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Vanadium

By Désirée E. Polyak

Domestic survey data and tables were prepared by Darlene V. Thompson, statistical assistant.

In 2019, the United States produced 460 metric tons (t) of primary vanadium measured in vanadium content (table 1). This was the first time that primary vanadium had been produced since 2013. The United States continued to be a major producer of vanadium products from secondary sources such as spent catalysts, ashes, and petroleum residues. Total imports for consumption (measured in vanadium content) decreased by 25% from that in 2018. The United States imported 3,660 t of vanadium pentoxide (V_2O_5), 2,280 t of ferrovanadium (FeV), and 105 t of other oxides and hydroxides of vanadium (all measured in vanadium content), collectively valued at $285 million (table 3). The United States imported 222 t (vanadium content) of aluminum-vanadium master alloy valued at $17.6 million and 45 t (vanadium content) of vanadium metal valued at $4.1 million (table 4). Imports of ash and residues equaled 2,120 t (vanadium content) valued at $58.8 million (table 5). Imports of vanadium chemicals (sulfates and vanadates) equaled 146 t (vanadium content) valued at $3.9 million (table 6). In terms of vanadium content, the United States exported 750 t of other oxides and hydroxides of vanadium, 423 t of V_2O_5, and 295 t of FeV, collectively valued at $24.3 million (table 3). Exports of aluminum-vanadium master alloy equaled 51 t (gross weight) valued at $2.9 million and exports of vanadium metal equaled 27 t (vanadium content) valued at $1.7 million (table 4). Exports of ash and residues equaled 2,280 t (gross weight) valued at $1.9 million (table 5). Reported vanadium consumption in the United States was 4,840 t (vanadium content) 14% less than the reported consumption in 2018 (table 1). In 2019, estimated worldwide production of vanadium increased by 4% to 86,800 t (vanadium content), compared with 83,500 t (revised) in 2018 (tables 1, 7).

Vanadium's primary use was as a hardening agent in steel because it is critical for imparting toughness and wear resistance. These properties are especially important in high-strength low-alloy (HSLA) steels. Vanadium-containing steels can be subdivided into (1) microalloy or low-alloy steels that usually contain less than 0.15% vanadium and (2) high-alloy steels that contain as much as 5% vanadium. Catalysts were the leading nonmetallurgical use for vanadium.

Production

Industry convention for describing the production of V_2O_5 usually applies the terms primary production, joint production, and secondary production according to the raw material source for production. Primary production occurs from mined ore as mineral concentrates derived from vanadiferous titanomagnetite. Joint production refers to vanadium slags that are produced during steelmaking. When a vanadiferous titanomagnetite iron ore is used to produce iron, vanadium is contained in the crude steel that must be extracted whether or not the finished steel will contain vanadium. Secondary vanadium is produced from various industrial waste materials, such as vanadium-bearing fly ash, petroleum residues, and spent catalysts. Secondary vanadium was produced primarily in Arkansas, Delaware, Ohio, Pennsylvania, and Texas, where processed waste materials were used to produce FeV, specialty alloys, vanadium chemicals, vanadium metal, and vanadium oxides.

The major vanadium commodities were aluminum-vanadium master alloy; FeV; vanadium-bearing ash, residues, and slag; vanadium chemicals; and V_2O_5 and other oxides and hydroxides of vanadium. Vanadium oxides were the most commonly produced vanadium compounds, although most V_2O_5 and trioxide are further processed into FeV. The most widely produced oxide is V_2O_5. In 2019, companies in the United States produced all these materials, except vanadiferous slag from the manufacture of iron and steel.

Energy Fuels Inc.'s (Canada) White Mesa Mill, near Blanding, UT, had the only vanadium coproduct recovery circuit in the United States. The mill had produced approximately 20,400 t of V_2O_5 (11,400 t vanadium content) during its 40-year operating history. In 2018, the company completed facility upgrades to the mill to begin vanadium recovery in January 2019. In 2019, the company produced 820 t of high-purity V_2O_5 (460 t vanadium content). However, vanadium production was stopped during the fourth quarter of 2019 owing to weakened vanadium market conditions and lowered recoveries. The company announced that it had 730 t of high-purity V_2O_5 (410 t vanadium content) in inventory that it would sell when vanadium prices spiked (Energy Fuels Inc., 2020).

