



# 2012 Minerals Yearbook

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## VANADIUM

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In 2012, reported vanadium consumption in the United States was 3,980 metric tons (t) of contained vanadium, a 4% decrease from the revised quantity of 2011 (table 1). The United States imported (measured in vanadium content) 4,190 t of ferrovanadium (FeV), 1,640 t of vanadium pentoxide ( $V_2O_5$ ), and 905 t of other oxides and hydroxides of vanadium collectively valued at \$147 million (table 4). Total imports for consumption of these vanadium materials increased by 14% from those of 2011. The United States exported 337 t of FeV, 62 t of  $V_2O_5$ , and 287 t of other oxides and hydroxides of vanadium collectively valued at \$15.7 million (table 4). Total exports of these vanadium-bearing materials increased by 3% from those of 2011.

Vanadium's primary use is 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. Catalysts represented the leading nonmetallurgical use for vanadium.

Secondary vanadium production from various industrial waste materials, such as vanadium-bearing fly ash, petroleum residues, pig iron slag, and spent catalysts, was the leading source of U.S. vanadium production. A small amount of vanadium was obtained as a coproduct from the mining of uraniferous sandstones on the Colorado Plateau. Fewer than 10 firms, primarily in Arkansas, Ohio, Pennsylvania, and Texas, processed waste materials to produce FeV,  $V_2O_5$ , and vanadium metal.

## Legislation and Government Programs

In August, the U.S. International Trade Commission (ITC) voted unanimously to revoke the existing 108% antidumping duty on FeV and nitride vanadium from Russia. The antidumping duty on Russian FeV had been in effect since July 1995. Many U.S. producers anticipated that the 5-year sunset review would result in the ITC agreeing that terminating the duty would lead to continuation or recurrence of material injury. Instead, the ITC determined that revoking the duty would not be likely to lead to continuation or recurrence of material injury within a reasonably foreseeable period of time (Ryan's Notes, 2012).

## Production

The major vanadium commodities comprise aluminum-vanadium master alloys; FeV; vanadium-bearing ash, residues, and slag; vanadium chemicals; and  $V_2O_5$  and other oxides and hydroxides of vanadium. In 2012, companies in the United States produced all of these materials with the exception of vanadium-bearing slag from the manufacture of iron and steel. 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.

Uranium production from carnotite ores creates a vanadium-bearing waste solution that must be neutralized to fix the heavy metals before waste disposal. An alternative treatment is a circuit which extracts vanadium and produces  $V_2O_5$ . In June 2012, Energy Fuels Inc. (Toronto, Ontario, Canada) acquired the U.S. Mining Division of Denison Mines Corp. (Toronto, Ontario, Canada), which included the White Mesa uranium processing mill, near Blanding, UT. White Mesa processed feed from its own Colorado Plateau ores as well as uranium/vanadium ores purchased from independent miners. For every 1 kilogram (kg) of triuranium octoxide concentrate (yellowcake) produced, White Mesa's vanadium coproduct recovery circuit produced approximately 4 kg of vanadium in the form of  $V_2O_5$ . Energy Fuels reported no  $V_2O_5$  production or  $V_2O_5$  sales in 2012. However, the company was expected to sell an estimated 860 to 900 t  $V_2O_5$  in 2013 (Energy Fuels Inc., 2012). In the first half of 2012, before Energy Fuels acquired the White Mesa Mill, Denison announced that vanadium production at its White Mesa Mill was expected to be 272 t  $V_2O_5$  in 2012 (Denison Mines Corp., 2012).

In December, American Vanadium Corp. (Vancouver, British Columbia, Canada) submitted a plan of operations for its Gibellini project in Nevada to the U.S. Bureau of Land Management. The plan covered mine design, processing facilities, and eventual reclamation. The plan also included a micro-grid design using solar power generation and a vanadium storage battery, which was expected to be capable of powering the mine offgrid (American Vanadium Corp., 2012). In September 2011, the company completed a feasibility study that projected annual production of 5,170 t of  $V_2O_5$ , with a total capital cost of \$95.5 million, including contingencies (Metal-Pages, 2011).

EVRAZ Group S.A. comprised Nikom in the Czech Republic, Strategic Minerals Corp. (Stratcor Inc.) in the United States and South Africa, Vametco Alloys Proprietary Ltd. in South Africa, and Vanady Tula in Russia. Stratcor 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 (EVRAZ Group S.A., 2013, p. 49–50).

