2017 Minerals Yearbook

VANADIUM [ADVANCE RELEASE]

U.S. Department of the Interior
U.S. Geological Survey

February 2020

Vanadium

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In 2017, the United States continued to be a major producer of vanadium products from secondary sources such as spent catalysts, ashes, and petroleum residues. The United States was 100% import reliant for vanadium, and total imports for consumption (measured in vanadium content) increased by 19% from those of 2016 (table 1). The United States imported 2,810 metric tons (t) of ferrovanadium (FeV), 3,400 t of vanadium pentoxide (V_2O_5), and 148 t of other oxides and hydroxides of vanadium (measured in vanadium content), collectively valued at $157 million (table 3). Imports of aluminum-vanadium master alloys and vanadium metal, including waste and scrap, were 342 t of contained vanadium valued at $13.4 million (table 4). Imports of ash and residues were 2,530 t of contained vanadium valued at $15 million (table 5) and imports of vanadium chemicals were 349 t of contained vanadium valued at $6 million (table 6).

The United States exported 229 t of FeV (vanadium content), 127 t of V_2O_5 (gross weight), and 148 t (gross weight) of other oxides and hydroxides of vanadium, collectively valued at $9.3 million (table 3). Exports of aluminum-vanadium master alloy and vanadium metal, including waste and scrap, were 295 t (gross weight) valued at $8.5 million (table 4). Exports of ash and residues were 2,870 t (gross weight) valued at $1 million (table 5). Reported vanadium consumption in the United States was 3,880 t of contained vanadium, a slight increase from reported consumption in 2016 (table 1). In 2017, estimated worldwide production of vanadium slightly increased to 71,200 t of contained vanadium compared with the revised 69,600 t in 2016 (tables 1, 7).

Vanadium's primary use was as a hardening agent in steel, in which 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 microalloy or low-alloy steels that generally contain less than 0.15% vanadium and high-alloy steels that contain as much as 5% vanadium. Catalysts are the leading nonmetallurgical use for vanadium.

Legislation and Government Programs

In March 2017, the International Trade Administration of the U.S. Department of Commerce determined that imports of ferrovanadium from the Republic of Korea were, or were likely to be, sold at less than fair value following a period of investigation from January 1, 2015, through December 31, 2015 (International Trade Administration, 2017b). Following this determination, an antidumping order was issued with antidumping rates of 54.69% applied to imports of FeV from Fortune Metallurgical Group Co., Ltd. and Woojin Ind. Co., Ltd. and 3.22% applied to all other FeV exporters and producers from the Republic of Korea. The product covered by this order included all FeV, regardless of chemistry, form, grade, shape, or size. The case was initiated by the U.S. Department of Commerce following a March 2016 petition from the U.S. Vanadium Producers and Reclaimers Association (International Trade Administration, 2017a).

Production

Industry convention for describing the production of V_2O_5 usually applies the terms primary production, coproduction, and secondary production according to the raw material source for production. Primary production occurs from mined ore as mineral concentrates derived from vanadiferous titanomagnetite (VTM). Coproduction refers to vanadium slags that are produced during steelmaking. When a VTM 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 production occurs from various industrial waste materials, such as vanadium-bearing fly ash, petroleum residues, and spent catalysts. Secondary vanadium production was the only source of U.S. vanadium production in 2017, taking place primarily in Arkansas, 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 are aluminum-vanadium master alloys; FeV; vanadium-bearing ash, residues, and slag; vanadium chemicals; and V_2O_5 and other oxides and hydroxides of vanadium. Vanadium oxides are 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 2017, companies in the United States produced all these materials, except vanadiferous slag from the manufacture of iron and steel.

Energy Fuels Inc.'s (Toronto, Ontario, Canada) White Mesa Mill, near Blanding, UT, has the only vanadium joint product recovery circuit in the United States. It has not produced vanadium since 2013 owing to low vanadium prices (Energy Fuels Inc., undated).

