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2020 Minerals Yearbook

VANADIUM [ADVANCE RELEASE]

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

March 2025

U.S. Geological Survey, Reston, Virginia: 2025

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Vanadium

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In 2020, the United States produced 17 metric tons (t) of primary vanadium measured in vanadium content. The United States continued to be a major producer of vanadium products from secondary sources such as spent catalysts, ashes, and petroleum residues. However, secondary producers continued to rely on imported feedstock for a large portion of their production. Total imports for consumption (measured in vanadium content) decreased by 67% from those in 2019 (table 1). The United States imported 1,350 t of ferrovanadium (FeV), 67 t of other oxides and hydroxides of vanadium, and 1,670 t of vanadium pentoxide (V_2O_5) (all measured in vanadium content), collectively valued at $95 million (table 3). The United States imported 101 t of aluminum-vanadium master alloy (vanadium content) valued at $6.10 million (table 4). Imports of ash and residues were 60 t (vanadium content) valued at $7.6 million (table 5). Imports of vanadium chemicals were 211 t (vanadium content) valued at $3.49 million (table 6). The United States exported 165 t of FeV, 51 t of other oxides and hydroxides of vanadium, and 50 t of V_2O_5 (all measured in vanadium content), collectively valued at $5.71 million (table 3). Exports of aluminum-vanadium master alloy were 24 t (gross weight) valued at $1.06 million, and exports of vanadium metal were 846 kilograms (kg) (vanadium content) valued at $35,600 (table 4). Exports of ash and residues were 898 t (gross weight) valued at $1.11 million (table 5). Reported vanadium consumption in the United States was 5,010 t of vanadium content, 3% more than reported consumption in 2019 (table 1). In 2020, worldwide production of vanadium was 105,000 t, slightly more than the 103,000 t (revised) in 2019 (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 were the leading nonmetallurgical use for vanadium.

Government Actions and Legislation

In November 2019, domestic vanadium producers AMG Vanadium LLC and U.S. Vanadium LLC requested that the U.S. Department of Commerce launch an investigation under section 232 of the Trade Expansion Act of 1962 into whether the quantities of vanadium imported into the United States threatened to affect national security. The two applicants claimed that the U.S. industry had been negatively affected by "unfairly traded low-priced imports, limited export markets due to value-added tax regimes in other vanadium-producing countries, and the distortionary effect of Chinese and Russian industrial policies" (U.S. Department of Commerce, Bureau of Industry and Security, 2020). As a result, the Secretary of Commerce initiated an investigation into vanadium imports on May 28, 2020 (U.S. Department of Commerce, 2020a). The deadline for written comments was July 20, 2020, and the rebuttal comment deadline was August 17, 2020. A second notice was published on September 25, 2020, reopening the public comment period with a deadline of October 9, 2020, to allow additional time for the public to submit comments (U.S. Department of Commerce, 2020b).

Production

Industry convention for describing the production of V_2O_5 usually applies the terms primary production, joint production, and secondary production depending on the raw source material for production. Primary production refers to vanadium produced from mined ore as mineral concentrates derived from vanadiferous titanomagnetite (VTM) and sandstone-hosted vanadium (with or without uranium). Joint production 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 production refers to vanadium produced from various industrial waste materials, such as vanadium-bearing fly ash, petroleum residues, and spent catalysts.

In 2020, there was one primary producer of vanadium in the United States, two active secondary producers, and two idle secondary producers, one of which had been upgrading its idled Texas facility. The United States had no primary production of vanadium from 2014 through 2018. The major vanadium commodities are aluminum-vanadium master alloy; FeV; oxides and hydroxides of vanadium; vanadium-bearing ash, residues, and slag; vanadium chemicals; and V_2O_5. V_2O_5 is the most widely produced oxide, and most V_2O_5 and vanadium trioxide (V_2O_3) are further processed into FeV.