In October, Prophecy Development Corp. (Canada) submitted water and air permit applications to the State of Nevada for its Gibellini vanadium project in Eureka County, NV (Prophecy Development Corp., 2019, p. 1). The previous feasibility study in 2011 projected mine production to average 5,170 metric tons per year (t/yr) of V_2O_5 (Prophecy Development Corp., 2017).

U.S. Vanadium LLC announced that it signed an agreement to acquire EVRAZ Stratcor Inc. (previously owned by EVRAZ plc). Stratcor had operated a facility in Hot Springs, AR, where vanadium ash, residues, and other raw materials were converted into vanadium alloys and vanadium chemicals used by the chemical, steel, and titanium industries. From 2008 to 2018, production at the facility declined from full capacity to very low levels. In 2019, U.S. Vanadium increased production through a variety of tolling contracts, and the company was expected to restore the facility's production operations to its full processing capacity of approximately 5,400 t/yr of V_2O_5. The oxide produced at the Hot Springs facility would be converted into an aluminum-vanadium alloy that met the requirements for titanium alloys used in jet aircraft and other aerospace applications and many other specialty products used in the production of chemicals, gases, and storage batteries (Elysee Development Corp., 2019; EVRAZ plc, undated b). EVRAZ consisted of EVRAZ Nikom in Czechia and Vanady Tula in Russia (EVRAZ plc, undated c).

AMG Vanadium LLC, a wholly owned subsidiary of AMG Advanced Metallurgical Group N.V. (Netherlands), in Cambridge, OH, was a major producer of FeV and other ferroalloys from spent oil refinery catalysts and powerplant residues (AMG Vanadium LLC, undated a). AMG announced that its new spent catalyst recycling and ferroalloy production facility would be a replicate of its existing facility. The new facility would be located in Washington Township in Muskingum County, OH. The company expected the new facility to double the company's spent catalyst recycling capacity and ferrovanadium production capacity (AMG Vanadium LLC, undated b).

Bear Metallurgical Co. continued to produce FeV from V_2O_5 at its facility in Butler, PA. Bear produced 80%-grade FeV and was reliant on imported V_2O_5 as its primary feedstock (Bear Metallurgical Co., undated).

Gladieux Metals Recycling LLC continued to recover V_2O_5 from spent petroleum catalysts at its recycling plant in Freeport, TX (Gladieux Metals Recycling LLC, undated).

Consumption

The U.S. Geological Survey (USGS) derived vanadium consumption data from a voluntary survey of domestic consuming companies. For this survey, more than 50 companies were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 2 include estimates to account for nonrespondents.

Metallurgical applications continued to dominate U.S. vanadium use in 2019, accounting for 96% of reported consumption (table 2). Reported vanadium consumption in the United States was 4,840 t (vanadium content), 14% less than that in 2018 (table 1). Nonmetallurgical applications included batteries, catalysts, ceramics, electronics, and vanadium chemicals. The leading nonmetallurgical use was in catalysts. A number of vanadium chemicals were used in catalysts to manufacture a variety of industrial chemicals and to clean industrial process waste streams.

Most vanadium was consumed in the form of FeV, which was used to introduce vanadium into steel to provide additional strength and toughness. In 2019, 3,090 t of FeV was consumed, representing 64% of the total amount of the reported vanadium consumed (table 2). FeV is available as alloys containing either 45% to 50% or 80% vanadium. The 45%-to-50%-grade FeV is produced by silicothermic reduction of V_2O_5 in slag or other vanadium-containing materials. Most of the 80%-grade FeV is produced by aluminothermic reduction of V_2O_5 in the presence of steel scrap or by direct reduction in an electric arc furnace.

Vanadium was becoming more widely used in renewable technology applications, especially in battery technology. Vanadium redox flow batteries (VRFBs), unlike conventional batteries, use a liquid vanadium electrolyte to store energy in separated storage tanks instead of in the power cell of the battery. The main advantages of the VRFB were that it can offer almost unlimited capacity by using sequentially larger storage tanks, can be left completely discharged for long periods of time with no ill effects, can be recharged by replacing the electrolyte if no power source is available to charge it, and suffers no permanent damage if the electrolytes are accidentally mixed (Johnstone, 2008). However, cost, equipment, and raw material availability continued to be barriers for entry into the battery market. Some of the U.S.-based manufacturers establishing VRFB production lines in 2019 included Ashlawn Energy, LLC; Invinity Energy Systems; Perennial Power Holdings, Inc.; Primus Power Corp.; StorEn Technologies Inc.; UniEnergy Technologies, LLC; Vionx Energy Corp.; and ViZn Energy Systems Inc.