In May, Prophecy Development Corp. (Vancouver, British Columbia, Canada) entered into a binding agreement to acquire, through a lease, the Gibellini vanadium project in Eureka County, NV, with the intent to carry out mining operations at the property. The project was previously owned by American Vanadium Corp., which was unable to raise the required cash to sustain operations. Under the agreement, Prophecy was expected to lease the mining claims by paying yearly advanced royalty claims based on the average V_2O_5 price of the prior year. The lease was expected to be for a term of 10 years. A 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).

EVRAZ Stratcor, owned by EVRAZ plc, 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. Stratcor has the capacity to produce up to approximately 5,400 t/yr of vanadium oxide. Some of this oxide is then converted into an aluminum-vanadium alloy that meets the requirements of titanium alloys used in jet aircraft and other aerospace applications. The Hot Springs facility also converts the vanadium oxide into many other specialty products that play an important role in the production of chemicals, gases, and storage batteries (EVRAZ plc, undated c). EVRAZ consisted of EVRAZ Nikom in Czechia, EVRAZ Stratcor in the United States, and Vanady Tula in Russia (EVRAZ plc, undated a).

AMG Vanadium, a wholly owned subsidiary of Advanced Metallurgical Group in Cambridge, OH, was a major producer of FeV and other ferroalloys from spent oil refinery catalysts and powerplant residues (AMG Vanadium, undated). Kennametal International Specialty Alloys Inc. produced FeV and vanadium master alloys in New Castle, PA. In 2017, Gulf Chemical and Metallurgical Corp., a subsidiary of Eramet Group, was acquired by Gladieux Metals Recycling LLC (Bloomberg, 2018). Gladieux has a processing facility for spent petroleum catalysts at its Freeport plant in Texas (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 60 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 2017, accounting for 95% of reported consumption (table 2). Nonmetallurgical applications included batteries, catalysts, ceramics, electronics, and vanadium chemicals. The dominant 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 is consumed in the form of FeV, which is used to introduce vanadium into steel to provide additional strength and toughness. In 2017, 3,050 t of FeV was consumed, representing 79% of the total amount of the reported vanadium consumed (table 2). Ferrovanadium 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 is becoming more widely used in green technology applications, especially in battery technology. Vanadium redox batteries (VRBs) are being installed for commercial energy storage across Africa, Asia, Europe, and North America. The main advantages of the VRB are that it can offer almost unlimited capacity simply 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. The U.S.-based manufacturers, all at different levels of establishing VRB production lines, included Ashlawn Energy, LLC; StorEn Technologies Inc.; UniEnergy Technologies, LLC; United Technologies Corp.; Vionx Energy Corp.; and Willey Battery Utility, LLC.

StorEn Technologies Inc. (New York) and Multicom Resources Pty Ltd. (Queensland, Australia) entered into an agreement to establish a vertically integrated supply chain model for the low-cost manufacturing, sale, and distribution of StorEn VRBs. StorEn has made technological improvements to the standard VRBs to increase overall battery density to develop a VRB that was suitable for households. The company announced that the StorEn household VRBs would be safer, significantly cheaper, longer lasting, and more environmentally friendly than lithium-based batteries. The home battery would charge using electricity generated from solar panels. The binding agreement with Multicom, which is seeking to develop the Saint Elmo vanadium project in Australia, secured the company with a supply of V_2O_5 at a long-term fixed price. The main hurdle for widespread adoption of VRBs continued to be the ability of VRB manufacturers to secure a stable long-term supply of V_2O_5 (StorEn Technologies Inc., 2017, p. 2–4).