Energy Fuels Inc.'s (Canada) White Mesa Mill, near Blanding, UT, had the only vanadium-uranium coproduct recovery circuit in the United States. The mill had produced approximately 20,400 t of V_2O_5 (11,400 t of vanadium content) during its 40-year operating history. In 2018, the company completed facility upgrades to the mill in order to begin vanadium recovery in January 2019. In 2019, the company produced 820 t of high purity V_2O_5 (460 t of vanadium content) (Energy Fuels Inc., 2020a). However, the company produced only 17 t of vanadium (vanadium content) in 2020, before suspending production at the end of the first quarter owing to low prices. Energy Fuels announced that production could be stopped and started at minimal cost in response to any vanadium market changes. The company estimated that approximately 680 to 1,400 t of recoverable V_2O_5 (380 to 780 t of vanadium content) of inventory was in its tailings facility awaiting future

recovery when market conditions improved (Energy Fuels Inc., 2020b, p. 27).

In July 2020, the Nevada Vanadium Mining Corp. announced that it submitted a Notice of Intent to prepare an Environmental Impact Statement for its proposed Gibellini vanadium project in Eureka County, NV. The preliminary economic assessment study in 2018 determined that mine production would average approximately 4,600 metric tons per year (t/yr) of V_2O_5. The open pit mining operation and heap leach processing facility were expected to produce approximately 60,000 t of V_2O_5 during the project's lifetime. The Gibellini project did not have a timeline of when production was expected to commence (Nevada Vanadium Mining Corp., undated).

U.S. Vanadium (previously owned by EVRAZ plc) operated its facility in Hot Springs, AR, where vanadium ash, residues, and other raw materials were converted into high-purity vanadium oxides and vanadium chemicals used by the chemical, steel, and titanium industries (U.S. Vanadium LLC, 2020).

AMG Vanadium, 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). AMG Vanadium announced that its new spent catalyst recycling and ferroalloy production facility would be almost identical to its existing facility. The new facility would be located in Washington Township in Muskingum County, OH. The company expected the new $300 million facility to double the company's spent catalyst recycling capacity and FeV production capacity. The first of two phases—the roaster and flue gas desulfurization unit, rail unloading station, and spent catalyst raw material storage building—was expected to be commissioned in the middle of 2021. Operation of the new ferroalloy production facility was expected to begin in the middle of 2022 (AMG Vanadium LLC, undated).

Gladieux Metals Recycling LLC continued modernizing and renovating its idle V_2O_5 facility in Freeport, TX. Gladieux purchased the facility out of bankruptcy from Gulf Chemical and Metallurgical Corp. in 2017 (Callahan, 2017; 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 2020, accounting for 96% of reported consumption (table 2). Reported vanadium consumption in the United States was 5,000 t of contained vanadium, 3% more than reported consumption in 2019 (tables 1, 2). Nonmetallurgical applications included batteries, catalysts, ceramics, electronics, pigments, vanadium chemicals, and miscellaneous other chemical applications. 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 2020, 3,240 t of FeV was consumed, representing 65% 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 is becoming more widely used in renewable energy 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 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, overall cost, equipment, and raw material availability continued to be barriers for entry into the battery market. The vanadium used in the VRFB accounts for approximately 30% of the cost of the battery, requiring 3 to 6 kg of vanadium per kilowatthour of energy storage (Bushveld Minerals Ltd., 2018, p. 25, 41).

Some of the U.S.-based manufacturers, all at different stages of establishing VRFB production lines, included Ashlawn Energy, LLC (Springfield, VA); Invinity Energy Systems (London, United Kingdom); Perennial Power Holdings, Inc. (New York, NY); Primus Power Corp. (Hayward, CA); StorEn Technologies Inc. (Stony Brook, NY); UniEnergy Technologies, LLC (Mukilteo, WA); and ViZn Energy Systems Inc. (Columbia Falls, MT).

Largo Resources Ltd. (Canada) announced the launch of its new VRFB company, Largo Clean Energy Corp., headquartered in Virginia, with its manufacturing facility located in Delaware. The vanadium for the VRFBs would come from Largo's Maracás Menchen Mine in Brazil. Largo Clean Energy had acquired the VRFB technology from Vionx Energy Corp. and was expected to further develop and deploy a variety of VRFB systems to its customers (Largo Clean Energy Corp., 2020; Largo Resources Ltd., undated).

