Indian Minerals Yearbook 2016

(Part- II : Metals & Alloys)

55th Edition

VANADIUM

(FINAL RELEASE)

GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

Indira Bhavan, Civil Lines,
NAGPUR – 440 001

PHONE/FAX NO. (0712) 2565471
PBX : (0712) 2562649, 2560544, 2560648
E-MAIL : cme@ibm.gov.in
Website: www.ibm.gov.in

February, 2018

19 Vanadium

Vanadium,was discovered in 1801 by a mexican mineralogist Del.Rio. It is a scarce element, hard, silvery grey, ductile and malleable transition metal with good structural strength. It occurs naturally in about 65 different minerals among which are patronite, vanadinite, roscoelite and cacnotite. It is also present in bauxite and in fossil fuel deposits. It occurs in association with titaniferous magnetite and is recovered as a by-product during iron & steel manufacture. Vanadium is also concentrated in many end-products of organic material including coal, crude oil, oil shale and tar sands. It is also found in small percentages in meteorites. In addition, vanadium present in bauxite can also be recovered as vanadium sludge from red mud during the production of alumina. Vanadium is widely used in green technology applications, especially in battery technology.

Vanadium has the property to increase the tensile strength of steel and its high strength to weight ratio supports fuel efficiency mandates in the Automotive and Aerospace Industries.

RESERVES/RESOURCES

In India, vanadium is associated with titaniferous magnetite which contains 0.8 to 3% V_2O_5. It also occurs in significant amounts in association with chromite, laterite, bauxite and ferromagnesian-rich rocks, such as, pyroxenite, base anorthosite and gabbro.

As per NMI database, based on UNFC system, the total estimated reserves/resources of vanadium ore as on 1.4.2015 are placed at 24.63 million tonnes with an estimated V_2O_5 content of 64,594 tonnes. The entire resources of vanadium, are placed under remaining resources category only (Table-1).

PRODUCTION

Vanadium is recovered from slag that is collected from the processing of vanadiferous magnetite ore where iron and steel are the principal products. The processing of gas and petroleum products is also an important source of vanadium, which is recovered both from the raw material and from the recycling of vanadium-bearing catalyst.

Vanadium sludge is separated as a by-product during the Bayer process for production of alumina hydrate. NALCO has completed lab-scale studies to recover vanadium sludge from various Bayer Liquors. Lanjigarh Alumina has developed an in-house process for extraction of V_2O_5 (vanadium pentoxide) present in the bauxite involving simple operations with very low energy consumption. Thus, it is considered as innovative cost effective and environment friendly besides ensuring optimum utilisation of natural resources. This project was taken up as a part of Vedanta's ambitious project of Zero Discharge and Zero Waste Alumina Refinery. The production at Lanjigarh Plant, in Kalahandi district was 1124 tonnes during the period 2015-16. Vanadium recovery makes the country self-sufficient in meeting demand of vanadium as most of these raw materials are imported to make ferrovanadium. Vanadium recovery projects help in additional generation of revenue. The vanadium sludge obtained at BALCO's Korba plant contains 6 to 10% V_2O_5, Hindalco's Renukoot plant 18.2% V_2O_5 and Muri and Belgaum plants 6 to 20% V_2O_5.

EXPLORATION

During 2015-16 GSI carried out exploration work for assessing potentiality of titanium, vanadium, gallium and REE in bauxite around Betvatoli block, Netarhat plateau, Latehar district in Jharkhand. GSI had drilled seven boreholes of cumulative length of 500.65 m. Besides detailed mapping on 1:5000 scale was carried out in 5 sq. km area, which revealed two bauxite zones.

The chemical analysis of core samples of two boreholes in respect of V_2O_5 content varies between 0.001 to 0.064%.