Prices

In 2017, the U.S. average monthly price for domestic FeV, as published by CRU Group, ranged from $12.178 to $21.101 per pound of contained vanadium, compared with $5.950 to $11.520 per pound reported in 2016. In 2017, the European average monthly price for FeV ranged from $24.681 to $42.219 per kilogram, compared with $14.225 to $23.156 per kilogram in 2016. The average monthly price for domestic V_2O_5 published by CRU Group ranged from $4.900 to $5.200 per pound from January through June 2017, compared with $2.784 to $4.650 per pound in 2016. CRU Group discontinued publishing U.S. V_2O_5 prices as of August 1, 2017.

The U.S. average price of ferrovanadium increased from $12.691 to $19.125 per pound from July to August. This 51% increase was due to a combination of maintenance at the Panzhihua Steel furnace that took place in July and August, which decreased V_2O_5 production by approximately 300 to 400 metric tons per month (t/mo), and a decrease in vanadium production in July and August owing to China's continued environmental protection efforts. Many V_2O_5 producers have signed long-term c supply contracts because when vanadium production decreases, the already limited vanadium supply affects FeV producers the most. Ferrovanadium prices continued to remain high, peaking at $20.250 per pound in December, as China continued enforcement of its environmental regulations causing many vanadium producers to remain either closed or operating at significantly lower levels than previously (Ferroalloynet, 2017).

World Review

Most of the world's supply of vanadium was derived from either primary or joint production. Production from these two sources is shown in table 7. The leading vanadium-producing nations remained China, Russia, and South Africa; these countries provided more than 90% of world production. Secondary production in Canada, Germany, Japan, and the United States, as well as several other European countries, continued.

World vanadium reserves, estimated at more than 15 million metric tons, 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.—In November, Multicom submitted an environmental impact statement to the Queensland Government outlining its details for developing the Saint Elmo vanadium project, 25 kilometers (km) east of Julia Creek, Queensland. The project had estimated production of 50,000 t/yr of V_2O_5 with a 30-year mine life (Epic Environmental Pty Ltd., 2018, p. 1).

Brazil.—Largo Resources Ltd.'s (Toronto, Ontario, Canada) Maracas Menchen Mine, located 813 km northeast of Brasilia, produced 9,300 t of V_2O_5 in 2017, a 16% increase compared with the 8,000 t of V_2O_5 produced in 2016. Annual production capacity was expected to be 9,634 t/yr of V_2O_5 (Largo Resources Ltd., 2018). According to the company, the vanadium is contained within a massive titaniferous magnetite deposit that has much higher grades of V_2O_5 and iron than any other vanadium deposit in the world. The very low level of contaminants in the deposit, particularly silica, was expected to make the extraction and processing of vanadium much easier. This in turn was expected to lower operating costs and produce superior concentrate (Largo Resources, undated). Largo has an offtake agreement with Glencore International plc for 100% of its material for the first 6 years of operation (Largo Resources Ltd., 2017). In the first two quarters of 2018, Largo was expected to focus on stabilizing monthly production and performance following a series of improvements in maintenance and production practices in January and February 2018. The company anticipated production would be approximately 800 t/mo of V_2O_5 from March through December 2018 (Largo Resources Ltd., 2018).

Canada.—In December, VanadiumCorp Resource Inc. (Vancouver) announced the successful completion of Phase II of its production trials at the Electrochem Technologies & Materials Inc. facilities in Boucherville, Quebec. According to Electrochem, Phase II resulted in the efficient processing of a variety of feedstocks using chemical technology that other related industries are unable to use. Electrochem announced that the successful production of a battery-ready electrolyte was established (VanadiumCorp Resource Inc., 2017).

China.—Many vanadium producers in the Panzhihua Vanadium and Titanium High-Tech Industrial Development Zone continued to suspend or decrease vanadium production owing to local governments conducting environmental inspections following the discovery of polluted water in the Jinsha River in Panzhihua. Tighter environmental controls also were expected in other vanadium-producing regions.