EVRAZ reported total FeV production in 2012 decreased by 14% to 14,381 t FeV compared with 16,683 t FeV in 2011. EVRAZ's 2012 FeV production at its facilities increased 15% to 7,259 t FeV (2,715 t FeV at Vanady Tula; 4,544 t FeV at Nikom) compared with 6,321 t FeV in 2011 (2,562 t FeV at Vanady Tula; 3,759 t FeV at Nikom). EVRAZ's 2012 production of oxides, vanadium aluminum, and chemicals increased by 4.1% to 1,330 t compared with 1,277 t in 2011. Output of oxides,

vanadium aluminum and chemicals was only 186 t in the fourth quarter compared with 443 t in the third quarter (EVRAZ Group S.A., 2013, p. 50). EVRAZ attributed the overall decreases to problems with primary feedstock availability following significant disruptions to supplies as a result of a major explosion at a third party's operation. EVRAZ also announced that production of oxides, vanadium aluminum and chemicals in the first quarter of 2013, was potentially affected by scheduled maintenance work at its Hot Springs plant. To potentially mitigate the adverse impact of disruptions, Stratcor's electrical equipment was expected to be upgraded in order to process vanadium-bearing slag (Ryan's Notes, 2013a).

## Consumption

The U.S. Geological Survey (USGS) derived vanadium consumption data from a voluntary survey of domestic consuming companies. For this survey, more than 80 companies were canvassed on a monthly or annual basis.

Metallurgical applications continued to dominate U.S. vanadium use in 2012, accounting for 94% of reported consumption (table 2). In 2012, approximately 3,000 t of vanadium was consumed in titanium alloy production. Vanadium consumption in titanium alloys was expected to reach 6,000 t in 2016 (TTP Squared Inc., 2013, p. 20).

Nonmetallurgical applications included catalysts, ceramics, electronics, and vanadium chemicals. The dominant nonmetallurgical use was in catalysts. A number of vanadium chemicals were used in catalysts which were used in the manufacturing process of some important industrial chemicals and in the cleaning of industrial process waste streams.

Most vanadium is consumed in the form of FeV, which is used as a means of introducing vanadium into steel to provide additional strength and toughness. 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.

## Prices

In 2012, the annual average price for domestic FeV, as published in Ryan's Notes, ranged from \$14.038 to \$15.728 per pound of vanadium content, compared with \$14.606 to \$15.004 per pound reported in 2011. In 2012, the European annual average price for FeV, ranged from \$24.786 to \$25.475 per kilogram, compared with \$28.533 to \$29.273 per kilogram in 2011. The Ryan's Notes published annual average price for domestic  $V_2O_5$  ranged from \$6.231 to \$6.762 per pound in 2012, compared with \$6.563 to \$6.960 per pound in 2011.

## World Review

A large majority of the world's supply of vanadium was derived from mined ore, either directly as mineral concentrates derived from vanadiferous titanomagnetite (VTM) or from steelmaking slags, where the steel has been produced from VTM. Five countries recovered vanadium from ores,

concentrates, slag, or petroleum residues (table 7). The leading vanadium-producing nations remained China, South Africa, and Russia. Japan and the United States were thought to be the only countries to recover significant quantities of vanadium from petroleum residues.

World vanadium reserves, at more than 13 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 catalyst is not taken into account and is expected to extend the life of the reserves significantly.

**Australia.**—Midwest Vanadium Pty. Ltd.'s (subsidiary of Atlantic Ltd.) Windimurra project continued to ramp up annual production to a capacity of 6,300 t of contained vanadium in 2013. Following construction and commissioning completion in late 2011 and the first FeV production in January 2012, the Windimurra project achieved its first shipment of FeV in May 2012. The Windimurra project is approximately 600 kilometers (km) north of Perth, in Western Australia. The production of FeV from vanadiferous magnetite involves production of a magnetite concentrate via crushing, screening, grinding, and magnetic separation. The magnetite concentrate then is roasted with soda ash in a rotary kiln. The roasted ore is leached with water, followed by desilication using sulfuric acid and aluminum sulfate. Precipitation of ammonium metavanadate using ammonium sulfate follows, and the ammonium metavanadate is reduced to vanadium trioxide and finally to FeV (Atlantic Ltd., 2012, p. 6, 8, 9).

**Brazil.**—Construction at Largo Resources Ltd.'s (Toronto, Ontario, Canada) 100%-owned Maracas vanadium project commenced in June 2012. The company set a production target for the fourth quarter of 2013, with expected production of 11,400 t  $V_2O_5$  equivalent during a 29-year mine life. Largo had an offtake agreement with Glencore International plc for 100% of the material for the first 6 years. The Maracas property is located 813 km northeast of Brasilia (Largo Resources Ltd., 2013).

