



2010 Minerals Yearbook

VANADIUM

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In 2010, reported vanadium consumption in the United States was 5,000 metric tons (t) of contained vanadium, a 7% increase from that of 2009 (table 1). The United States exported 611 t of ferrovandium (FeV), 140 t of vanadium pentoxide (V_2O_5), and 1,098 t of other oxides and hydroxides of vanadium collectively valued at \$30.9 million. Total exports of these vanadium-bearing materials increased by 17% from those of 2009. The United States imported (measured in vanadium content) 1,340 t of FeV; 3,998 t of V_2O_5 ; and 167 t of other oxides and hydroxides of vanadium collectively valued at \$98.2 million. Total imports for consumption of these vanadium materials increased by 267% from those of 2009.

Vanadium's primary use is as a hardening agent in steel, in which it is critical in imparting toughness and wear resistance. These properties are especially important in high-strength low-alloy 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.

Production

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. In 2010, 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 have the heavy metals fixed before waste disposal. An alternative treatment is a circuit which extracts vanadium and produces V_2O_5 . Denison Mines Corp. (Toronto, Ontario, Canada) owns the White Mesa uranium processing mill near Blanding, UT. White Mesa processed feed from Denison's mine properties on the Colorado Plateau as well as uranium/vanadium ores purchased from independent miners. For every 0.45 kilogram (kg) of triuranium octoxide concentrate (yellowcake) produced, White Mesa's vanadium coproduct recovery circuit produced approximately 1.8 kg of vanadium in the form of V_2O_5 . After being idle for more than one-half of 2009, the

facility produced 1,060 t of V_2O_5 in 2010. According to the company, 541,000 pounds (lbs) (245 t) of V_2O_5 was sold at an average price of \$6.44 per lb V_2O_5 and 1,003,000 lbs (455 t) of FeV at an average price of \$13.40 per lb (Denison Mines Corp., 2011a, p. 5). Denison's vanadium production was projected to total approximately 770 t V_2O_5 in 2011 (Denison Mines Corp., 2011b). The company anticipated, except for scheduled maintenance shutdowns, that it would continue processing conventional ore during most of 2011 (Denison Mines Corp., 2011a, p. 11).

American Vanadium Corp.'s 100%-owned, open pit, heap-leach Gibellini project in Eureka County, NV, was expected to begin a feasibility study based on its preliminary economic assessment, under which mine production was projected to average 6,350 tons per year (t/yr) of V_2O_5 . According to the company, mine production could begin as early as the first quarter of 2013, which would make American Vanadium the only primary vanadium mine in the United States (American Vanadium Corp., 2011).

Evraz Group S.A. (Moscow, Russia), an important vanadium producer, announced that its FeV production rose 68% in 2010 to 13,507 t of contained vanadium compared with 8,029 t of contained vanadium in 2009, following the acquisition of Vanady-Tula, a vanadium refinery in Russia in November 2009. Production of oxides, vanadium alumina and vanadium chemicals increased by 35% to 1,317 t compared with 976 t in 2009 (Ryan's Notes, 2011). Evraz comprises Evraz Highveld Steel and Vanadium in South Africa, Nikom in the Czech Republic, Strategic Minerals Corp. (Stratcor Inc.) in the United States and South Africa, and Vanady-Tula in Russia. Stratcor operates a facility in Hot Springs, AR, where vanadium ash, residues, and other raw materials are converted into vanadium alloys and vanadium chemicals used by the chemical, steel, and titanium industries.

AMG Vanadium Inc., formerly Metallurg Vanadium Corp., completed construction of a new \$6 million storage facility as part of a long-term project to increase vanadium production capacity at its Cambridge, OH, facility. The building met all standards for safe containment of spent refinery catalyst, a raw material used in the production of FeV, the company's primary product offering. The building was linked to a dedicated railcar unloading and conveyor system, which was expected to enhance efficiency (AMG Vanadium Inc., 2010).