USES

Vanadium is used primarily as an alloying element in Iron & Steel Industry and to some extent as a stabiliser in titanium and aluminium alloys

Table – 1 : Reserves/Resources of Vanadium as on 1.4.2015
(By Grades/States)

(In tonnes)

Grade/State	Reserves				Remaining Resources								Total Resources (A+B)
	Proved STD111	Probable		Total (A)	Feasibility STD211	Pre-feasibility		Measured STD331	Indicated STD332	Inferred STD333	Reconnaissance STD334	Total (B)	
		STD121	STD122			STD221	STD222						
All India : Total													
By Grades													
Ore	**-**	**-**	**-**	**-**	**276530**	**1720000**	**4108100**	**-**	**232000**	**18297225**	**-**	**24633855**	**24633855**
Contained V_2O_5	**-**	**-**	**-**	**-**	**1106**	**2835**	**6032**	**-**	**487**	**54133**	**-**	**64594**	**64594**
By States													
Karnataka													
Ore	-	-	-	-	-	500000	4000000	-	-	14884430	-	19384430	19384430
Contained V_2O_5	-	-	-	-	-	700	5600	-	-	43198	-	49498	49498
Maharashtra													
Ore	-	-	-	-	276530	-	108100	-	-	-	-	384630	384630
Contained V_2O_5	-	-	-	-	1106	-	432	-	-	-	-	1539	1539
Odisha													
Ore	-	-	-	-	-	1220000	-	-	232000	3412795	-	4864795	4864795
Contained V_2O_5	-	-	-	-	-	2135	-	-	487	10936	-	13558	13558

Figures rounded off.

which are used in aerospace applications. It imparts toughness and strength to steel, alloys and also acts as scavenger for oxygen. Vanadium is consumed in the Steel Industry in the manufacture of wide range of products, from low carbon flat rolled steels, high strength plates & structural steels to pipes, reinforcing bars, forging steels, rail steels and tool steels. Vanadium (about 80%) is mostly used in the form of ferro vanadium as a means of introducing vanadium into steel. There are two groups of vanadium steel alloys. Vanadium High carbon steel alloys contains 0.15% to 0.25% vanadium and high speed tool steels (HSS) have a vanadium content of 1% to 5%. HSS steel is used in surgical instruments and other tools. The content of vanadium in ferro vanadium varies from 45 to 50% and sometimes it is up to 80%, depending upon the demand. The 45 to 50% grade is produced from slag and other vanadium containing material by silicothermic reduction of pentoxide (V_2O_5) in presence of steel scrap or by direct reduction in an electric arc furnace. The resultant vanadium steels can be divided into micro-alloy or low-alloy steels with less than 0.15% vanadium and high-alloy steels with up to 5% vanadium. Non-metallurgical applications include its use as catalyst and in ceramic, chemical, pigments, health preparations and electronic industries. It is also used to produce a super conductive magnet with a field of 1,75,000 gauss. The most common oxide of vanadium i.e., vanadium pentoxide (V_2O_5) is used as a catalyst in manufacturing sulphuric acid. In biological context, vanadium is a micro-nutrient found naturally in mushroom, shellfish, black pepper, parsley dill, grain and grain products. It exists as both vanadyl sulphate, the form most commonly used in food supplements and vanadale.

Modern applications of vanadium include its use as vanadium secondary batteries for power plants and rechargeable vanadium redox battery (VRB) for commercial applications. The main advantages of 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. The VRB has also been shown to have the least ecological impact of all energy storage technologies.

SUBSTITUTES

Substitution of vanadium in steel by niobium, chromium, titanium, manganese, molybdenum and tungsten is possible although at higher cost or with lower performance. Heat-treated carbon steels can replace vanadium steels in some applications. Platinum and nickel can be used in some catalytic processes but at higher cost. Presently, there is no acceptable substitute for vanadium in aerospace titanium alloys.