Prices

In 2019, the U.S. average monthly price for domestic FeV (80% vanadium content), as published by CRU Group, ranged from \$10.781 to \$43.098 per pound of vanadium content, compared with \$24.489 to \$55.856 per pound reported in 2018. In 2019, the European average monthly price for FeV (80% vanadium content) ranged from \$21.513 to \$79.275 per kilogram, compared with \$53.111 to \$121.889 per kilogram in 2018. The average monthly price for Chinese V_2O_5, published by CRU Group, ranged from \$10.200 to \$17.000 per pound in 2019, compared with \$10.250 to \$22.500 per pound in 2018.

Vanadium prices for both FeV and V_2O_5 decreased in 2019. Domestic FeV prices in January 2019 averaged \$43.098 per pound and at yearend 2019 averaged \$10.911 per pound. Chinese V_2O_5 prices averaged \$16.500 per pound in January 2019 and averaged \$10.200 per pound at yearend 2019. This rapid decrease followed a record year of price increases for both FeV and V_2O_5 in 2018. The rapid decrease of vanadium prices in 2019 was attributed to a variety of factors including China's failure to completely enforce new rebar standards, higher than expected production from slag producers in China, and higher niobium substitution than originally expected. China's new rebar standards were expected to generate a significant increase in vanadium consumption; however, the implementation of the new regulation was much slower than originally anticipated (Vanadium Investing News, 2019).

World Review

Most of the world's supply of vanadium was derived from either primary or joint production. The leading vanadium-producing nations, in order of production, remained China, Russia, and South Africa; these countries provided 93% of world production (table 7). Secondary production continued in Canada, Germany, Japan, the United States, and several European countries.

World vanadium reserves, estimated at more than 20 million metric tons (Mt), are likely sufficient to meet vanadium needs into the next century at the present rate of consumption. Increased recovery of vanadium from fly ash, petroleum residues, slag, and spent catalysts is not considered here and is expected to significantly extend the life of the reserves.

Australia.—Neometals Ltd. announced that it had signed a memorandum of understanding with the Institute of Multipurpose Utilization of Mineral Resources Chinese Academy of Geological Sciences to jointly develop its Barrambie titanium-vanadium project located approximately 80 kilometers (km) northwest of Sandstone in Western Australia.

Neometals would own 50% interest in the right to mine a fixed quantity of ore at the project and rights to the beneficiation plant. The initial test work was expected to take approximately 18 months, and a decision on investment of the project would be announced in mid-2021 (Mining Technology, 2019).

Brazil.—Largo Resources Ltd.'s (Canada) Maracás Menchen Mine, located 813 km northeast of Brasilia, produced 10,600 t of V_2O_5 in 2019, an 8% increase compared with the 9,830 t produced in 2018. The company expected to produce between 11,800 and 12,300 t of V_2O_5 in 2020. According to the company, the vanadium was contained within a massive titaniferous magnetite deposit that was expected to have high grades of V_2O_5. The low level of contaminants in the deposit, particularly silica, was expected to make the extraction and processing of vanadium more efficient (Largo Resources Ltd., 2020a). All V_2O_5 produced by Largo was sold through Glencore plc (Switzerland) as part of a 6-year agreement which was expected to end on April 30, 2020. The company was expected to sell its V_2O_5 on the open market from May 2020 onwards (Roskill Information Services Ltd., 2020).

Largo also announced that it received approval for the construction of a vanadium trioxide processing plant at the Maracás Menchen Mine. The company anticipated construction to begin in the first quarter of 2021 with commissioning and rampup of the plant to take place in the third quarter of 2021 (Largo Resources Ltd., 2020b).

Canada.—In March, VanadiumCorp Resource Inc. announced that Electrochem Technologies & Materials Inc. had begun commercial production at its facilities in Boucherville, Quebec. Electrochem produced a battery-ready vanadium electrolyte directly from V_2O_5 purchased on the open market by using VanadiumCorp-Electrochem Processing Technology (VEPT). According to the companies, VEPT is a chemical process used to recover vanadium, ferrous sulfate, titanium dioxide, and silica from a variety of feedstocks containing vanadium (VanadiumCorp Resource Inc., 2019).