The Vanadium Technology Partnership estimated that approximately 2,700 t/yr of vanadium was recycled from spent catalysts (Vanadium Technology Partnership, undated). Vanadium's major end use was as an alloying-element in iron, steel, and titanium-bearing alloys, from which it is lost to slag and usually not recovered when those metals are recycled.

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. Based on USGS data, reported domestic vanadium consumption in 2010 was 5,000 t, a 7% increase from that of 2009.

Metallurgical applications continued to dominate U.S. vanadium use in 2010, accounting for 95% of reported consumption. Nonmetallurgical applications included catalysts, ceramics, electronics, and vanadium chemicals. The dominant nonmetallurgical use was in catalysts.

Most vanadium is consumed in the form of FeV, which is used as a means of introducing vanadium into steel, in which it provides 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 2010, the price for domestic FeV, as published in Metal Bulletin, ranged from \$10.50 to \$17.25 per pound of contained vanadium, compared with \$7.40 to \$35.00 per pound reported in 2009. In January, prices averaged \$11.40 per pound. Prices increased to a monthly high of \$17.25 in May and gradually decreased to end the year at an average of \$13.50 per pound in December. The European FeV price ranged from \$21.00 to \$34.50 per kilogram compared with \$17.50 to \$36.00 per kilogram in 2009. The European price averaged \$26.22 per kilogram in January and gradually increased to a monthly high of \$34.50 per kilogram in May. The price decreased in June and continued to slowly decrease for the remainder of the year to an average of \$29.24 per kilogram in December.

The Metal Bulletin published price for domestic V_2O_5 ranged between \$6.00 and \$7.85 per pound in 2010, compared with \$3.60 and \$7.60 per pound in 2009. The price averaged about \$6.35 per pound in January and increased to a monthly high of \$7.85 per pound in May. Prices slowly decreased the rest of the year to end the year with an average of \$6.60 in December.

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, Russia, and South Africa. 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 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.—Atlantic Ltd. (Perth) announced in September that vanadium production was expected to begin in mid-2011 at its newly acquired Windimurra vanadium project in Western Australia, following raising \$55.5 million in capital. The previous owners of the project failed to secure the necessary \$81 million financing in 2009. According to Atlantic, Windimurra production was expected to be 5,700 t/yr of V_2O_5 and to meet approximately 7% of world demand. According to the current mine plan for the project, at a cutoff grade of 0.275% V_2O_5 , 97.8 Mt of ore was expected to be generated at an average grade of 0.47% V_2O_5 during 24.5 years (Atlantic Ltd., 2010).

In November, Reed Resources Ltd. (West Perth) announced that it entered into a memorandum of understanding (MOU) with Chinese conglomerate, China Nonferrous Metal Industry's Foreign Engineering and Construction Co. Ltd. (NFC), for the Barrambie vanadium project in Western Australia. According to the company, the MOU formalizes discussions between Reed and NFC, specifically construction, an engineering procurement, and project financing, and represents the next step towards the successful development of the project (Reed Resources Ltd., 2010).

Brazil.—Largo Resources Ltd. (Toronto, Ontario, Canada) has completed extensive work on its Maracas vanadium project including a feasibility study which outlined proven and probable mineral reserves of 13.1 Mt grading 1.34% V_2O_5 produced during a 23-year project life-span. The Maracas vanadium project was expected to produce 5,000 t/yr of FeV. The property is located in the municipality of Campo Alegre de Lourdes, State of Bahia (Largo Resources Ltd., 2010).

Canada.—Apella Resources Inc. (Vancouver, British Columbia) owns two vanadiferous magnetite deposits in Canada, the Iron-T vanadium project in central Quebec and the Lac Dore vanadium project in northern Quebec. According to the company, the Lac Dore project is an advanced vanadium project and was expected to be the largest vanadium deposit in North America, and the second largest in the world (Apella Resources, 2011b). Apella was expected to continue exploration and development on the Lac Dore project into 2011. Simultaneously, Apella was expected to study the feasibility of its Iron-T vanadium project, which was expected to take 12 to 18 months and cost approximately \$18 million (Apella Resources, 2011a).