CONSUMPTION

Ferrovanadium producing units in India consume either imported V_2O_5 concentrates or indigenous vanadium sludge. The domestic availability of vanadium sludge from Aluminium Industry is limited and insufficient for ferro-vanadium production and the gap is met by imports. During 2015-16, the total consumption of ferrovanadium by different industries was 1,106 tonne. Iron and steel was the major consuming industry accounting for 92% consumption followed by alloy steel (7%). The consumption of ferrovanadium during 2013-14 to 2015-16 by various units in the Organised Sector is furnished in Table-2.

Table –2 : Consumption *of Ferrovanadium, During 2013-14 to 2015-16 (By Industries)

(In tonnes)

Industry	2013-14	2014-15 (R)	2015-16 (P)
All Industries	**1110**	**1131**	**1106**
Alloy steel	26	43	80
Electrode	1	1	2
Foundry	4	4	4
Iron & steel	1079	1083	1020

**Includes actual reported consumption and /or estimates made whereever required and due to paucity of data, coverage may not be completed.*

WORLD REVIEW

The world reserves of vanadium were about 19 million tonnes of metal located mainly in China, Russia, South Africa, Australia and the USA and are expected to last till next century at the current rate of consumption (Table-3). Titaniferous magnetite is the most important source accounting about 85% of current world V_2O_5 production from which vanadium could be extracted as a by-product of iron. The resources are also available in crude oil (in Caribbean basin, parts of Middle East and Russia), tar sands, (in Western Canada), phosphate rock, uraniferous sandstone and siltstone. In all these cases, extraction depends on economic recovery of the product.

Table – 3: World Reserves of Vanadium (By Principal Countries)

(In '000 tonnes of vanadium content)

Country	Reserves
World: Total (rounded off)	**19000**
Australia	1800
China	9000
Russia	5000
South Africa	3500
USA	45

Source: *Mineral Commodity Summaries,2017*

The world production of vanadium in 2015 was at about 72 thousand tonnes which increased as compared to 71 thousand tonnes during last year. This excludes vanadium recovered as by-product from refining and burning of heavy oils. Major producing countries were China (58%), Russia (22%) and South Africa (14%) (Table-4).

Nearly all the world's vanadium supply originates from primary sources. Five countries recovered vanadium from ores, concentrates, slag or petroleum residues. Japan and the United States of America are probably the only countries to recover significant quantities of vanadium from petroleum residues.

Countries like Brazil, South Africa and Australia are concentrating more on exploring the deposits with higher vanadium grades than those typically mined in titaniferous magnetite operated by integrated steel-vanadium producers.

Australia

Australian Vanadium Ltd is exploring its Gabamintha Vanadium project located in the Murchison province, south of the mining town of Meekotharra in western Australia. The total resources of 125.8 million tonnes of titaniferous magnetite deposit with average grade of 0.7% V_2O_5. was reported. The company has also signed a contract to purchase a vanadium electrolyte pilot plant from C- Tech Innovation Ltd.

Atlantic Ltd announced that due to substantial fire at the benefication plant of its Windimurra Vanadium Project (Perth, Western Australia), the production of vanadium was suspended. The beneficiation plant was undergoing planned maintenance and was not operating at the time of fire.

Brazil

The mine production of vanadium increased considerably to 3,254 tonnes in 2015 from 578 tonnes in the previous year. First production at Largo Resources Ltd (Toranto, Ontario, Canada) Maracas Menchen mine commenced operation in August 2014. According to the company, the vanadium is contained within a massive titaniferous magnetite deposit that has much higher grades in both V_2O_5 and iron than any other vanadium project in the world. In 2016 vanadium production was 6,000 MT as compared 5,800 MT in 2015. The company Maracas Mine has achieved record production of 823 tonnes in Dec. 2016. Largo has an offtake agreement with Glencore International Plc for 100% of its material for the first 6 years. Average annual production was estimated at 11,400 tonnes of V_2O_5 equivalent through its 29-year mine life.