The California Energy Commission selected Invinity to provide VRFBs for four of its eight energy storage projects. The projects were part of a $20 million initiative to develop nonlithium energy storage technologies. The VRFB sites were situated throughout California and were expected to perform a range of services including energy peak shaving, consumer demand charge reduction, and providing backup power, to help to achieve California's new decarbonization targets of net zero carbon emissions by 2045 (Power Technology, 2020).

Prices

In 2020, the U.S. average monthly price for domestic FeV (80% vanadium content), as published by CRU Group, ranged from $9.672 to $13.453 per pound of vanadium content,

compared with $10.781 to $43.098 per pound in 2019. In 2020, the European average monthly price for FeV (80% vanadium content) ranged from $22.972 to $28.581 per kilogram, compared with $21.513 to $79.275 per kilogram in 2019. The average monthly price for Chinese V_2O_5, published by CRU Group, ranged from $5.893 to $9.517 per pound in 2020, compared with $10.200 to $17.000 per pound in 2019.

Vanadium prices for both FeV and V_2O_5 fluctuated in 2020. European FeV prices in January 2020 averaged $25.192 per pound and decreased to an annual low of $22.972 per pound in July 2020. From August 2020, FeV prices continued to increase for the remainder of the year to $24.125 per pound in December 2020. Chinese V_2O_5 prices averaged $9.517 per pound in January 2020 and continued to decrease until April 2020, when they averaged $5.994 per pound. In May and June, Chinese V_2O_5 prices increased and remained at $6.400 per pound until November 2020 before decreasing in December 2020 to $5.893 per pound.

Foreign Trade

Vanadium enters international trade in the form of FeV; V_2O_5; vanadium-bearing ash, residues and slag; and vanadium metal including aluminum-vanadium master alloy and waste and scrap. It is difficult to calculate the total quantity of vanadium entering international trade owing to multiple factors. The first factor is that not all countries publish data for all forms of vanadium. The second factor is that when countries do publish trade data, some data are not distinguished correctly between different vanadium forms. Data can be quoted in terms of gross weight, V_2O_5 content, or vanadium content. Data in this report are quoted in either gross weight or vanadium content, unless otherwise noted.

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, South Africa, and Brazil; these countries accounted for essentially all of world primary production. Secondary production in Canada, Germany, Japan, the United States, and several other European countries continued, but data were not available on the quantity of secondary production.

World vanadium reserves, estimated at 22 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 was not included in the reserve estimate and was expected to significantly extend the life of the reserves.

Australia.—In April, Atlantic Vanadium Pty Ltd. (Perth, Western Australia) announced that it had completed a definitive feasibility study for its Windimurra vanadium project in the State of Western Australia. The Windimurra project, currently on hold, was expected to produce 7,600 t/yr of high-purity V_2O_5 during its 31-year mine life. Atlantic Vanadium was in the process of finalizing offtake agreements and solidifying prospective financiers to be able to make a final decision on its future (Australian Financial Review, The, 2020; Atlantic Vanadium Pty Ltd., undated).

Neometals Ltd. announced that it continued development of its Barrambie titanium-vanadium project located approximately 80 kilometers (km) northwest of Sandstone in the State of Western Australia (Neometals Ltd., undated a). Neometals also announced that it was evaluating a joint venture with a Swedish mineral development company to construct a recycling facility to recover and process vanadium products from vanadium-bearing steel slag from Swedish steel producer, Svenskt Stal AB (Neometals Ltd., undated b). In December, Neometals and partner, Swedish-based Critical Metals Ltd., announced the selection of a potential location for its recycling project. Critical Metals entered into an initial agreement with the city of Pori in Finland to develop the facility at its Tahkolutoto Port. The companies expected a final investment decision to be made by the end of 2022 (Argus Media group—Metal Pages, 2020a).

Brazil.—Largo Resources' Maracás Menchen Mine, located 813 km northeast of Brasilia, produced 11,800 t of V_2O_5 in 2020, a 12% increase from 2019 production. The company expected to produce between 12,300 and 12,800 t of V_2O_5 in 2021 despite a planned shutdown in January 2021. The company announced that it would undertake kiln improvements to increase capacity to 1,100 metric tons per month (t/mo) of V_2O_5 from the current 1,000 t/mo (Largo Resources Ltd., 2021). Largo was expected to continue construction of a processing plant at its Maracás Menchen Mine for V_2O_3, which was expected to be used for VRFBs. Largo expected construction of the plant 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., undated).