China.—The Chinese vanadium industry continued to feel pressure from niobium, particularly in high-strength low-alloy steels (HSLA). The additive amount of niobium in steel production is only one-half of that of vanadium, so every 3,000 t of ferroniobium can substitute 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.

Sino Vanadium Inc. (Xi'an) owns 100% of the Daquan property in Shaanxi Province, and according to the company, the property was expected to become one of the largest global producers of V_2O_5 , with indicated resources of 15.8 Mt at an average grade of 0.95% V_2O_5 . In advance of completion of the feasibility study for the project, the company was proceeding

with the necessary applications to the Chinese government authorities to amend the Daquan project mining license, valid to July 2, 2030, to include both open pit and underground mining. The feasibility study was expected to confirm the construction schedule, which was anticipating completion in the second quarter of 2012 (Sino Vanadium Inc., 2010).

India.—The Indian Ferro Alloy Producers Association continued to urge the Indian Finance Ministry to reconsider the 7.5% import tax on V_2O_5 and vanadium sludge/ammonium metavanadate. They have asked that the tax be removed completely to protect the domestic FeV producers from completely shutting down their operations owing to lack of profits caused by the excessive costs of importing the raw material (V_2O_5) (Indian Ferro Alloy Producers Association, 2011).

Japan.—Japan's vanadium imports increased in 2010 compared with those in 2009; however, they have not recovered to 2008 levels. Japan's imports of V_2O_5 rose to 1,382 t V_2O_5 compared with 942 t V_2O_5 for the same period in 2009. Japanese FeV production increased to 2,825 t FeV in the first 8 months of 2010, up from 1,362 t FeV in the same period in 2009 and 2,620 t FeV in the same period of 2008 (Ryan's Notes, 2010).

Madagascar.—In November, Energizer Resources Inc. (Toronto, Ontario, Canada), formerly known as Uranium Star Corp., updated the resource estimate for its Green Giant vanadium project in Madagascar to include an indicated resource of 49.5 Mt at an average grade of 0.693% V_2O_5 . The mineral resource is contained in three separate zones on the Green Giant property, totaling approximately 5.3 kilometers (km) in strike length. According to the company, a preliminary economic assessment, to include analysis of the existing and additional infrastructure necessary for the project, was to begin in 2011. One important and potential benefit to the company would be the development of the adjacent Sakoia coal project, situated 30 km away from the Green Giant project (Energizer Resources Inc., 2011).

According to the company, the Green Giant vanadium deposit is a sedimentary-hosted deposit, in contrast to most vanadium deposits which are magnetite hosted. As a result, the metallurgical process for the Green Giant vanadium is different from that used by other vanadium producers. The unique characteristics of the Green Giant vanadium would allow the company to produce a high-purity V_2O_5 , which is required in battery power and in battery storage for both automotive and large-scale applications. FeV, which is the usual end product from magnetite-hosted deposits, can only be used for steel applications (Energizer Resources Inc., 2011).

Russia.—Evraz announced that it focused on increasing the efficiency of its Vanady-Tula plant, and upon implementation of its plan, the plant's production capacity was expected to increase by 3% to 5% in 2011 and by up to 10% by 2013. In 2011, Vanady-Tula had a capacity to produce 12,500 t/yr of V_2O_5 and up to 7,100 t/yr of FeV (Evraz Group S.A., 2011, p. 45).

South Africa.—Xstrata plc (Zug, Switzerland) announced that its Rhovan vanadium facility, located 30 km northwest of Brits, achieved record production during 2010. The Rhovan facility produced 4,300 t of FeV in 2010, an 89% increase compared with 2,280 t of FeV produced in 2009. The facility produced

9,920 t of V_2O_5 in 2010, a 90% increase compared with 5,210 t of V_2O_5 produced in 2009. In part of 2009, the facility suspended all vanadium production owing to an extended maintenance program (Xstrata plc, 2011).