**Canada.**—Apella Resources Inc. (Vancouver) approved plans to change the company's name to PacificOre Mining Corp., effective May 2012. According to the company, it changed its name to clearly distinguish itself from existing and potential competitors in the iron ore, vanadium, and titanium industry (PacificOre Mining Corp., 2012c). In early 2012, Apella decided on a strategy of placing three of its vanadium-iron-titanium assets—the Game Changer project, the Iron-T project, and the Lac Dore project—into wholly owned subsidiaries dedicated primarily to those particular assets. Funds to develop the projects were held within subsidiaries; therefore, share dilution to the company as a whole was expected to be avoided. In February 2012, Apella sold its Lac Dore project in northern Quebec to its wholly owned Prestige Mining Resources Pty. Ltd. unit. In early March, the first phase of exploration work on Lac Dore was completed. The exploration work involved reestablishing and extending the previous grid, establishing a minimum of three permanent benchmarks for future infrastructure and mine construction, and surveying the previous historic drill holes, trenches, and stripping used in the earlier feasibility study. It was anticipated that the first or second phase

of diamond drilling, upon completion, would bring the Lac Dore project to prefeasibility study level (PacificOre Mining Corp., 2012a).

In March, Apella sold its Iron-T vanadium-iron-titanium project to its wholly owned subsidiary, Power Vanadium Corp. Apella was expected to act as operator of the Iron-T project and would receive a management fee totaling 15% of Power Vanadium's total expenditures in each fiscal year. Power Vanadium was expected to deliver a feasibility study for the project by the end of July 2014. The latest resource estimate for the project, completed in May 2011, included results from the company's previous exploration activities (PacificOre Mining Corp., 2012b).

**China.**—The Chinese vanadium industry continued to feel pressure from niobium substitution, particularly in HSLA steels. The amount of niobium additives in steel production is only about one-half that of vanadium; therefore, to achieve the same effect, about 3,000 t of ferroniobium can substitute for as much as 7,000 t of 50% grade FeV (Metal-Pages, 2010). The substitution of ferroniobium, however, is only economic at very high vanadium prices.

China's consumption of vanadium was expected to increase substantially as grade 2 rebar (0% V content) was being phased out and being replaced with the new grade 3 rebar (0.03% V content). Requirement for the use of the new grade 3 rebar was expected to take effect starting July 2012. In 2012, 166 Mt of Chinese rebar was produced comprising 86 Mt of grade 2 rebar and 66 Mt of grade 3 rebar. Once fully implemented, the new China grade 3 rebar standard was expected to increase global vanadium demand (TTP Squared Inc., 2013).

China was expected to continue to move towards more efficient use of its vanadium resources and development of higher strength steels requiring vanadium to supports its ongoing infrastructure development, and control vanadium production to support its domestic economic development (TTP Squared Inc., 2013).

**Czech Republic.**—Nikom (part of the EVRAZ Group) had an annual capacity of 4,455 t of FeV production and delivered most of its products to North America (58%) and Europe (20%) (EVRAZ Group S.A., 2013, p. 49–50).

**Japan.**—In 2012, Japan's imports of FeV decreased to 4,291 t compared with 4,792 t in 2011. Japan's FeV production increased 16% to 4,121 t in the first 11 months in 2012 compared with 3,551 t for the same period in 2011, according to the Ministry of Economy, Trade, and Industry (Ryan's Notes, 2013b).

**Russia.**—The Vanady Tula facility, 200 km south of Moscow, joined EVRAZ in 2009. Vanady Tula has an annual capacity of 5,000 t FeV and 7,200 t V<sub>2</sub>O<sub>5</sub> in its electrometallurgical and hydrometallurgical plants (EVRAZ Group S.A., 2013, p. 49–50). In 2012, Vanady Tula produced 7,117 t of V<sub>2</sub>O<sub>5</sub> and 2,715 t of FeV. Also in 2012, a program of operational improvements was undertaken to increase V<sub>2</sub>O<sub>5</sub> production capacity at Vanady Tula. Additional work continued on the pulp filtration plant, with the aim of improving working conditions, cutting operational losses, and increasing V<sub>2</sub>O<sub>5</sub> production in 2013 (EVRAZ Group S.A., 2013, p. 50–52).

**South Africa.**—In February 2012, EVRAZ Highveld transferred mining rights for the Mapochs Mine, 140 km northeast of eMalahleni, to Mapochs Mine Proprietary Limited, as well as 23% of the shareholding to Umnotho Iron and Vanadium Proprietary Ltd. (EVRAZ Highveld Steel and Vanadium Ltd., 2013, p. 10). EVRAZ also announced that, as of 2012 yearend, it would sell its stake in EVRAZ Highveld Steel and Vanadium (EVRAZ Group S.A., 2013, p. 110).