Canada.—In October, VanadiumCorp Resource Inc. announced results of the Mineral Resource Estimate (MRE) for its Lac Doré vanadium project in the Eeyou Istchee James Bay Territory, northern Quebec Province. Measured and indicated mineral resources were 214 Mt at 0.4% V_2O_5. Measured and indicated mineral resources were estimated to contain 53 Mt of magnetite concentrate grading 1.3% V_2O_5. With the results of the MRE, VanadiumCorp announced that it would proceed with either a preliminary economic assessment or a prefeasibility study (VanadiumCorp Resource Inc., 2020).

China.—China exported approximately 4,510 t of FeV in 2020, a 9% decrease from 2019 exports. China exported approximately 4,520 t of V_2O_5 in 2020, a 10% increase from 2019 exports. China imported 3,900 t of FeV in 2020, almost four times more than in 2019. China imported 9,230 t of V_2O_5 in 2020, more than six times more than in 2019 (Zen Innovations AG, 2021).

Panzhihua Iron and Steel Group Co. Ltd. (Panzhihua, Sichuan Province) reported that it expected to produce 42,000 t of V_2O_5 in 2020, a slight increase from that in 2019. Chengde Iron and Steel Group Co. Ltd. (Chengde, Hebei Province), a subsidiary of China-based steel producer Hebei Iron & Steel Group Mining Co., Ltd. (Tangshan, Hebei Province), reported that it expected to produce 18,600 t of V_2O_5 in 2020, an increase of 16% compared with that in 2019 (Argus Media group—Metal Pages, 2020b).

In 2017, the China National Development and Reform Commission called for more investment in energy storage, specifically projects involving VRFBs. China's goal was to install more than 1,000 gigawatts of wind and solar power by 2030. One such project was the vanadium energy storage project in Hubei Province. In early 2019, VRB Energy (Canada) announced that it had successfully commissioned a 12-megawatthour energy storage project in phase 1 of the Hubei Zaoyang utility-scale solar and storage integration demonstration project, which was expected to be a 40-megawatthour storage facility when completed (Colthorpe, 2019). Owing to the success of its 2019 VRFB project, VRB Energy announced that it would deploy a new VRFB project at a 100-megawatthour solar energy power plant in Xiangyang, Hubei Province. The company announced that in addition to the large-scale VRFB project, it also expected to construct a VRFB manufacturing facility and a research and development institute for flow battery technology in Xiangyang. The first phase of construction was expected to begin in the second quarter of 2021 (Colthorpe, 2021).

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

The global coronavirus disease 2019 (COVID-19) pandemic caused great uncertainty not only in the vanadium market but in most global markets. Many companies were required to completely rearrange their operations owing to the variety of global pandemic restrictions. According to many analysts, China experienced a strong industrial response to the pandemic in 2019 and 2020, increasing steel production and therefore vanadium consumption. However, the increase in steel production during that period was seen mainly in China and not the rest of the world, causing Chinese vanadium prices to dramatically increase. As a result, China, traditionally a net exporter of vanadium, became a net importer of V_2O_5 in 2020 (Barrera, 2020). The combination of record-high steel production in China, the ongoing implementation of new rebar standards in China, and many Chinese steel mills switching back to ferrovanadium from ferroniobium caused Chinese vanadium consumption to increase in 2020.

Czechia.—EVRAZ Nikom had one processing facility, which was used to process V_2O_5 from Russia and China and V_2O_3 from Bushveld Minerals Ltd.'s Vametco Mine (South Africa) into FeV. The processing facility was in Mnisek pod Brdy, 30 km southwest of Prague. Nikom's FeV production in 2020 was 4,000 t of vanadium content (EVRAZ plc, undated a).

