300	122,000	13,200	9,890
Taiwan	2,330	2,600	--	--
United Kingdom	708,000	3,760,000	224,000	722,000
Venezuela	19,700	60,800	--	--
Total	3,030,000	9,960,000	1,800,000	6,940,000
Slag, from the manufacture of iron and steel, South Africa 2/	1,250,000	10,500,000	1,150,000	1,740,000

-- Zero.
1/ Data are rounded to no more than 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	1998		1999	
	Quantity	Value	Quantity	Value
Sulfates, India	350	$19,300	8	$14,300
Vanadates:				
Belgium	14,400	37,400	--	--
Chile	695	259,000	--	--
Germany	4,680	75,900	77,700	724,000
Japan	99	10,100	24	79,500
Mexico	3,400	8,550	--	--
South Africa	106,000	1,020,000	96,400	837,000
Total	129,000	1,410,000	174,000	1,640,000

-- Zero.
1/ Data are rounded to no more than 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	1995	1996	1997	1998	1999 e/
Production from ores, concentrates, slag: 3/					
China (in vanadiferous slag product) e/	13,700	14,000	15,000 r/	15,500 r/	16,000
Hungary e/	200	200	200	100	--
Kazakhstan e/	924 4/	900	900	1,000	1,000
Russia e/	11,000	11,000	9,000	9,000	9,000
South Africa	16,297	14,770	15,590	18,868 r/	16,000
United States (recoverable vanadium)	W	W	W	W	W
Total	42,100	40,900	40,700 r/	44,500 r/	42,000
Production from petroleum residues, ash spent catalysts: 5/					
Japan e/	245	245	245	245	245
United States	1,990	3,730	NA	NA	NA
Total	2,240	3,980	NA	NA	NA
Grand total	44,400	44,800	NA	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 no more than 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 9, 2000.

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.