EVRAZ Highveld produced 43,132 t of vanadium slag in 2012 compared with 61,083 t of vanadium slag in 2011. The 29% decrease was attributed to the labor unrest at the company during the third quarter as well as the nationwide transportation strike. The Steelworks, the eMalahleni-based operating division of EVRAZ Highveld, comprised the iron plant, the steel plant, the vanadium slag plant, the flat products mill, and the structural products mill. The iron plant treats the magnetite ore in a prereduction process in 13 rotary kilns. Once reduced, hot metal is produced in four open-slag bath furnaces and two submerged-arc furnaces. Vanadium slag is extracted in four shaking ladle emplacements in the steel plant and then is crushed, milled, and packaged for sale to Hochvanadium Handels GmbH at the vanadium slag plant. Hochvanadium (a 100%-EVRAZ Highveld subsidiary in Europe), supplied vanadium slag to Treibacher Industrie AG for further processing into vanadium products, primarily FeV, for steelmaking in the European market. Toll conversion of vanadium slag to products such as modified vanadium oxide and Nitrovan<sup>®</sup> is also undertaken by Vametco, in Brits, North West Province (EVRAZ Highveld Steel and Vanadium Ltd., 2013, p. 10–12). Vametco has an annual capacity to produce 3,600 t of vanadium trioxide, a high purity product used in a variety of applications, including batteries and catalysts. Vametco also has an annual capacity to produce 2,900 t of Nitrovan<sup>®</sup>, a vanadium-nitrogen alloy, which, according to the company, strengthens steel more effectively than FeV. Output of Nitrovan<sup>®</sup> at Vametco in 2012 was 2,723 t compared with 2,874 t in 2011 (EVRAZ Group S.A., 2013, p. 49–50).

Xstrata plc (Zug, Switzerland) announced that its Rhovan vanadium facility, 30 km northwest of Brits, produced 1,880 t of FeV in 2012, a 5% increase compared with 1,790 t of FeV produced in 2011. The facility produced 9,630 t of V<sub>2</sub>O<sub>5</sub> in 2012, a slight increase compared with 9,540 t of V<sub>2</sub>O<sub>5</sub> produced in 2011 (Xstrata plc, 2013, p. 35).

## Outlook

Vanadium consumption is heavily influenced by steel production, especially the production of high-strength steel grades. High-strength steels are increasing in use as the construction, energy, and transportation industries seek to maximize the strength and to minimize the weight of their products. Other end-use industries for vanadium also show potential growth. Aerospace applications are rapidly expanding, and vanadium consumption has been increasing with the introduction of the next generation of commercial aircraft. The quest for fuel efficiency is key in the aerospace industry but also extends to automobiles, high-speed drilling, powerplants, and rail cars.

Vanadium is becoming more widely used in green technology applications, especially in battery technology. One battery technology showing promise in stabilizing energy distribution in renewable systems is the vanadium redox battery (VRB), which consists of an assembly of power cells in which two vanadium-based electrolytes are separated by a proton exchange membrane. 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). The VRB also may have relatively low environmental impact compared to other energy storage technologies.

The outlook for the vanadium market in 2013 appears to be strong. Increasing steel demand projected through at least 2015, mandates for higher quality steel in emerging markets, and the potential for a whole new battery market, were expected to contribute to increased vanadium consumption (World Steel Association, 2013). However, the precise rate of growth in consumption was expected to depend on a number of factors, most notably new regulations for Chinese high-strength construction steel, which have the potential to significantly increase vanadium demand. Fluctuation in the supply and demand balance has resulted in significant volatility in vanadium prices during the past few years (Roskill Information Services Ltd., 2013). Global production has been disrupted by power shortages in South Africa and labor disputes in Russia. However, a number of new projects were expected to become operational in the short term, aiming to meet future increases in vanadium demand, despite these issues.