China.—Chengde Iron and Steel Group Co. Ltd. (Chengde), a subsidiary of China-based steel producer Hebei Iron & Steel Group Mining Co., Ltd. (Tangshan), reported that it produced 15,000 t of V_2O_5 in 2019, an increase of 69% compared with 8,900 t of V_2O_5 produced in 2018 (Argus Media group—Metal Pages, 2020). Chengde also produced high-purity vanadium oxides, FeV, and a vanadium nitride alloy. Panzhihua Iron and Steel Group Co. Ltd. (Panzhihua) reported that it produced 11,000 t of V_2O_5 in 2019, an 11% decrease from that in the previous year. The company attributed the decrease to lower prices and lower consumption from the rebar industry (Argus Media group—Metal Pages, 2019b).

In February 2018, the Standardization Administration of China (SAC) released a new standard for high-strength rebar that would decrease the use of substandard steels in construction and make buildings in China more earthquake resistant. The implementation date for the new standard was November 1, 2018. The new rebar standard eliminated the low-strength Grade 2 rebar, and the SAC authorized Grade 3, Grade 4, and Grade 5 high-strength standards. The newly authorized standards had 0.03% vanadium content in Grade 3, 0.06% vanadium content in Grade 4, and greater than 0.1% vanadium content in Grade 5 rebar (Metal Bulletin, 2017; Roskill Information Services Ltd., 2020).

In January 2019, China's State Bureau of Quality and Technical Supervision conducted quality inspections of rebar producers in small steel mills to ensure that they had adopted the new rebar standards. It was reported that approximately 30% to 40% of mills had not fully switched to the new standards. Many of the small mills could not afford to implement the technology needed to produce the upgraded rebar (Argus Media group—Metal Pages, 2019a).

In 2017, the China National Development and Reform Commission called for more investment in energy storage, specifically projects involving flow batteries. One such successful project was the vanadium energy storage project in Hubei Province. In January 2019, VRB Energy (Canada) announced that it had successfully commissioned a 12-megawatthour energy storage project for Phase 1 of the Hubei Zaoyang utility-scale solar and storage integration demonstration project, which when completed, was expected to be a 40-megawatthour storage facility (Colthorpe, 2019).

VRFB companies based in China included Big Pawer Electrical Technology Xiangyang Inc. Co. Ltd.; Dalian Rongke Power Co. Ltd.; Shanghai Shenli Technology Co., Ltd.; Shanxi Golden Energy Century Ltd.; and VRB Energy. According to Shanghai Shenli Technology Co., Ltd. (undated), Shanghai Shenli Technology was funded by the Ministry of Science and Technology of China and the Shanghai municipal government.

Czechia.—EVRAZ Nikom had one FeV-processing facility, which used V_2O_5 from Russia and China and vanadium trioxide from Bushveld Minerals Ltd.'s Vametco Mine. Nikom's FeV production capacity was 4,600 t/yr (EVRAZ plc, undated a).

Kazakhstan.—Ferro-Alloy Resources Group (FAR) (United Kingdom) commissioned new equipment to expand its vanadium-processing plant to process approximately 1,500 t/yr of V_2O_5. FAR announced that it was in advanced discussions to secure financing to develop its Balasausqandiq vanadium project in Kyzylordinskaya Oblast, in the south of Kazakhstan. According to the company, the deposit is a large black shale deposit that was not composed of vanadiferous titanomagnetite and therefore could be processed by a low-cost method. A two-phase development plan was proposed: Phase 1 was expected to treat 1 million metric tons per year (Mt/yr) of ore to produce 5,600 t/yr of V_2O_5. Phase 2 was expected to increase the ore treated to 4 Mt/yr, producing 16,800 t/yr of V_2O_5. The company expected that output could reach approximately 22,400 t/yr of V_2O_5. The cash flows from the company's processing operations were expected to help with the development of the first phase of the new facility (Ferro-Alloy Resources Group, undated a, b).

Russia.—EVRAZ Nizhny Tagil metallurgical plant (NTMK), an integrated metallurgical complex located in Nizhny Tagil in the Sverdlovsk region, continued to be one of the world's leading processors of vanadiferous titanomagnetite. EVRAZ announced that vanadium slag production increased by 8% to 18,400 t (vanadium content) owing to higher vanadium content in the pig iron it processed (EVRAZ plc, 2020, p. 24). The Vanady Tula facility, located 200 km south of Moscow, used low-cost, highly efficient technology to process the vanadium slag produced by NTMK. Vanady Tula had a capacity of 5,000 t/yr of FeV at its electrometallurgical plant (EVRAZ plc, 2016, p. 62).