In February, the Standardization Administration of China (SAC) released a new high strength rebar standard that would decrease the use of substandard steels in construction to make buildings in China more earthquake resistant. The implementation date for the new standard was expected to be November 1, 2018. The new rebar standard would eliminate the low strength Grade 2 rebar and the SAC authorized Grade 3, Grade 4, and Grade 5 high strength standards. The newly authorized standards would have 0.03% vanadium content in Grade 3, 0.06% vanadium content in Grade 4, and more than 0.1% vanadium content in Grade 5 rebar. The increase of vanadium in rebar was expected to increase the overall consumption of vanadium in China by approximately 10,000 t/yr (Metal Bulletin, 2017). However, this consumption increase estimate was expected to vary depending on the enforcement of these new rebar standards (Vanitec Ltd., 2018).

In August, it was announced that 24 types of materials, including vanadium slag, would be prohibited from entering China. The announcement was issued by five agencies, including the Ministry of Environmental Protection and the Ministry of Commerce, in an effort to comply with new environmental regulations. The ban on vanadium slag imports was expected to reduce the amount of raw material available for Chinese V_2O_5 production (Metal-Pages, 2017; EVRAZ plc, 2018, p. 24; Metal Bulletin, 2018).

China-based VRB companies included Dalian Rongke Power Co. Ltd., Golden Energy Century Ltd., Golden Energy Fuel Corp., Pu Neng Energy, and Shanghai Shen-Li High Tech Co. Ltd. According to the company, Shanghai Shen-Li High Tech was funded by the Ministry of Science and Technology of China and financially supported by the Shanghai municipal government (Shanghai Shen-Li High Tech Co., Ltd., undated).

In September, the China National Development and Reform Commission published a document that called for more investment in energy storage, specifically flow batteries. One such battery flow system was the 800-megawatthour vanadium flow battery project being built on the Dalian Peninsula in northern China. The project, built by Uni Energy Technologies (Seattle, Washington) and Rongke Power, was expected to come online in 2020. The facility was expected to help balance the power grid, which served approximately 40 million people. Wind generation in the region was approximately 15% of total power generation, but much of the wind power was not being used because other power sources already met grid demand. The Dalian project was expected to store any unused wind energy for later use rather than wasting the power (Yang, 2017).

Czechia.—Nikom (part of EVRAZ plc) had an FeV production capacity of 4,600 t/yr. Nikom had one processing facility, which was used to process V_2O_5 from Russia and China and also vanadium trioxide from Vametco into FeV (EVRAZ plc, undated 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 VTM. The Vanady Tula facility, located 200 km south of Moscow, used low-cost, highly efficient technology to process the vanadium slag produced by NTMK (EVRAZ plc, undated d). Vanady Tula had a capacity of 5,000 t/yr of FeV and 7,500 t/yr of V_2O_5 in its electrometallurgical and hydrometallurgical plants (EVRAZ plc, 2016, p. 62).

South Africa.—On April 13, 2015, EVRAZ Highveld Steel and Vanadium Ltd. plant was placed under business rescue procedures to avoid liquidation. In February 2017, EVRAZ announced that it would seek to sell individual components of the company (Mining Weekly, 2017). In June, ArcelorMittal South Africa and Highveld Structural Mill Pty Ltd. (a subsidiary of EVRAZ Highveld Steel and Vanadium Ltd.) officially restarted the heavy structural mill. The terms of their agreement were that ArcelorMittal would provide the raw steel and Highveld would toll process the final product. The remainder of the plant was transformed into the Highveld Industrial Park which consisted of 17 businesses that have rented the space. Highveld further expected to sell the two iron plants, the steel plant, and the flat products mill. The park also had a fully equipped vanadium slag crushing plant, which was designed to process vanadium from titaniferous ore deposits, that was currently being rented (Engineering News, 2017).