Kazakhstan.—Ferro-Alloy Resources Ltd. (FAR) (United Kingdom) produced 237 t of V_2O_5 at its vanadium-processing plant in southern Kazakhstan. The company also installed and commissioned new equipment to increase plant capacity to process 80 t/mo of V_2O_5. The focus of the new equipment was to expand the new pyrometallurgical process line to treat a wider variety of raw materials. The company developed a new process to produce the vanadium electrolyte needed for VRFBs and was in the process of looking for sales partners. The global COVID-19 pandemic was cited for the negative effects on FAR's operations in 2020, especially in the fourth quarter of 2020, but FAR expected to improve its productivity in 2021 when many of the travel bans were lifted (Ferro-Alloy Resources Ltd., 2021, p. 1–4).

FAR was in phase 1 of the feasibility study to develop its Balasausqandiq vanadium project in Qyzylorda Province, in southern Kazakhstan. According to the company, the deposit was a large black shale formation not composed of VTM and therefore could be processed by a low-cost method. The feasibility study was significantly delayed owing to the global COVID-19 pandemic (Ferro-Alloy Resources Ltd., 2021, p. 5).

Russia.—EVRAZ Nizhny Tagil Metallurgical plant (NTMK), an integrated metallurgical complex located in Nizhny Tagil in Sverdlovsk Province, continued to be one of the world's leading processors of VTM. EVRAZ's vanadium slag production increased by 6% to 19,500 t of vanadium content in 2020 (EVRAZ plc, 2021, p. 2). The Vanady Tula facility, located 200 km south of Moscow, used low-cost, highly efficient technology to process the vanadium slag produced by NTMK into FeV and V_2O_5 (EVRAZ plc, undated b).

South Africa.—Bushveld Minerals Ltd.'s assets consisted of the Brits Mine, the Mokopane Mine, the Vametco Mine, and the Vametco and Vanchem processing facilities. Bushveld announced that it produced 3,630 t of vanadium content in 2020, an increase compared with that in 2019. The company projected production in 2021 to be between 4,100 and 4,350 t of vanadium content (Harrington, 2021).

The Vametco Mine and processing facility was located in Brits, North West Province. Vametco produced Nitrovan, a proprietary steel-alloying vanadium carbon nitride product. The Vanchem processing facility consisted of three roasting kilns, a vanadium chemical facility, two ferrovanadium processing facilities, and a V_2O_5-processing plant. Vanchem produced FeV, V_2O_5, a variety of vanadium chemicals, and also had the ability to produce V_2O_3. The Mokopane Mine was expected to be the primary source of feedstock for Bushveld's Vanchem facility (Bushveld Minerals Ltd., undated).

Glencore plc's Rhovan vanadium facility, 30 km northwest of Brits, produced 8,850 t of V_2O_5 in 2020, compared with 9,160 t of V_2O_5 in 2019 (Glencore plc, 2021, p. 69).

Outlook

The World Steel Association forecast global steel consumption to increase by 5.8% in 2021, after declining slightly in 2020, attributing the decline in 2020 mainly to the global COVID-19 pandemic (World Steel Association, 2021). Because almost all vanadium is consumed in the production of steel, vanadium consumption trends are greatly influenced by trends in steel production; however, the use of vanadium in a wider range of steels is expected to continue to gradually increase. The outlook for consumption in nonferrous alloys is largely dependent on trends in consumption for titanium alloys in business, commercial, and military aircraft.

The outlook for vanadium through 2021 in the rest of the world is expected to depend on the evolution of the global

COVID-19 pandemic (Roskill Information Services Ltd., 2021). In addition to continued growth from the steel sector, one area of anticipated growth is 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 and VRFB storage is proving to be a potential solution, with many countries having numerous projects already underway. However, the growth of VRFB implementations has been slower than originally anticipated. The major disadvantages of VRFBs continue to be 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 may 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)