South Africa.—With the closure of EVRAZ Highveld Steel and Vanadium Ltd.'s operations in early 2016, Bushveld's Vametco vanadium mine and Glencore plc's Rhovan facility were South Africa's only active primary vanadium producers in 2019. Bushveld announced that its Vametco vanadium mine and plant in Brits, North West Province, was on track to meet 2019 production guidance of approximately 2,800 to 2,900 t of vanadium content (Bushveld Minerals Ltd., 2019).

In November, Bushveld announced the successful completion of the acquisition of the Vanchem plant in South Africa from Vanchem Vanadium Products, a subsidiary of Duferco Vanadium Investment Holding. Vanchem consisted of a vanadium-processing facility with a beneficiation plant capable of producing FeV, vanadium pentoxide, and vanadium trioxide. Bushveld announced that after its expected 5-year refurbishment of the facility, it would produce approximately 4,200 t/yr of vanadium products using three kilns. Bushveld determined that the refurbishment would require more vanadium feedstock and considered sourcing vanadium from the Mokopane project (64% owned by Bushveld) and the Brits Mine (62.5% owned by Bushveld), both of which were under development. Bushveld announced that Vanchem would have sufficient feedstock supply from third parties to support current levels of production until Mokopane's development was completed. The Vanchem plant was located in the Mpumalanga Province. The FeV facilities were located at the Highveld site, approximately 10 km from the Vanchem plant. Vanchem Vanadium Products announced that its facility was expected to produce between 960 and 1,100 t (vanadium content) in 2020 (Bushveld Minerals Ltd., 2019, undated).

Glencore announced that its Rhovan vanadium facility, 30 km northwest of Brits, produced 9,070 t of V_2O_5 in both 2018 and 2019 (Glencore plc, 2020, p. 21).

Sweden.—Pursuit Minerals Ltd. announced that it would commence a drilling program at the Airijoki project in northern Sweden in the third quarter of 2019. A second phase of test work of 16 drill holes was intended to develop a Definitive Feasibility Study to produce high-grade vanadium magnetite concentrate at the project (Pursuit Minerals Ltd., 2019, p. 1–2).

Outlook

A combination of high vanadium prices in 2018, slow implementation of new rebar standards in China, higher expectations of VRFBs than materialized, and substitution of niobium for vanadium by Chinese steel mills was responsible for a decline in global vanadium consumption in 2019. High vanadium prices led some mills to switch to ferroniobium in 2018. However, niobium substitution has its limits because niobium has a lower solubility than vanadium, making it an imperfect substitute. As a result of these factors, prices for both V_2O_5 and FeV rapidly decreased in 2019. Only a very small amount of vanadium is openly traded, therefore causing a perception of volatility in the small amount of vanadium that is traded and, in turn, easily creating rapid price fluctuations.

The World Steel Association forecast global steel consumption to increase by 1.0% in 2020, following an increase of 1.3% in 2019 (World Steel Association, 2019). Because almost all vanadium is consumed in the production of steel, consumption trends are greatly influenced by trends in steel production; however, the use of vanadium in a wider range of steels has continued to increase. The outlook for consumption in nonferrous alloys is largely dependent on trends in consumption for titanium alloys in business, commercial, and military aircraft.

In addition to continued growth in vanadium consumption from the steel sector, another area of anticipated growth was in the energy storage market, specifically with VRFBs. China, India, and the United States are expected to account for two-thirds of the global renewable energy expansion to 2022. All European Union countries have adopted national renewable energy action plans showing what actions they intend to take to meet their renewable energy targets (European Commission, undated). Many countries are seeking to meet renewable energy targets by 2022 or earlier and VRFB storage is proving to be a potential solution, with many countries having numerous implementations already underway. However, the growth of VRFB implementation has been slower than originally anticipated. The major disadvantages of VRFBs include the high cost of the vanadium electrolyte used in the battery and the system complexity of the batteries. These factors make it difficult for VRFBs to compete with lithium-ion batteries. The market leader in flow battery chemistry is vanadium, but researchers continue to work on other chemistries that could potentially be less expensive. Companies are expected to continue to improve VRFBs to make them more competitive in the battery market.