Vametco Alloys (Brits), a division of Stratcor, part of Evraz, announced that it improved production efficiency at its Vametco plant through optimizing the feed mix of vanadium ore and vanadium slag to its process. Vametco was therefore able to raise its production to full capacity during the second half of 2010. Vametco's primary end product is Nitrovan vanadium, a specialty vanadium-nitrogen alloy, which according to the company, strengthens steel more efficiently than FeV. The company was expected to continue to improve its vanadium recovery rate in 2011 as well as perform several safety improvements and environmental projects (Evraz S.A., 2011, p. 45).

Evraz Highveld Steel and Vanadium Ltd. (Emalahleni) reported producing 64,202 t of vanadium slag in 2010, a 38% increase from 46,614 t of vanadium slag produced in 2009. The company mines titaniferous magnetite ore at its Mapochs Mine at Roosenekal, Limpopo, and produces iron and steel products and vanadium bearing slag at its Steelworks facility in Emalahleni, Mpumalanga. The company marketed the vanadium-bearing slag locally as well as in Europe through its Austrian-based subsidiary, Hochvanadium Holdings AG (Evraz Highveld Steel and Vanadium Ltd., 2011, p. 5, 7).

Outlook

Vanadium consumption is heavily influenced by steel production, high-strength steel grades in particular. In 2010, vanadium benefited from an improvement in the global economy and a consequent improvement in the demand for steel. High-strength steels are growing in use as the construction, energy, and transportation industries seek to maximize the strength and minimize the weight of their products. There continues to be growth potential in vanadium's other end-use industries as well. 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.

There are several different battery technologies in the development and early commercialization stages. One technology showing continued 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 has also been shown to have the least ecological impact of all energy storage technologies.

Another emerging technology is the use of lithium-vanadium phosphate or fluorophosphate cathodes and lithium-vanadium oxide anodes in rechargeable lithium batteries. These batteries exhibit much improved safety compared with the more generic lithium-cobalt oxide type cathodes seen in cellular telephone or laptop batteries, which have higher operating voltages and higher rates of energy storage. The vanadium phosphate cathode material can support 20% more energy storage than the conventional cobalt oxide, as much as 26% more than iron phosphate, and 56% more than manganese oxide. However, in order for such a battery to be practical, the cost of the battery is key. Subaru, owned by Fuji Heavy Industries Ltd., has unveiled a prototype of its G4e electric car, powered by lithium-vanadium phosphate batteries. This concept car has a 200-km range that is provided by a relatively small vanadium phosphate battery pack, double what their earlier R1e concept car could achieve (Hykawy, 2009).

Vanadium is also emerging as an anticorrosion agent in some rare-earth magnets, enabling use of a new set of materials for use in strong magnets. Vanadium acts to increase the effectiveness of rare-earth magnets, including making the magnets much more resistant to corrosion across a broader range of temperature and humidity (Hykawy, 2009).

The outlook for the vanadium market in 2011 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 market for battery production, were all expected to contribute to increased vanadium consumption.