	2016	2017	2018	2019	2020
United States:					
Production, ore and concentrate, recoverable vanadium	--	--	--	460	17
Consumption, reported	4,610	4,670	5,640	4,840	5,000
Imports for consumption:					
Aluminum-vanadium master alloy	157	288	281	222	101
Ash and residues[2]	5,030 r	4,530 r	5,020 r	3,780 r	60
Ferrovanadium[3]	1,590	2,810	2,970	2,280	1,350
Hydrides and nitrides, of vanadium	82	173	72	54	57
Oxides and hydroxides, other	660	148	98	105	67
Sulfates	12	4	9	73	39
Vanadates	313	349	389	73	104
Vanadium chlorides	148	81	45	1	11
Vanadium metal	33	54	28	45	(4)
Vanadium ores and concentrates	32 r	2 r	590 r	192 r	4
Vanadium pentoxide (anhydride)	2,460	3,400	4,600	3,620 r	1,670
Total imports	10,500 r	11,800 r	14,100 r	10,400 r	3,460
Exports:					
Aluminum-vanadium master alloy[5]	95	236	161	51	24
Ash and residues[2, 5]	1,100	2,870	2,560 r	2,280	898
Ferrovanadium	525 r	229	575	295	165
Oxides and hydroxides, other	81	148	53	750	51
Vanadium metal	19	59	39	27	1
Vanadium ores and concentrates[5]	773 r	109 r	86 r	170 r	164
Vanadium pentoxide (anhydride)	5	126	563	423	50
Stocks, yearend:					
Ferrovanadium	144	166	188	197	206
Other[6]	63	61	62	60	63
World, production from ore, concentrate, slag[7]	78,200	85,900	83,500	103,000 r	105,000

rRevised. -- Zero.
[1]Table includes data available through August 11, 2021. Data are rounded to no more than three significant digits; may not add to totals shown. Includes U.S. Geological Survey estimates.
[2]Includes both Harmonized Tariff Schedule of the United States codes 2620.04.0030 and 2620.99.1000.
[3]Some data suppressed according to the U.S. Census Bureau; not included in ferrovanadium total.
[4]Less than ½ unit.
[5]Gross weight.
[6]Includes chlorides, vanadates, vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, and other specialty chemicals.
[7]May include estimated data.

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

(Kilograms, vanadium content)

	2019	2020
End use:		
Steel:		
Carbon	763,000	788,000
Full alloy	1,260,000	1,260,000
High-strength low-alloy	W	W
Stainless and heat resisting	63,100	62,800
Tool	W	W
Total	2,090,000	2,110,000
Cast irons	W	W
Alloys (including steels and superalloys)	1,690,000	1,700,000
Chemical and ceramic:		
Catalysts	W	W
Pigments	W	W
Miscellaneous and unspecified[3]	1,060,000	1,200,000
Grand total	4,840,000	5,000,000
Form:		
Ferrovanadium	3,090,000	3,240,000
Other[4]	1,750,000	1,770,000
Total	4,840,000	5,000,000

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1]Table includes data available through August 11, 2021. 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 electrical steel and unspecified steel.
[4]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:									
2019	3,400,000	2,280,000	$167,000,000 r	3,910,000	3,620,000 r	$110,000,000	162,000	105,000	$6,840,000
2020:									
Austria	679,000	483,000	11,500,000	24,000	16,100	311,000	--	--	--
Brazil	--	--	--	1,340,000	863,000	17,800,000	--	--	--
Canada	1,070,000	799,000	22,100,000	--	--	--	--	--	--
China	--	--	--	32,200	22,700	587,000	--	--	--
Czechia	(5)	(5)	19,500,000	--	--	--	--	--	--
Germany	--	--	--	155,000	118,000	2,930,000	1	1	3,820
Latvia	50,100	24,400	1,020,000	--	--	--	--	--	--
Morocco	--	--	--	--	--	--	983	627	5,970
Russia	16,200	13,000	325,000	94,100	88,500	934,000	--	--	--
South Africa	--	--	--	561,000	388,000	11,700,000	100,000	65,900	2,820,000
Sweden	2,000	1,610	57,900	--	--	--	--	--	--
Taiwan	--	--	--	155,000	155,000	2,110,000	--	--	--
Ukraine	48,000	19,600	600,000	--	--	--	--	--	--
United Kingdom	--	--	--	20,800	20,800	300,000	--	--	--
Vietnam	7,000	5,540	150,000	--	--	--	--	--	--
Total	1,880,000	1,350,000	55,300,000	2,390,000	1,670,000	36,700,000	101,000	66,500	2,830,000
Exports:									
2019	436,000	295,000	10,600,000	XX	423,000	6,410,000	XX	750,000	7,280,000
2020:									
Australia	92	69	7,450	NA	117	13,200	NA	510	4,540
Brazil	20,000	15,000	568,000	--	--	--	--	--	--
Canada	34,000	25,500	831,000	--	--	--	NA	702	8,520
Chile	4,090	3,070	82,400	--	--	--	--	--	--
China	23,200	17,400	397,000	--	--	--	NA	3,000	29,400
Colombia	1,120	837	30,900	--	--	--	--	--	--
Germany	--	--	--	NA	150	3,960	NA	502	4,470
India	20,400	16,000	372,000	NA	8,950	85,000	NA	11,000	42,000
Italy	--	--	--	NA	2,040	7,680	--	--	--
Jamaica	--	--	--	--	--	--	NA	635	5,230
Korea, Republic of	2,370	1,780	76,800	--	--	--	--	--	--
Kuwait	--	--	--	--	--	--	NA	300	4,590
Mexico	60,800	46,100	1,480,000	NA	500	27,000	--	--	--
Netherlands	51,900	38,900	914,000	--	--	--	--	--	--
Peru	411	252	8,410	--	--	--	--	--	--
Trinidad and Tobago	--	--	--	NA	37,900	360,000	NA	33,900	342,000
United Kingdom	45	34	3,210	--	--	--	--	--	--
Total	218,000	165,000	4,770,000	XX	49,700	497,000	XX	50,600	440,000