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TABLE 1
SALIENT VANADIUM STATISTICS[1]

(Metric tons, vanadium content, unless otherwise specified)

	2015	2016	2017	2018	2019
United States:					
Production, ore and concentrate, recoverable vanadium	--	--	--	--	460
Consumption, reported	4,700 r	4,610 r	4,670 r	5,640 r	4,840
Imports for consumption:					
Vanadium ores and concentrates	72	18	1	330	108
Ferrovanadium	1,980	1,590	2,810	2,970 r	2,280
Vanadium pentoxide (anhydride)	2,870	2,460	3,400	4,600	3,660
Oxides and hydroxides, other	94	660	148	98	105
Aluminum-vanadium master alloy	143	157	288	281	222
Ash and residues[2]	4,600	2,820	2,540	2,810	2,120
Hydrides and nitrides, of vanadium	106	82	173	72	54
Sulfates	13	12	4	9	73
Vanadates	173	313	349	389	73
Vanadium metal	135	33	54	28	45
Total imports	10,200	8,150	9,770	11,600 r	8,730
Exports:					
Vanadium ores and concentrates	166	260	37	29	57
Ferrovanadium	122	394 r	229	575	295
Vanadium pentoxide (anhydride)	356	5	126	563	423
Oxides and hydroxides, other	100	81	148	53	750
Aluminum-vanadium master alloy[3]	229	95	236	161	51
Ash and residues[2, 3]	370 r	1,100	2,870	2,580 r	2,280
Vanadium metal	5	19	59	39	27
Stocks, yearend:					
Ferrovanadium	148 r	144 r	166 r	188 r	197
Other[4]	62 r	63 r	61 r	62 r	60
World, production from ore, concentrate, slag	85,700 r	78,200 r	85,900 r	83,500 r	86,800

rRevised. -- Zero.

[1]Table includes data available through July 7, 2020. Data are rounded to no more than three significant digits; may not add to totals shown. Includes U.S. Geological Survey estimates.

[2]Not from the manufacture of iron and steel.

[3]Gross weight.

[4]Includes vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, vanadates, chlorides, and other specialty chemicals.

TABLE 2
U.S. REPORTED CONSUMPTION OF VANADIUM, BY END USE AND FORM[1]

(Kilograms, vanadium content)

	2018	2019
End use:		
Steel:		
Carbon	798,000	763,000
Full alloy	1,270,000	1,260,000
High-strength low-alloy	W	W
Stainless and heat resisting	62,700	63,100
Tool	W	W
Total	2,130,000	2,090,000
Cast irons	W	W
Alloys (including steels and superalloys)	2,440,000	1,690,000
Chemical and ceramic:		
Catalysts	W	W
Pigments	W	W
Miscellaneous and unspecified[2]	1,080,000 r	1,060,000
Grand total	5,640,000 r	4,840,000
Form:		
Ferrovanadium	3,140,000 r	3,090,000
Other[3]	2,500,000	1,750,000
Total	5,640,000 r	4,840,000

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

[1]Table includes data available through July 7, 2020. Data are rounded to no more than three significant digits; may not add to totals shown. Includes U.S. Geological Survey estimates.

[2]Includes electrical steel and unspecified steel.

[3]Includes vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, vanadates, chlorides, and other specialty chemicals.

TABLE 3

U.S. IMPORTS AND EXPORTS OF FERROVANADIUM, VANADIUM PENTOXIDE (ANHYDRIDE), AND OTHER OXIDES AND HYDROXIDES OF VANADIUM[1]

(Kilograms)