## References Cited

- American Vanadium Corp., 2012, American Vanadium announces submission of the plan of operations to the Bureau of Land Management: Vancouver, British Columbia, Canada, American Vanadium Corp. press release, December 24, 2 p. (Accessed March 8, 2013, at <http://www.americanvanadium.com/cms-assets/documents/92116-151238.avc-nr-dec-poo-final12.24.12.pdf>.)
- Atlantic Ltd., 2012, Annual report 2012: Perth, Western Australia, Australia, Atlantic Ltd., October 31, 108 p.
- Denison Mines Corp., 2012, Denison outlines 2012 operating plans and releases final 2011 production and sales volume: Toronto, Ontario, Canada, Denison Mines Corp., January 16. (Accessed May 18, 2012, at [http://www.denisonmines.com/s/SiteResources/data/MediaArchive/pdfs/press\\_releases/2012/jan16-12pr.pdf](http://www.denisonmines.com/s/SiteResources/data/MediaArchive/pdfs/press_releases/2012/jan16-12pr.pdf).)
- Energy Fuels Inc., 2012, Energy Fuels announces FY-2012 annual results: Toronto, Ontario, Canada, Energy Fuels Inc. press release, December 21, 5 p. (Accessed April 2, 2013, at [http://www.energyfuels.com/\\_resources/news/nr\\_2012\\_12\\_21.pdf](http://www.energyfuels.com/_resources/news/nr_2012_12_21.pdf).)
- EVRAZ Group S.A., 2013, Annual report and accounts 2012: Moscow, Russia, EVRAZ Group S.A., April 10, 188 p.
- EVRAZ Highveld Steel and Vanadium Ltd., 2013, Integrated annual report 2012: Mpumalanga, South Africa, EVRAZ Highveld Steel and Vanadium Ltd., March 13, 200 p.
- Johnstone, Bob, 2008, The element that could change the world: Discover, October 29. (Accessed May 7, 2013, at <http://discovermagazine.com/2008/oct/29-the-element-that-could-change-the-world>.)
- Largo Resources Ltd., 2013, Maracas vanadium-PGE project Brazil: Toronto, Ontario, Canada, Largo Resources Ltd., April 5. (Accessed April 16, 2013, at <http://www.largoresources.com/projects/maracas/default.aspx>.)
- Metal-Pages, 2010, China vanadium industry facing fatal threat from niobium—Chengde Xinxin: Metal-Pages, March 19. (Accessed May 21, 2013, via <http://www.metal-pages.com>.)
- Metal-Pages, 2011, American Vanadium sees 11.4 million lbs annual output: Metal-Pages, September 13. (Accessed June 18, 2013, via <http://www.metal-pages.com/>.)
- PacificOre Mining Corp., 2012a, Lac Dore drilling program outlined: PacificOre Mining Corp. news release, July 25. (Accessed April 25, 2013, at <http://www.pacificoremining.com/news/2012/179-lac-dore-drilling-program-outlined>.)
- PacificOre Mining Corp., 2012b, Lac Dore vanadium-titanium-iron project mag survey provides confirmation: PacificOre Mining Corp. news release, December 14. (Accessed April 25, 2013, at <http://www.pacificoremining.com/news/2012/185-lac-dore-vanadium-titanium-iron-project-mag-survey-provides-confirmation>.)
- PacificOre Mining Corp., 2012c, PacificOre begins trading: PacificOre Mining Corp. news release, May 24. (Accessed April 25, 2013, at <http://www.pacificoremining.com/news/2012/173-pacificore-begins-trading>.)
- Roskill Information Services Ltd., 2013, Vanadium—Global industry markets and outlook: London, United Kingdom, Roskill Information Services Ltd. leaflet. (Accessed July 28, 2013, at <http://www.roskill.com/reports/steel-alloys/vanadium>.)
- Ryan's Notes, 2012, US ITC shocks industry by revoking antidumping duty on Russian FeV imports: Ryan's Notes, v. 18, no. 32, August 13, p. 1.
- Ryan's Notes, 2013a, Ferroalloy notes: Ryan's Notes, v. 19, no. 6, February 11, p. 2.
- Ryan's Notes, 2013b, Nitrided vanadium tightness persists—Evraz's Q1 Nitrovan output may be lower: Ryan's Notes, v. 19, no. 4, January 28, p. 1.
- TTP Squared Inc., 2013, Vanadium market outlook: TTP Squared Inc., April, 28 p. (Accessed April 10, 2013, at <http://atlanticltd.com.au/upload/documents/VanadiumInformation/VanadiumMarketOutlook.pdf>.)
- World Steel Association, 2013, World steel short range outlook: World Steel Association, April 11. (Accessed May 1, 2013, at <http://www.worldsteel.org/media-centre/press-releases/2013/worldsteel-Short-Range-Outlook-April.html>.)
- Xstrata plc, 2013, Annual report 2012: Zug, Switzerland, Xstrata plc, April 26, 152 p.

## GENERAL SOURCES OF INFORMATION

### U.S. Geological Survey Publications

- Historical Statistics for Mineral and Material Commodities in the United States, Data Series 140.
- Vanadium. Ch. in Mineral Commodity Summaries, annual.
- Vanadium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
- Vanadium. International Strategic Minerals Inventory Summary Report, Circular 930–K, 1992.
- Vanadium. Mineral Industry Surveys, monthly.
- Vanadium (V). Ch. in Metal Prices in the United States Through 2010, Scientific Investigations Report 2012–5188, 2013.