References Cited

- American Vanadium Corp., 2011, Gibellini project: Vancouver, British Columbia, Canada, American Vanadium Corp. (Accessed July 22, 2011, at <http://www.americanvanadium.com/gibellini-project.php>.)
- AMG Vanadium Inc., 2010, Construction of raw material storage building complete: Cambridge, OH, AMG Vanadium Inc., November 16. (Accessed June 22, 2011, at http://www.metallurgvanadium.com/news_rmsb2event.html.)
- Apella Resources Inc., 2011a, 250 km Iron-T Mag survey complete and topo mapping underway: Vancouver, British Columbia, Canada, Apella Resources Inc., November 10. (Accessed July 27, 2011, at <http://www.apellaresources.com/news/2010/123-250-km-iron-t-mag-survey-complete-and-topo-mapping-underway>.)
- Apella Resources Inc., 2011b, Overview—Apella Resources—Leading the vanadium super-charge: Vancouver, British Columbia, Canada, Apella Resources Inc., undated. (Accessed July 27, 2011, at <http://www.apellaresources.com/company/overview>.)
- Atlantic Ltd., 2010, Windimurra vanadium project: Perth, Australia, Atlantic Ltd., April 27. (Accessed June 28, 2011, at http://atlanticltd.com.au/upload/documents/InvestorRelations/asx/0100427_100427WindimurraVanadiumProject-InvestorPresentation.pdf.)
- Denison Mines Corp., 2011a, Annual report 2010: Toronto, Ontario, Canada, Denison Mines Corp., March 29, 68 p.
- Denison Mines Corp., 2011b, Denison Mines Corp. reports first quarter 2011 results: Toronto, Ontario, Canada, Denison Mines Corp., May 11. (Accessed June 17, 2011, at http://www.denisonmines.com/s/SiteResources/data/MediaArchive/pdfs/press_releases/2011/may11-11pr.pdf.)
- Energizer Resource Inc., 2011, Energizer Resources provides business update on its Green Giant vanadium project, Madagascar—President Obama recognizes vanadium redox battery technology: Toronto, Ontario, Canada, Energizer Resource Inc., March 16. (Accessed July 27, 2011, at http://www.energizerresources.com/index.php?option=com_content&view=article&id=430&Itemid=217.)
- Evrz Highveld Steel and Vanadium Ltd., 2011, Annual report 2010: Emalahleni, South Africa, Evraz Highveld Steel and Vanadium Ltd., March 16, 289 p.
- Evrz Group S.A., 2011, Annual report and accounts 2010: Moscow, Russia, Evraz Group S.A., March 30, 217 p.
- Hykawy, Jon, 2009, Vanadium—The supercharger: Byron Capital Markets, November 12. (Accessed July 29, 2011, at <http://www.tngltd.com.au/images/tngltd--doiru.pdf>.)
- Indian Ferro Alloy Producers Association, 2011, Pre-budget proposals for 2011–2012—Ferro alloys: Indian Ferro Alloy Producers Association, undated. (Accessed July 22, 2011, via <http://www.ifapaindia.org/>.)
- Johnstone, Bob, 2008, The element that could change the world: Discover, October 29. (Accessed August 5, 2009, at <http://discovermagazine.com/2008/oct/29-the-element-that-could-change-the-world>.)
- Largo Resources Ltd., 2010, Largo Resources increases landholdings to 27,000 hectares around the Maracas Vanadium property, Bahia, Brazil: Toronto, Ontario, Canada, Largo Resources Ltd., November 22. (Accessed July 1, 2011, at <http://www.largoresources.com/Investors/Press-Releases/Press-Release-Details/2010/Largo-Resources-Increases-Landholdings-to-27000-Hectares-Around-the-Maracas-Vanadium-Property-Bahia-Brazil1123316/default.aspx>.)
- Metal-Pages, 2010, China vanadium industry facing fatal threat from niobium-Chengde Xinxin: Metal-Pages, March 19. (Accessed July 21, 2011, via <http://www.metal-pages.com/news/>.)
- Reed Resources Ltd., 2010, MoU signed with NFC for development of Barrambie Vanadium project: West Perth, Australia, Reed Resources Ltd., November 11. (Accessed September 28, 2011, at <http://www.reedresources.com/announce-blog.php?id=379>.)
- Ryan's Notes, 2010, Ferroalloy notes: Ryan's Notes, v. 16, no. 40, October 18, p. 4.
- Ryan's Notes, 2011, Ferroalloy notes: Ryan's Notes, v. 17, no. 4, January 24, p. 3.
- Sino Vanadium Inc., 2010, Sino Vanadium provides update on progress of 100%-owned Daquan project: Toronto, Ontario, Canada and Xi'an, China, Sino Vanadium Inc., July 9. (Accessed July 22, 2011, at http://www.sinovaniadium.com/sites/default/files/100709_SVX_Provides_Update_on_Progress_of_100_percent-Owned_Daquan_Project.pdf.)
- Vanadium Technology Partnership, [undated], Vanadium—Creating a stronger, lighter U.S. Army: Vanadium Technology Partnership (Accessed September 28, 2011, at <http://vanadiumtechnologypartnership.org/>.)
- Xstrata plc., 2011, Production report for the 12 months ended 31 December 2010: Zug, Switzerland, Xstrata plc. press release, February 1. (Accessed April 20, 2011, via <http://www.xstrata.com/media/news/2011/02/01/0800CET/pdf>.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