	Ferrovanadium[2]			Vanadium pentoxide (anhydride)[3]			Other oxides and hydroxides of vanadium[4]		
Country or locality	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value
Imports for consumption:									
2018	4,010,000 r	2,970,000 r	$233,000,000 r	4,700,000	4,600,000	$169,000,000 r	149,000	97,600	$5,450,000
2019:									
Austria	755,000	565,000	24,000,000	--	--	--	--	--	--
Brazil	--	--	--	2,110,000	1,980,000	53,200,000	--	--	--
Canada	1,270,000	970,000	64,500,000	--	--	--	--	--	--
China	--	--	--	92,300	52,900	2,310,000	--	--	--
Czechia	(5)	(5)	45,800,000	--	--	--	--	--	--
Germany	10,400	8,320	425,000	150,000	139,000	4,980,000	1	1	3,650
India	11,000	5,750	429,000	--	--	--	--	--	--
Japan	460,000	238,000	11,400,000	--	--	--	--	--	--
Korea, Republic of	--	--	--	40,000	39,300	2,470,000	--	--	--
Latvia	219,000	103,000	4,960,000	--	--	--	--	--	--
Russia	200,000	151,000	4,990,000	220	198	2,850	--	--	--
South Africa	--	--	--	1,430,000	1,370,000	45,500,000	162,000	105,000	6,840,000
Sweden	2,000	1,610	84,800	--	--	--	--	--	--
Switzerland	--	--	--	1,920	1,920	51,100	--	--	--
Taiwan	--	--	--	65,300	63,400	1,150,000	--	--	--
Thailand	--	--	--	10,000	5,490	331,000	--	--	--
Ukraine	474,000	233,000	11,400,000	--	--	--	--	--	--
Total	3,400,000	2,280,000	168,000,000	3,910,000	3,650,000	110,000,000	162,000	105,000	6,840,000
Exports:									
2018	820,000	575,000	20,900,000	XX	563,000	6,070,000	XX	53,200	480,000
2019:									
Australia	--	--	--	NA	407	3,860	NA	847	7,540
Austria	--	--	--	--	--	--	NA	24,100	214,000
Canada	55,400	41,500	1,540,000	--	--	--	NA	80,100	731,000
Chile	3,040	1,750	82,500	--	--	--	--	--	--
China	--	--	--	NA	241,000	4,910,000	NA	18,800	64,700
Colombia	14,000	10,500	388,000	--	--	--	--	--	--
Czechia	--	--	--	NA	274	2,610	--	--	--
Germany	--	--	--	NA	49,600	460,000	NA	46,600	415,000
India	45,300	34,000	320,000	NA	98,300	703,000	--	--	--
Korea, Republic of	2,860	2,150	111,000	--	--	--	--	--	--
Mexico	315,000	205,000	8,160,000	NA	987	19,900	--	--	--
Netherlands	--	--	--	--	--	--	NA	562,000	5,680,000
New Zealand	--	--	--	--	--	--	NA	1,810	8,330
Saudi Arabia	--	--	--	NA	1,530	14,500	--	--	--
Trinidad and Tobago	--	--	--	NA	31,100	295,000	NA	14,800	163,000
Total	436,000	295,000	10,600,000	XX	423,000	6,410,000	XX	750,000	7,280,000

[r]Revised. NA Not available. XX Not applicable. -- Zero.

[1]Table includes data available through June 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes Harmonized Tariff Schedule of the United States (HTS) code and Schedule B number 7202.92.0000.

[3]May include catalysts that contain vanadium pentoxide. HTS code and Schedule B number 2825.30.0010.

[4]Includes HTS code and Schedule B number 2825.30.0050.

[5]Data suppressed by the U.S. Census Bureau; not included in "Total."

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS AND EXPORTS OF ALUMINUM-VANADIUM MASTER ALLOY
AND VANADIUM METAL, INCLUDING WASTE AND SCRAP[1]

(Kilograms)

	Aluminum-vanadium master alloy[2]			Vanadium metal, including waste and scrap[3]		
Country or locality	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value
Imports for consumption:						
2018	431,000	281,000	$17,200,000	37,400	28,400	$2,210,000
2019:						
Belgium	--	--	--	2,750	2,750	210,000
China	26,700	17,600	990,000	9,810	7,610	629,000
Czechia	5	5	5,360	8	7	3,900
France	--	--	--	17	15	7,500
Germany	6,050	4,910	251,000	44,200	33,200	2,940,000
Latvia	--	--	--	989	918	303,000
Mexico	2,610	2,140	75,000	--	--	--
Netherlands	14,200	11,400	148,000	--	--	--
Russia	283,000	186,000	16,200,000	--	--	--
United Kingdom	3	3	11,900	--	--	--
Total	332,000	222,000	17,600,000	57,800	44,500	4,100,000
Exports:						
2018	161,000	XX	7,910,000	XX	39,400	2,600,000
2019:						
Australia	1,140	NA	146,000	NA	4,280	535,000
Bahamas, The	94	NA	2,560	--	--	--
Brazil	--	--	--	NA	67	2,570
Chile	66	NA	2,540	--	--	--
China	491	NA	18,700	--	--	--
Czechia	184	NA	7,110	--	--	--
France	7,370	NA	414,000	NA	2,710	207,000
Germany	852	NA	134,000	NA	2,460	95,000
Ireland	525	NA	14,700	--	--	--
Italy	--	--	--	NA	176	6,770
Japan	10,800	NA	939,000	NA	17,300	831,000
Peru	200	NA	7,170	--	--	--
Russia	24,500	NA	1,020,000	--	--	--
Spain	978	NA	33,700	--	--	--
Switzerland	72	NA	2,780	--	--	--
United Kingdom	3,870	NA	156,000	--	--	--
Total	51,200	XX	2,900,000	XX	27,000	1,680,000

NA Not available. XX Not applicable. -- Zero.