In September, the Mapochs Mine was auctioned off and purchased by International Resources Ltd. (Hong Kong, China). The Mapochs Mine is an open pit mine near Roosemekal in the Mpumalanga Province. Vanchem Vanadium Products Pty Ltd. (eMalahleni) stopped production in May 2015 after its raw material supplier, the Mapochs Mine, went into business rescue along with its owner, EVRAZ Highveld (Metal-Pages, 2015). The mine's right to extract magnetite ore that contained vanadium and iron ore was sold along with variety of mining equipment, mining infrastructure, and various residential properties (Mining Weekly, 2017).

In November, Bushveld Minerals Ltd. announced the completion of its acquisition of Bushveld Vametco Ltd. Through this acquisition, Bushveld Minerals was expected to own a 78.8% interest in Strategic Minerals Corp. Strategic Minerals, in turn held a 75% interest in Vametco Holdings, which had a 100% interest in the Vametco vanadium mine and plant in Brits, North West Province. Vametco produced 1,440 t of contained vanadium in the form of vanadium nitride and vanadium oxide in the first 6 months of 2017. Production in 2016 was 2,800 t of contained vanadium. Vametco had the capacity of approximately 3,000 t/yr of contained vanadium. Vametco commenced a multiphased expansion project to increase annual production to more than 5,000 t/yr over the next 3 to 5 years. Phase I of the expansion project was expected to be completed in September 2017 with production capacity of approximately 3,040 t/yr of contained vanadium. Vametco used the standard salt roast and leach process to produce a trademark vanadium carbon nitride product called Nitrovan (Bushveld Minerals Ltd., 2017, p. 6, 12).

Glencore plc (Baar, Switzerland) announced that its Rhovan vanadium facility, 30 km northwest of Brits, produced 9,480 t of V_2O_5 in 2017, essentially unchanged compared with 9,570 t of V_2O_5 produced in 2016 (Glencore plc, 2018, p. 69).

Outlook

China's continued commitment to reduce pollution resulted in a reduction of local vanadium production and lower vanadium exports from China. At the same time, vanadium demand in China was expected to increase following a revision to its standards of rebar products. The new Chinese standards would increase the vanadium content in rebar products, which was expected to increase Chinese vanadium consumption. Some Chinese vanadium producers could forgo their annual supply agreements with foreign buyers to prioritize domestic vanadium sales.

The World Steel Association forecast global steel consumption to increase by 1.8% in 2018, followed by an increase of 0.7% in 2019 (World Steel Association, 2018). 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 growth from the steel sector, one area of continued growth was in the energy storage market, specifically with VRBs. China, the United States, and India were 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 VRB storage is proving to be a potential solution, with many countries having numerous implementations already underway. According to the U.S. Department of Energy's global energy storage database, 59 VRB storage projects in 16 countries began construction or were in operation as of May 2018 (U.S. Department of Energy, undated).

Some disadvantages of VRBs include the high cost of the vanadium electrolyte used in the battery, as well as the system complexity of the batteries. These factors make it difficult for VRBs to compete with lithium-ion batteries. The market leader in flow battery chemistry was vanadium, but researchers continued to work on other chemistries that could potentially be less expensive. Companies were expected to continue to improve the safety and environmental profile of the VRB batteries to make them more competitive in the battery market (Maloney, 2017).

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TABLE 1
SALIENT VANADIUM STATISTICS[1]

(Metric tons of contained vanadium, unless otherwise specified)

	2013	2014	2015	2016	2017
United States:					
Production, ore and concentrate, recoverable vanadium[2]	591	--	--	--	--
Consumption, reported	3,980	4,070	3,930	3,830	3,880
Imports for consumption:					
Ferrovanadium	3,710	3,230	1,980	1,590	2,810
Vanadium pentoxide (anhydride)	2,040	3,410	2,870	2,460	3,400
Oxides and hydroxides, other	205	104	94	660	148
Aluminum-vanadium master alloy	124	320	143	157	288
Ash and residues[3]	2,340 r	3,450 r	4,600 r	2,820 r	2,540
Sulfates	30	19	13	12	4
Vanadates	276	197	173	313	349
Vanadium metal	32	117	135	33	54
Total imports	8,760	10,800	10,000	8,050	9,590
Exports:					
Ferrovanadium	299	253	122	400	229
Vanadium pentoxide (anhydride)[4]	90	201	356	5	127
Oxides and hydroxides, other[4]	407	350	100	81	148
Aluminum-vanadium master alloy[4]	347	443	229	95	236
Ash and residues[3, 4]	4,000	2,300	370	1,100	2,870
Vanadium metal[4]	58	32	5	19	59
Total exports	XX	XX	XX	XX	XX
Stocks, yearend:					
Ferrovanadium	93	100	96	98	87
Other[5]	73	70	70	70	68
World, production from ore, concentrate, slag	81,400	85,300 r	82,000 r	69,600 r	71,200