- Vanadium. Ch. in *Metal Prices in the United States Through 1998, 1999*.
- 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*.

Other

- Chemical & Engineering News.
- Engineering & Mining Journal.
- 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 STATISTICS¹

(Metric tons of contained vanadium, unless otherwise specified)

	2006	2007	2008	2009	2010
United States:					
Production, ore and concentrate:					
Recoverable vanadium	--	--	W	W	W
Recoverable vanadium: ² value thousand dollars	--	--	W	W	W
Consumption, reported	4,030	4,970 ^r	5,170	4,690 ^r	5,030
Exports:					
Ferrovandium	515 ^r	206 ^r	452 ^r	672	611
Vanadium pentoxide (anhydride)	341	327	249	401	140
Other oxides and hydroxides of vanadium	832	626	1,040	506	1,100
Imports for consumption:					
Ferrovandium	2,140 ^r	2,220 ^r	2,800 ^r	353	1,340
Ash and residues ³	637	1,000	1,040	791	521
Vanadium pentoxide (anhydride)	1,920	2,390	3,700	1,120	4,000
Other oxides and hydroxides of vanadium	129	42	144	25	167
Stocks:					
Ferrovandium	275	253	229 ^r	232	181
Oxide	6	22	24	5	5
Other ⁴	49	49 ^r	82 ^r	58	62
World, production from ore, concentrate, slag ^{6,5}	57,900	58,500	56,400	51,400 ^r	57,600

⁶Estimated. ^rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.

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

²Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mill, plus vanadium recovered from ferrophosphorous slag derived from domestic phosphate rock.

³Ash and residues from the manufacture of iron and steel.

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

⁵Excludes U.S. production.

TABLE 2
U.S. CONSUMPTION OF VANADIUM, BY END USE AND FORM¹

(Kilograms of contained vanadium)

	2009	2010
End use:		
Steel:		
Carbon	832,000	843,000
Full alloy	1,920,000	2,030,000
High-strength low-alloy	W	W
Stainless and heat resisting	119,000	120,000
Tool	W ^r	W
Total	2,870,000 ^r	2,990,000
Cast irons	W	W
Superalloys	11,500 ^r	9,230
Alloys (excluding steels and superalloys):		
Welding and alloy hard-facing rods and materials	W	W
Other alloys ²	W	W
Chemical and ceramic uses:		
Catalysts	W	W
Pigments	W	W
Miscellaneous and unspecified	1,800,000 ^r	2,030,000
Grand total	4,690,000 ^r	5,030,000
Form:		
Ferrovanadium	3,910,000 ^r	4,210,000
Oxide	44,300 ^r	3,530
Other ³	732,000 ^r	815,000
Total	4,690,000 ^r	5,030,000

^rRevised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

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

²Includes magnetic alloys.

³Consists principally of vanadium-aluminum alloy, small quantities of other vanadium alloys, vanadium metal, and ammonium metavanadate.