### Other

- Metal Bulletin.
- Metal Bulletin Monthly.
- Roskill Information Services Ltd.
- Vanadium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1  
SALIENT VANADIUM STATISTICS<sup>1</sup>

(Metric tons of contained vanadium, unless otherwise specified)

	2008	2009	2010	2011	2012
United States:					
Production, ore and concentrate, recoverable vanadium <sup>2</sup>	520	230	1,060	590	272
Consumption, reported	5,170	4,690	5,030	4,140 <sup>r</sup>	3,980
Imports for consumption:					
Ferrovandium	2,800	353	1,340	2,220	4,190
Vanadium pentoxide (anhydride)	3,700	1,120	4,000	2,800	1,640
Other oxides and hydroxides of vanadium	144	25	167	886	905
Ash and residues <sup>3</sup>	1,040	791	521	1,420	2,040
Exports:					
Ferrovandium	452	672	611	314	337
Vanadium pentoxide (anhydride)	249	401	140	98 <sup>r</sup>	62
Other oxides and hydroxides of vanadium	1,040	506	1,100	254	287
Stocks, end of period:					
Ferrovandium	229	232	181	126 <sup>r</sup>	167
Oxide	24	5	5	W	W
Other <sup>4</sup>	82	58	62	67 <sup>r</sup>	56
World, production from ore, concentrate, slag <sup>c</sup>	62,000 <sup>r</sup>	59,000 <sup>r</sup>	72,000 <sup>r</sup>	74,000 <sup>r</sup>	74,000

<sup>c</sup>Estimated. <sup>r</sup>Revised.

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

<sup>2</sup>Denison Mines Corp. Web site.

<sup>3</sup>Ash and residues from the manufacture of iron and steel.

<sup>4</sup>Consists principally of vanadium-aluminum alloy, small quantities of other vanadium alloys, vanadium metal, and ammonium metavanadate.

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

(Kilograms of contained vanadium)

	2011	2012
End use:		
Steel:		
Carbon	815,000 <sup>r</sup>	759,000
Full alloy	1,530,000 <sup>r</sup>	1,510,000
High-strength low-alloy	W	W
Stainless and heat resisting	61,500	61,500
Tool	W	165,000
Total	2,400,000 <sup>r</sup>	2,500,000
Cast irons	W	--
Superalloys	16,400 <sup>r</sup>	9,050
Alloys (excluding steels and superalloys):		
Welding and alloy hard-facing rods and materials	1,660 <sup>r</sup>	1,660
Other alloys <sup>2</sup>	W	W
Chemical and ceramic uses:		
Catalysts	W	W
Pigments	W	W
Miscellaneous and unspecified	1,720,000 <sup>r</sup>	1,470,000
Grand total	4,140,000 <sup>r</sup>	3,980,000
Form:		
Ferrovandium	3,240,000 <sup>r</sup>	3,140,000
Other <sup>3</sup>	900,000 <sup>r</sup>	839,000
Total	4,140,000 <sup>r</sup>	3,980,000

<sup>r</sup>Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified." -- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Includes magnetic alloys.

<sup>3</sup>Consists of vanadium-aluminum alloy, vanadium pentoxide, quantities of other vanadium alloys, vanadium metal, and ammonium metavanadate.