[r]Revised. XX Not applicable. -- Zero.
[1]Table includes data available through July 25, 2018. Data are rounded to no more than three significant digits.
[2]Source: Energy Fuels Inc. website in 2013.
[3]Not from the manufacture of iron and steel.
[4]Gross weight.
[5]Includes aluminum-vanadium 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, 2]

(Kilograms of contained vanadium)

	2016	2017
End use:		
Steel:		
Carbon	718,000	755,000
Full alloy	1,460,000	1,470,000
High-strength low-alloy	W	W
Stainless and heat resisting	61,400	62,400
Tool	W	W
Total	2,240,000	2,280,000
Cast irons	W	W
Superalloys	10,400	8,580
Alloys (excluding steels and superalloys):		
Welding and alloy hard-facing rods and materials	W	W
Other[3]	W	W
Chemical and ceramic:		
Catalysts	W	W
Pigments	W	W
Miscellaneous and unspecified[4]	1,580,000	1,590,000
Grand total	3,830,000	3,880,000
Form:		
Ferrovanadium	3,000,000	3,050,000
Other[5]	830,000	831,000
Total	3,830,000	3,880,000

W Withheld to avoid disclosing company proprietary data; included with "End use: Miscellaneous and unspecified."
[1]Table includes data available through July 25, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes U.S. Geological Survey estimates.
[3]Includes magnetic alloys.
[4]Includes electrical steel and unspecified steel.
[5]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	Contained weight	Value	Gross weight	Contained weight	Value	Gross weight	Contained weight	Value
Imports for consumption:									
2016	2,220,000	1,590,000	$47,800,000	2,940,000	2,460,000	$25,400,000	1,020,000	660,000	$10,000,000
2017:									
Austria	1,810,000	1,360,000	36,900,000	--	--	--	84,000	56,400	1,270,000
Brazil	--	--	--	1,180,000	1,090,000	17,000,000	--	--	--
Canada	767,000	616,000	16,500,000	--	--	--	--	--	--
China	--	--	--	498,000	394,000	7,030,000	--	--	--
Czechia	(5)	(5)	19,000,000	--	--	--	--	--	--
Germany	--	--	--	139,000	128,000	2,530,000	2	2	8,110
India	46,500	36,500	815,000	--	--	--	--	--	--
Japan	80,000	40,000	813,000	--	--	--	--	--	--
Korea, Republic of	--	--	--	40,000	39,300	660,000	--	--	--
Latvia	10,300	6,400	428,000	--	--	--	--	--	--
Russia	1,160,000	755,000	18,400,000	--	--	--	--	--	--
South Africa	--	--	--	1,580,000	1,430,000	24,100,000	140,000	91,700	2,400,000
Taiwan	--	--	--	586,000	327,000	9,030,000	--	--	--
Total	3,880,000	2,810,000	92,800,000	4,020,000	3,400,000	60,300,000	224,000	148,000	3,680,000
Exports:									
2016	533,000	400,000	7,280,000	5,150	NA	108,000	81,300	NA	681,000
2017:									
Argentina	--	--	--	900	NA	39,400	--	--	--
Australia	--	--	--	14,100	NA	263,000	--	--	--
Austria	--	--	--	9,380	NA	180,000	38,800	NA	363,000
Canada	27,700	20,800	672,000	--	--	--	28,900	NA	390,000
Chile	2,000	1,620	72,900	--	--	--	--	--	--
China	19,000	14,300	141,000	5,260	NA	50,000	2,650	NA	11,500
Colombia	904	497	21,100	--	--	--	--	--	--
Czechia	--	--	--	294	NA	2,800	--	--	--
Ecuador	11,000	8,460	238,000	--	--	--	--	--	--
France	--	--	--	2,000	NA	35,100	--	--	--
Germany	--	--	--	8,970	NA	165,000	6,180	NA	55,000
India	20,000	15,000	200,000	68,400	NA	485,000	--	--	--
Italy	--	--	--	9,000	NA	153,000	--	--	--
Korea, Republic of	17,900	13,500	570,000	--	--	--	--	--	--
Malaysia	--	--	--	326	NA	3,100	--	--	--
Mexico	86,500	67,100	1,890,000	139	NA	3,600	--	--	--
Netherlands	111,000	84,800	2,060,000	6,000	NA	111,000	68,300	NA	852,000
Peru	4,020	3,040	139,000	--	--	--	--	--	--
Thailand	--	--	--	800	NA	27,600	--	--	--
Trinidad and Tobago	--	--	--	1,090	NA	44,000	2,820	NA	22,400
United Arab Emirates	--	--	--	502	NA	4,770	--	--	--
Total	300,000	229,000	6,000,000	127,000	XX	1,570,000	148,000	XX	1,690,000