TABLE 3
U.S. IMPORTS AND EXPORTS OF ALUMINUM-VANADIUM MASTER ALLOY
AND VANADIUM METAL, INCLUDING WASTE AND SCRAP¹

	Aluminum-vanadium master alloy		Vanadium metal, including waste and scrap	
	Quantity, gross weight (kilograms)	Value	Quantity, gross weight (kilograms)	Value
Imports for consumption:				
2009	282,000	\$979,000	21,700	\$940,000
2010:				
China	494	2,500	4,370	93,100
Germany	--	--	5,300	341,000
Mexico	9,170,000	20,000,000	--	--
Netherlands	17,300	69,100	--	--
United Kingdom	16,400	109,000	--	--
Total	9,200,000	20,200,000	9,660	434,000
Exports:				
2009	11,200,000	27,800,000	22,700	1,040,000
2010:				
Belgium	80,600	1,320,000	--	--
Canada	7,320,000	17,400,000	2,280	74,600
Chile	--	--	28	2,880
China	16,500	164,000	--	--
Colombia	271	3,530	--	--
France	319	4,150	--	--
Germany	401	7,660	108	5,420
Hong Kong	657	19,300	--	--
India	17,900	160,000	--	--
Israel	6,840	102,000	--	--
Italy	637	8,280	--	--
Japan	55,300	1,600,000	18,100	572,000
Korea, Republic of	3,160	80,100	--	--
Malaysia	3,150	40,900	--	--
Mexico	4,180,000	11,200,000	--	--
Netherlands	296	3,850	--	--
Panama	--	--	129	6,280
Russia	793	8,040	--	--
Singapore	480	6,230	--	--
South Africa	1,430	14,400	--	--
Taiwan	32,700	101,000	--	--
Trinidad and Tobago	37,600	182,000	572	9,880
Turkey	804	10,500	--	--
United Arab Emirates	147,000	701,000	--	--
United Kingdom	7,350	107,000	--	--
Total	11,900,000	33,300,000	21,200	671,000

-- Zero.

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

Source: U.S. Census Bureau.

TABLE 4
U.S. IMPORTS AND EXPORTS OF FERROVANADIUM, VANADIUM PENTOXIDE (ANHYDRIDE), AND
OTHER OXIDES AND HYDROXIDES OF VANADIUM¹

	Ferrovanadium		Vanadium pentoxide (anhydride) ²		Other oxides and hydroxides of vanadium	
	Quantity, V ³ content (kilograms)	Value	Quantity, V ³ content (kilograms)	Value	Quantity, V ³ content (kilograms)	Value
Imports for consumption:						
2009	353,000	\$12,600,000	1,120,000	\$16,500,000	25,200	\$551,000
2010:						
Albania	16,000	349,000	--	--	--	--
Australia	20,400	687,000	--	--	--	--
Austria	451,000	14,100,000	170	9,830	33,500	942,000
Canada	477,000	15,100,000	--	--	--	--
China	502	23,600	162,000	3,980,000	--	--
Germany	2,350	161,000	--	--	--	--
India	542	35,600	--	--	--	--
Korea, Republic of	372,000	10,600,000	--	--	--	--
Russia	--	--	2,520,000	29,900,000	--	--
South Africa	--	--	1,310,000	19,800,000	133,000	2,370,000
United Kingdom	--	--	3,000	39,700	5	22,600
Total	1,340,000	41,100,000	4,000,000	53,700,000	167,000	3,330,000
Exports:						
2009	672,000	15,000,000	401,000	4,970,000	506,000	5,270,000
2010:						
Argentina	1,450	44,500	1,530	48,100	48,300	283,000
Australia	393	13,100	--	--	--	--
Austria	--	--	--	--	32,500	289,000
Belgium	--	--	1,980	39,300	--	--
Brazil	--	--	20,500	256,000	24,900	222,000
Canada	310,000	9,690,000	--	--	223,000	2,100,000
China	13,700	243,000	--	--	42,300	400,000
Columbia	331	7,390	--	--	--	--
Germany	--	--	12,000	197,000	43,800	510,000
India	104,000	2,480,000	--	--	--	--
Ireland	--	--	--	--	4,470	39,800
Japan	--	--	--	--	558	4,970
Korea, Republic of	66,500	2,130,000	--	--	--	--
Mexico	56,200	1,930,000	1,290	28,600	37,700	493,000
Morocco	--	--	433	14,100	--	--
Netherlands	13,500	263,000	65,500	975,000	346,000	3,670,000
Pakistan	--	--	1,100	18,000	--	--
Peru	3,420	153,000	--	--	--	--
Russia	--	--	--	--	219,000	1,950,000
Saudi Arabia	15,000	478,000	10,400	183,000	--	--
Senegal	--	--	--	--	75,400	672,000
Singapore	--	--	225	9,320	--	--
Spain	--	--	19,000	247,000	--	--
Trinidad and Tobago	--	--	6,170	121,000	--	--
United Arab Emirates	25,900	698,000	--	--	--	--
Total	611,000	18,100,000	140,000	2,140,000	1,100,000	10,600,000