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

	Aluminum-vanadium master alloy <sup>2</sup>		Unwrought aluminum-vanadium master alloy		Vanadium metal, including waste and scrap	
	Quantity, gross weight (kilograms)	Value	Quantity, gross weight (kilograms)	Value	Quantity, gross weight (kilograms)	Value
<b>Imports for consumption:</b>						
2011	86,100	\$2,460,000	278,000	\$1,210,000	43,900	\$1,930,000
<b>2012:</b>						
Australia	45,100	1,030,000	--	--	--	--
Belgium	758	17,400	--	--	--	--
China	971	26,600	78,200	460,000	--	--
Germany	12,300	423,000	--	--	154,000	4,840,000
Hong Kong	31	8,250	--	--	--	--
Netherlands	--	--	24,600	221,000	--	--
Russia	56,000	1,500,000	--	--	--	--
United Kingdom	360	10,100	--	--	--	--
Total	115,000	3,010,000	103,000	681,000	154,000	4,840,000
<b>Exports:</b>						
2011	318,000	10,000,000	881,000 <sup>†</sup>	2,170,000 <sup>†</sup>	102,000	3,340,000
<b>2012:</b>						
Australia	8,090	661,000	2,840	25,100	76	2,940
Belgium	20,400	1,320,000	691	8,980	--	--
Bolivia	--	--	3,710	48,200	--	--
Brazil	--	--	4,400	57,200	--	--
Canada	--	--	398,000	1,020,000	--	--
China	--	--	19,100	156,000	--	--
Colombia	--	--	20,400	62,800	--	--
France	307	43,400	--	--	--	--
Germany	490	18,900	--	--	107	6,650
Hong Kong	--	--	5,240	83,000	--	--
India	--	--	36,500	297,000	--	--
Israel	--	--	4,690	67,300	--	--
Italy	226	37,500	18,700	246,000	--	--
Japan	37,500	995,000	29,300	710,000	25,500	671,000
Korea, Republic of	295	16,400	4,100	72,300	--	--
Kuwait	--	--	24,000	103,000	--	--
Latvia	352	13,600	--	--	--	--
Mexico	--	--	196,000	509,000	218	8,400
Mongolia	--	--	20,300	53,800	--	--
Netherlands	19,400	530,000	1,520	20,500	--	--
New Zealand	--	--	9,320	51,000	--	--
Nigeria	--	--	30,400	142,000	--	--
Peru	--	--	141	2,840	--	--
Philippines	--	--	1,170	15,300	--	--
Poland	--	--	368	4,790	--	--
Romania	6,490	230,000	--	--	--	--
Russia	254,000	6,870,000	--	--	--	--
Saudi Arabia	--	--	360	9,190	--	--
Singapore	--	--	808	10,500	83	6,240
Taiwan	7,400	301,000	--	--	--	--
Turkey	--	--	769	10,000	--	--
United Kingdom	77,000	2,400,000	90,000	1,340,000	79	3,050
Venezuela	--	--	1,170	16,400	--	--
Total	432,000	13,400,000	924,000	5,140,000	26,000	698,000

<sup>†</sup>Revised. -- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium. Includes Harmonized Tariff Schedule code 8112.99.200.

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

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

	Ferrovanadium		Vanadium pentoxide (anhydride) <sup>2</sup>		Other oxides and hydroxides of vanadium	
	Quantity, V content (kilograms)	Value	Quantity, V content (kilograms)	Value	Quantity, V content (kilograms)	Value
<b>Imports for consumption:</b>						
2011	2,220,000	\$64,600,000	2,800,000	\$45,800,000	886,000	\$17,400,000
<b>2012:</b>						
Austria	444,000	11,900,000	59,000	803,000	101,000	2,330,000
Canada	832,000	22,500,000	--	--	--	--
China	--	--	513,000	7,170,000	--	--
Czech Republic	2,080,000	50,800,000	65,300	745,000	--	--
Germany	1,410	107,000	1,250	62,200	--	--
India	26,100	631,000	--	--	--	--
Korea, Republic of	803,000	22,400,000	39,400	452,000	--	--
Russia	--	--	94,500	745,000	--	--
South Africa	--	--	760,000	14,000,000	804,000	10,500,000
Taiwan	--	--	101,000	2,360,000	--	--
Thailand	--	--	8,830	245,000	--	--
Total	4,190,000	108,000,000	1,640,000	26,500,000	905,000	12,800,000
<b>Exports:</b>						
2011	314,000	9,970,000	97,600 <sup>†</sup>	1,650,000 <sup>†</sup>	254,000	2,390,000
<b>2012:</b>						
Austria	--	--	--	--	14,400	128,000
Brazil	--	--	103	5,200	18,500	271,000
Canada	221,000	7,330,000	--	--	1,740	33,700
China	--	--	--	--	15,300	230,000
Columbia	160	8,130	--	--	2,970	13,900
Germany	--	--	417	13,400	90,800	1,250,000
Hong Kong	--	--	--	--	767	6,830
Italy	--	--	14,400	249,000	--	--
Japan	11,600	372,000	4,100	43,900	4,090	72,900
Korea, Republic of	5,440	285,000	923	8,030	--	--
Mexico	50,800	1,310,000	2,610	80,800	52,600	496,000
Netherlands	--	--	--	--	41,200	366,000
Peru	32,600	888,000	--	--	--	--
Russia	--	--	--	--	34,100	597,000
Saudi Arabia	--	--	27,800	581,000	--	--
Spain	--	--	8,700	134,000	--	--
Thailand	--	--	200	7,200	--	--
Trinidad and Tobago	15,000	774,000	2,610	40,000	9,690	67,600
United Kingdom	--	--	--	--	542	8,350
Total	337,000	11,000,000	61,800	1,160,000	287,000	3,540,000

<sup>†</sup>Revised. -- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>May include catalysts that contain vanadium pentoxide.