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

[1]Table includes data available through August 10, 2021. 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]			Vanadium ores and concentrates[4]		
Country or locality	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value
Imports for consumption:									
2019	332,000	222,000	$17,600,000	57,800	44,500	$4,100,000	730,000	192,000	$9,490,000
2020:									
Belgium	2,750	1,600	103,000	--	--	--	--	--	--
Canada	--	--	--	--	--	--	278	167	19,200
China	12,000	8,030	316,000	--	--	--	--	--	--
Czechia	--	--	--	4	4	4,550	--	--	--
Germany	4,720	3,800	408,000	272	122	62,700	--	--	--
Mexico	840	840	58,900	--	--	--	6,500	3,600	542,000
Netherlands	22	22	10,900	--	--	--	--	--	--
Russia	131,000	86,500	5,160,000	--	--	--	--	--	--
Sweden	201	200	27,200	--	--	--	--	--	--
United Kingdom	3	3	8,210	39	39	7,560	--	--	--
Total	152,000	101,000	6,100,000	315	165	74,800	6,770	3,760	561,000
Exports:									
2019	50,900 r	XX	2,890,000 r	XX	27,000	1,680,000	XX	170,000	2,250,000
2020:									
Australia	914	NA	35,300	--	--	--	--	--	--
Cambodia	--	--	--	--	--	--	NA	23,000	299,000
Canada	--	--	--	--	--	--	NA	186	6,370
China	2,240	NA	86,600	--	--	--	NA	4,920	63,900
France	1,120	NA	49,800	--	--	--	--	--	--
Germany	282	NA	10,900	--	--	--	--	--	--
India	--	--	--	--	--	--	NA	5,730	74,400
Italy	732	NA	53,600	--	--	--	--	--	--
Kazakhstan	12,200	NA	652,000	--	--	--	--	--	--
Lithuania	--	--	--	--	--	--	NA	431	5,600
Mexico	16	NA	2,620	--	--	--	--	--	--
Netherlands	--	--	--	NA	724	27,900	--	--	--
Nicaragua	126	NA	4,870	--	--	--	--	--	--
Saudi Arabia	89	NA	3,420	--	--	--	--	--	--
Singapore	--	--	--	NA	113	4,370	--	--	--
Spain	40	NA	5,730	NA	9	3,310	--	--	--
Taiwan	--	--	--	--	--	--	NA	127,000	673,000
Ukraine	--	--	--	--	--	--	NA	1,600	20,800
United Kingdom	6,580	NA	154,000	--	--	--	--	--	--
Vietnam	--	--	--	--	--	--	NA	1,320	17,200
Total	24,400	XX	1,060,000	XX	846	35,600	XX	164,000	1,160,000

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

[1]Table includes data available through September 7, 2021. 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]Includes HTS code 8112.92.7000.

[4]Includes HTS code 2615.90.6090.