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

[1]Table includes data available through July 25, 2018. 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 7202.92.0000.

[3]May include catalysts that contain vanadium pentoxide. Includes HTS code 2825.30.0010.

[4]Includes HTS code 2825.30.0050.

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

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS AND EXPORTS OF ALUMINUM-VANADIUM MASTER ALLOYS
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	Contained weight	Value	Gross weight	Contained weight	Value
Imports for consumption:						
2016	235,000	157,000	$4,120,000	45,300	33,200	$1,040,000
2017:						
China	130,000	89,100	2,680,000	15,500	12,000	294,000
Germany	882	862	320,000	61,700	40,800	2,030,000
Netherlands	3,000	1,950	86,900	600	504	81,200
Russia	309,000	196,000	7,640,000	313	175	26,300
United Kingdom	9	8	21,900	803	675	174,000
Total	443,000	288,000	10,800,000	79,000	54,100	2,600,000
Exports:						
2016	95,200	NA	2,200,000	18,700	NA	641,000
2017:						
Australia	4,810	NA	350,000	1,000	NA	78,300
Austria	240	NA	9,440	--	--	--
Belgium	10,700	NA	410,000	--	--	--
Brazil	1,930	NA	50,600	436	NA	16,800
China	5,370	NA	212,000	--	--	--
Czechia	311	NA	12,000	--	--	--
France	1,750	NA	42,300	--	--	--
Germany	972	NA	297,000	--	--	--
Italy	288	NA	7,000	--	--	--
Japan	5,000	NA	200,000	55,500	NA	1,400,000
Korea, Republic of	3,860	NA	67,600	2,000	NA	48,000
Malaysia	403	NA	8,570	--	--	--
Netherlands	29,600	NA	615,000	--	--	--
Romania	2,790	NA	63,200	--	--	--
Russia	126,000	NA	3,410,000	--	--	--
Spain	5,420	NA	94,100	--	--	--
United Kingdom	36,500	NA	1,100,000	--	--	--
Total	236,000	XX	6,960,000	59,000	XX	1,540,000

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

[1]Table includes data available through July 25, 2018. 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 8112.99.2000.