[1]Table includes data available through June 23, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium. Includes Harmonized Tariff Schedule of the United States (HTS) code and Schedule B number 8112.99.2000.

[3]Vanadium metal, including waste and scrap. Includes HTS code and Schedule B number 8112.92.7000.

Source: U.S. Census Bureau.

TABLE 5

U.S. IMPORTS AND EXPORTS OF VANADIUM-BEARING ASH AND RESIDUES[1, 2]

(Kilograms)

	2018			2019		
Country or locality	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value
Imports for consumption:						
Belgium	128,000	19,700	$282,000	--	--	--
Canada	23,900,000	2,350,000	57,600,000	20,600,000	2,020,000	$57,600,000
Curacao	--	--	--	582,000	66,000	869,000
Kuwait	--	--	--	172,000	7,950	114,000
Mexico	2,830,000	429,000	5,790,000	--	--	--
Qatar	79,400	9,590	138,000	--	--	--
Trinidad and Tobago	96,100	5,380	71,200	--	--	--
Venezuela	--	--	--	58,700	28,000	200,000
Total	27,000,000	2,810,000	63,900,000	21,400,000	2,120,000	58,800,000
Exports:						
Belgium	338,000	NA	147,000	--	--	--
France	270,000	NA	155,000	839,000	NA	858,000
Germany	176,000	NA	108,000	1,350,000	NA	687,000
India	118,000	NA	80,600	--	--	--
Italy	19,300	NA	52,100	19,700	NA	41,600
Japan	443,000	NA	199,000	--	--	--
Korea, Republic of	389,000	NA	314,000	--	--	--
Mexico	804,000	NA	647,000	76,400	NA	280,000
United Arab Emirates	20,000	NA	50,000	--	--	--
United Kingdom	905	NA	5,000	--	--	--
Total	2,580,000 r	XX	1,760,000 r	2,280,000	XX	1,870,000

[r]Revised. NA Not available. XX Not applicable. -- Zero.

[1]Table includes data available through June 1, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes Harmonized Tariff Schedule of the United States codes 2620.40.0030 and 2620.99.1000 for imports and Schedule B numbers 2620.50.0000 and 2620.99.1000 for exports.

Source: U.S. Census Bureau.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS VANADIUM CHEMICALS[1]

(Kilograms)

	2018			2019		
Material and country or locality[2]	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value
Sulfates:						
Austria	4,200	4,200	$48,500	--	--	--
China	7,900	5,070	70,200	7,030	4,390	$42,200
Finland	--	--	--	79,500	69,000	581,000
Japan	160	100	5,130	--	--	--
Total	12,300	9,370	124,000	86,600	73,400	623,000
Vanadates:						
Austria	114,000	57,800	2,500,000	--	--	--
China	120,000	97,800	4,400,000	13,200	8,620	363,000
Germany	19,900	7,120	426,000	14,700	5,840	433,000
Hong Kong	5,000	500	160,000	--	--	--
India	127	45	11,600	26	18	13,600
Japan	271	168	11,400	364	209	21,000
Russia	--	--	--	5	2	2,200
South Africa	2,150	1,550	76,100	29,300	20,800	813,000
Taiwan	340,000	222,000	9,790,000	54,000	35,200	1,480,000
United Kingdom	5,700	2,310	86,100	5,700	2,230	144,000
Total	608,000	389,000	17,500,000	117,000	72,900	3,260,000

-- Zero.

[1]Table includes data available through June 1, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes Harmonized Tariff Schedule of the United States codes 2833.29.3000 and 2841.90.1000.

Source: U.S. Census Bureau.

TABLE 7

VANADIUM: WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1, 2]

(Metric tons, vanadium content)

Country or locality	2015	2016	2017	2018	2019
Brazil	3,254	4,461	5,206	5,500	5,936
China	48,700 r	48,700 r	54,100 r	53,200 r	54,000 e
Russia, metallurgical	16,000 e	16,886 r	18,636 r	17,052 r	18,400
South Africa	17,788	8,163	7,959	7,700	8,030
United States	--	--	--	--	460
Total	85,700 r	78,200 r	85,900 r	83,500 r	86,800

eEstimated. rRevised. -- Zero.

[1]Table includes data available through May 20, 2020. All data are reported unless otherwise noted. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Canada, Germany, Japan, and several other European countries continued to recover vanadium from petroleum residues, but available information was insufficient to make reliable estimates.