Source: U.S. Census Bureau.



TABLE 5  
U.S. IMPORTS FOR CONSUMPTION OF VANADIUM-BEARING ASH AND RESIDUES<sup>1,2</sup>

Country	2011		2012	
	Quantity, V <sub>2</sub> O <sub>5</sub> <sup>3</sup> content (kilograms)	Value	Quantity, V <sub>2</sub> O <sub>5</sub> <sup>3</sup> content (kilograms)	Value
Belgium	43,400	\$257,000	17,400	279,000
Canada	1,300,000	781,000	1,470,000	4,060,000
Mexico	7,580	30,300	435,000	4,600,000
Netherlands	--	--	23,700	233,000
Qatar	--	--	55,100	443,000
Saudi Arabia	62,200	459,000	--	--
Thailand	--	--	6,850	55,100
United Kingdom	5,950	43,000	26,500	213,000
Total	1,420,000	1,570,000	2,040,000	9,880,000

-- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Ash and residues from the manufacture of iron and steel.

<sup>3</sup>V<sub>2</sub>O<sub>5</sub> vanadium pentoxide.

Source: U.S. Census Bureau.

TABLE 6  
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS VANADIUM CHEMICALS<sup>1,2</sup>

Material and country	2011		2012	
	Quantity, V content (kilograms)	Value	Quantity, V content (kilograms)	Value
<b>Sulfates:</b>				
Belgium	18,900	\$439,000	6,000	\$53,900
China	23,100	290,000	23,100	306,000
India	--	--	11	11,000
Japan	144	8,680	--	--
Total	42,200	738,000	29,100	370,000
<b>Vanadates:</b>				
Austria	7,010	140,000	15,800	345,000
China	46,600	1,560,000	46,400	1,450,000
Germany	7,790	312,000	832	74,000
India	99	4,750	--	--
Japan	49	2,610	208	34,900
Netherlands	5,620	131,000	--	--
South Africa	224,000	5,100,000	213,000	4,200,000
Taiwan	12,000	147,000	238	14,500
United Kingdom	--	--	3,370	67,000
Total	303,000	7,400,000	280,000	6,190,000

-- Zero.

<sup>1</sup>Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Comprises vanadium ore and miscellaneous vanadium chemicals.

Source: U.S. Census Bureau.

TABLE 7  
VANADIUM: ESTIMATED WORLD PRODUCTION, BY COUNTRY<sup>1,2</sup>

(Metric tons, vanadium content)

Country	2008	2009	2010	2011	2012
Production from ores, concentrates, slag: <sup>3</sup>					
China <sup>4</sup>	26,000 <sup>r</sup>	29,000 <sup>r</sup>	32,000 <sup>r</sup>	36,000 <sup>r</sup>	39,000
Kazakhstan	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	--
Russia	14,500	14,500	15,000	15,000 <sup>r</sup>	15,000
South Africa	20,295 <sup>5</sup>	14,353 <sup>5</sup>	22,606 <sup>5</sup>	21,652 <sup>r,5</sup>	19,500
United States <sup>5,6</sup>	520	230	1,060	590	272
Total <sup>7</sup>	61,100 <sup>r</sup>	58,000 <sup>r</sup>	71,000 <sup>r</sup>	74,000 <sup>r</sup>	74,000
Petroleum residues, ash, and spent catalysts, Japan <sup>8</sup>	560	560	560	560	560
Grand total <sup>7</sup>	62,000 <sup>r</sup>	59,000 <sup>r</sup>	72,000 <sup>r</sup>	74,000 <sup>r</sup>	74,000

<sup>r</sup>Revised. -- Zero.

<sup>1</sup>World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>In addition to the countries listed, vanadium is also recovered from petroleum residues in Germany and several other European countries, but available information is insufficient to make reliable estimates. Table includes data available through May 29, 2013.

<sup>3</sup>Production in this section is credited to the country that was the origin of the vanadiferous raw material.

<sup>4</sup>To convert vanadium content to gross weight (V<sub>2</sub>O<sub>5</sub> in vanadiferous slag), divide by 0.56. V<sub>2</sub>O<sub>5</sub> content in vanadium slag is estimated to be 17%. Data rounded to two significant digits.

<sup>5</sup>Reported figure.

<sup>6</sup>In 2008, Denison Mines Corp. began producing vanadium as a coproduct from mining uraniumiferous sandstones. Source: Denison Mines Corp. Web site.

<sup>7</sup>Totals and grand totals are rounded to two significant digits.

<sup>8</sup>Production in this section is credited to the country where the vanadiferous product is extracted; available information is inadequate to permit crediting this output back to the country of origin of the vanadiferous raw material.