-- Zero.

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

²May include catalysts that contain vanadium pentoxide.

³Vanadium.

Source: U.S. Census Bureau.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF VANADIUM-BEARING ASH AND RESIDUES¹

Material and country	2009		2010	
	Quantity, V ₂ O ₅ ² content (kilograms)	Value	Quantity, V ₂ O ₅ ² content (kilograms)	Value
Ash and residues: ³				
Belgium	--	--	48,700	\$274,000
Canada	2,250	\$4,850	89,800	69,800
Mexico	788,000	12,300,000	361,000	5,190,000
Saudi Arabia	--	--	6,090	31,200
Trinidad and Tobago	--	--	15,400	4,710
United Kingdom	120	2,210	--	--
Total	791,000	12,300,000	521,000	5,570,000

-- Zero

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

²V₂O₅ Vanadium pentoxide.

³Ash and residues from the manufacture of iron and steel.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS VANADIUM CHEMICALS^{1,2}

Material and country	2009		2010	
	Quantity, V ³ content (kilograms)	Value	Quantity, V ³ content (kilograms)	Value
Sulfates, China	16,500	\$182,000	46,400	\$575,000
Vanadates:				
Austria	--	--	410	13,700
China	167	3,250	25,600	887,000
Germany	12,500	473,000	61,700	1,990,000
India	137	12,100	390	7,790
Japan	--	--	214	44,000
South Africa	182,000	2,550,000	69,500	1,100,000
Taiwan	--	--	293	10,200
United Kingdom	19,800	352,000	--	--
Total	214,000	3,390,000	158,000	4,050,000

-- Zero.

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

²Comprises vanadium ore and miscellaneous vanadium chemicals.

³Vanadium.

Source: U.S. Census Bureau.

TABLE 7
VANADIUM: ESTIMATED WORLD PRODUCTION, BY COUNTRY^{1,2}

(Metric tons, vanadium content)

Country	2006	2007	2008	2009	2010
Production from ores, concentrates, slag: ³					
China ⁴	17,500	19,000	20,000	21,000	22,000
Kazakhstan	1,000	1,000	1,000	1,000	1,000
Russia	15,100	14,500	14,500	14,500	15,000
South Africa	23,780 ⁵	23,486 ⁵	20,295 ⁵	14,353 ^{r,5}	19,000
United States	--	--	W	W	W
Total	57,400	58,000	55,800	50,900 ^r	57,000
Japan, petroleum residues, ash, and spent catalysts ⁶					
	560	560	560	560	560
Grand total	57,900	58,500	56,400	51,400 ^r	57,600

^rRevised. W Withheld to avoid disclosing company proprietary data; not included in totals. -- Zero.

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

²In 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 18, 2011.

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

⁴Estimated 40% of vanadium recovered from vanadiferous slag.

⁵Reported figure.

⁶Production 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.