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)

Country or locality	2019			2020		
	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value
Imports for consumption:						
Belgium	--	--	--	387,000	60,000	$482,000
Canada	20,600,000	3,600,000	$57,600,000	(3)	(3)	7,160,000
Curacao	582,000	118,000	869,000	--	--	--
Kuwait	172,000	14,200	114,000	--	--	--
Venezuela	58,700	50,000	200,000	--	--	--
Total	21,400,000	3,780,000	58,800,000	387,000	60,000	7,640,000
Exports:						
Belgium	--	--	--	238,000	NA	276,000
France	839,000	NA	858,000	48,400	NA	32,900
Germany	1,350,000	NA	687,000	87,200	NA	118,000
Italy	19,700	NA	41,600	204,000	NA	371,000
Mexico	76,400	NA	280,000	22,300	NA	35,800
Netherlands	--	--	--	264,000	NA	245,000
Thailand	--	--	--	34,200	NA	28,700
Total	2,280,000	XX	1,870,000	898,000	XX	1,110,000

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

[1]Table includes data available through September 7, 2021. 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; 2620.50.0000 and 2620.99.1000 for exports.

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

Source: U.S. Census Bureau.

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

(Kilograms)

Material and country or locality[2]	2019			2020		
	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value
Hydrides and nitrides:						
China	3,060	3,060	$119,000	3,550	2,810	$17,700
Czechia	--	--	--	655	518	6,870
Germany	3,020	2,430	45,100	27,900	22,800	258,000
Ireland	3,090	2,440	28,400	5,970	4,720	49,100
Japan	--	--	--	40	32	15,200
Poland	--	--	--	1	1	9,000
Russia	6	6	6,630	3,830	3,030	15,000
South Africa	56,700	44,800	585,000	28,200	22,300	343,000
Sweden	1,500	1,500	64,700	860	679	30,100
Total	67,300	54,200	848,000	71,000	56,900	744,000
Sulfates:						
China	7,030	4,390	42,200	4,190	2,620	25,200
Finland	79,500	69,000	581,000	42,700	30,900	309,000
Germany	--	--	--	8,000	4,990	59,800
Japan	--	--	--	100	62	3,180
Total	86,600	73,400	623,000	55,000	38,600	397,000
Vanadates:						
Austria	--	--	--	57,100	28,900	572,000
China	13,200	8,620	363,000	2,660	2,130	66,700
Germany	14,700	5,840	433,000	11,800	6,220	165,000
India	26	18	13,600	7	3	2,080
Japan	364	209	21,000	107	73	5,980
Russia	5	2	2,200	5	2	2,200
South Africa	29,300	20,800	813,000	15,000	11,300	192,000
Switzerland	--	--	--	57,000	28,900	569,000
Taiwan	54,000	35,200	1,480,000	36,000	23,300	345,000
United Kingdom	5,700	2,230	144,000	7,380	3,560	115,000
Total	117,000	72,900	3,260,000	187,000	104,000	2,030,000
Vanadium chlorides:						
Belgium	112	109	4,830	2,630	2,510	35,500
France	907	864	12,300	8,550	8,140	282,000
Germany	3	3	3,610	--	--	--
Total	1,020	976	20,700	11,200	10,600	318,000

-- Zero.
[1]Table includes data available through September 7, 2021. 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 2850.00.2000, 2833.29.3000, 2841.90.1000, and 2827.39.1000.

Source: U.S. Census Bureau.

TABLE 7
VANADIUM: WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1, 2]

(Metric tons, vanadium content)

Country or locality	2016	2017	2018	2019	2020
Brazil	4,461	5,206	5,500	5,923 [r]	6,622
China	48,700	54,100	53,200	70,600 [r]	70,000 [e]
Russia	16,886	18,636	17,052	18,380 [r]	19,533
South Africa	8,163	7,959	7,700	8,030	8,584
United States	--	--	--	460	17
Total	78,200	85,900	83,500	103,000 [r]	105,000

[e]Estimated. [r]Revised. -- Zero.
[1]Table includes data available through July 13, 2021. All data are reported unless otherwise noted; totals may include estimated data. 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 European countries, continued to recover vanadium from petroleum residues, but available information was insufficient to make reliable estimates.