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

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 5
U.S. IMPORTS AND EXPORTS OF VANADIUM-BEARING ASH AND RESIDUES[1, 2]

(Kilograms)

	2016			2017		
Country or locality	Gross weight	Contained weight	Value	Gross weight	Contained weight	Value
Imports for consumption:						
Canada	24,900,000	2,600,000 r	$7,530,000	24,000,000	2,350,000	$12,200,000
Chile	7,500	2,830 r	65,900	--	--	--
Mexico	--	--	--	1,470,000	166,000	2,270,000
Netherlands	660,000	207,000 r	2,200,000	49,900	20,800	54,700
Switzerland	40,000	11,300 r	241,000	--	--	--
Total	25,600,000	2,820,000 r	10,000,000	25,500,000	2,530,000	14,500,000
Exports:						
Belgium	33,700	NA	9,200	20,000	NA	20,000
Germany	111,000	NA	324,000	240,000	NA	110,000
India	--	--	--	78,900	NA	42,200
Korea, Republic of	818,000	NA	1,310,000	1,910,000	NA	375,000
Mexico	89,500	NA	151,000	586,000	NA	502,000
Netherlands	18,500	NA	13,600	--	--	--
Poland	26,800	NA	9,580	--	--	--
Ukraine	--	--	--	9,510	NA	13,000
United Kingdom	--	--	--	28,000	NA	10,400
Total	1,100,000	XX	1,810,000	2,870,000	XX	1,070,000

[r]Revised. NA Not available. XX Not applicable. -- Zero.
[1]Table includes data available through July 25, 2018. 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.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS
VANADIUM CHEMICALS[1]

(Kilograms)

Material and country or locality[2]	2016 Gross weight	2016 Contained weight	2016 Value	2017 Gross weight	2017 Contained weight	2017 Value
Sulfates:						
Canada	3	2	$3,200	--	--	--
China	9,540	5,990	73,500	1,970	1,310	$31,400
Finland	4,000	4,000	28,000	700	700	4,520
Germany	1,900	1,900	13,000	4	2	3,000
Japan	100	100	2,540	120	75	3,620
Netherlands	--	--	--	1,800	1,800	11,600
Total	15,500	12,000	120,000	4,600	3,880	54,200
Vanadates:						
Austria	121,000	62,400	823,000	158,000	103,000	2,390,000
China	167,000	82,600	1,370,000	57,700	47,700	634,000
Germany	30,800	12,100	240,000	31,500	12,200	321,000
India	100	99	2,920	100	98	3,110
Japan	1,270	916	59,300	711	514	28,700
Korea, Republic of	20,000	8,630	138,000	--	--	--
Netherlands	8,700	1,040	26,100	--	--	--
Russia	--	--	--	5	1	2,200
South Africa	31,100	20,700	290,000	--	--	--
Taiwan	189,000	118,000	1,330,000	227,000	186,000	2,860,000
United Kingdom	16,500	6,440	124,000	--	--	--
Total	586,000	313,000	4,400,000	475,000	349,000	6,240,000

-- Zero.
[1]Table includes data available through July 25, 2018. 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]

(Metric tons of contained vanadium)

Country or locality[2]	2013	2014	2015	2016	2017
Brazil	--	578 r	3,250 r	4,460 r	5,210
China	45,000	48,000	45,000	41,000 r	40,000 e
Russia	14,400	15,100	16,000 e	16,000 e	18,000 e
South Africa	21,397	21,600	17,788	8,160 r	7,960
United States[3]	591	--	--	--	--
Total	81,400	85,300 r	82,000 r	69,600 r	71,200

eEstimated. rRevised. -- Zero.
[1]Table includes data available through May 16, 2018. All data are reported unless otherwise noted. 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 and (or) localities listed, in 2013, a small amount of vanadium was produced in Australia from titanomagnetite ore; Canada, Germany, Japan, and the United States, as well as several European countries, continued to recover vanadium from petroleum residues, but available information is insufficient to make reliable estimates.
[3]In 2013, Energy Fuels Inc. produced vanadium. Source: Energy Fuels Inc. website.