Canada

Vanadium Corp. Resource Inc. announced that an updated technical resource estimate for its Lac Dore Project (Northern Quebec). The inferred resource estimate was 111.9 million tonnes grading 0.42% of V_2O_5.

Russia

The mine production of vanadium was 16,196 tonnes in 2015. The production of vanadium increased to 16,196 tonnes in 2015 as compared to 15,215 tonnes in the previous year. The Vanady Tula (200 km south of Moscow) has an annual capacity of

5,000 tonnes FeV and 7,350 tonnes V_2O_5 in its electrometallurgical and hydrometallurgical plants. It produced 7,309 tonnes of V_2O_5 in 2014 as compared to 7,352 tonnes in 2013. Of this production 2,755 tonnes further processed into FeV at EVRAZ Vanady Tula and 3,538 consumed in EVRAZ Nikom. The balance quantity was sold to a third party.

China

The mine production of vanadium in 2015 was 42,000 tonnes. The production of vanadium decreased to 42,000 tonnes in 2015 as compared to 45,000 tonnes in 2014. Pangang Group Vanadium Titanium and Resources Co. Ltd located in Panzhihua, Sichuan Province has a production capacity of 2,60,000 tonnes of vanadium slag, 22,000 tonnes of vanadium, 16,000 tonnes of FeV and 4,000 tonnes of vanadium nitrogen alloy. China's Xichang Steel and Vanadium Co. Ltd, a wholly owned subsidiary of Pangang Group Co. Ltd, announced that it produced a record-high level of 1,16,900 tonnes of vanadium slag.

Table – 4: World Mine Production of Vanadium (By Principal Countries)

(In tonnes of metal content)

Country	2013	2014	2015
World: Total (rounded)	**73994**	**71703**	**72450**
Brazil	-	578	3254
China[e]	44000	45000	42000
Kazakhstan[e]	1000	1000	1000
Russia[e]	14403	15125	16196
South Africa	14000	10000	10000
USA	591	-	-

Source: *World Mineral production, 2011-2015.*

FOREIGN TRADE

No exports and imports of vanadium & scrap were reported in 2015-16. There was no export of vanadium ores & concentrates during the period under review. On the other hand imports of vanadium ores and concentrates increased to 64 tonnes in 2015-16 from 19 tonnes in the previous year (Table-5).

Table – 5 : Imports of Vanadium Ores & Conc. (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**19**	**1378**	**64**	**6301**
Netherlands	19	1378	64	6301

Table – 6 : Exports of Ferrovanadium (By Countries)

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**176**	**213865**	**67**	**55755**
Iran	102	146357	22	29626
UAE	48	56582	12	13026
Malaysia	2	4355	3	5531
Mauritius	16	4662	27	4428
Turkey	7	827	1	1125
Congo, P. Rep.	-	-	1	1013
USA	-	-	1	805
Israel	++	163	++	139
Thailand	-	-	++	36
Chile	-	-	++	25
Other countries	1	919	++	1

The exports of ferrovanadium drastically decreased to 67 tonnes in 2015-16 as compared to 176 tonnes during the previous year. The exports were mainly to Mauritius (40%) followed by Iran (33%) and UAE (18%) (Table-6).

FUTURE OUTLOOK

The worldwide demand for vanadium is directly related to the demand for steel specially with demands of high-strength steel. In vanadium batteries, the consumption may increase in future.

The Indian alumina plants, which are mostly based on East Coast bauxite and that which have very low content of vanadium may not be able to generate adequate quantity of vanadium sludge to meet the internal demand. On the other hand, with growth of Automobile and Casting Sectors, demand for ferrovanadium is expected to increase and this will have to be met by imports. The accelerated growth in the Forging Industry and increased demand for die steels and tool steel too, have paved way for increased vanadium consumption. Imperatives for utilisation of the huge vanadium-bearing titaniferous ores available in the States viz, Karnataka, Maharashtra and Odisha, through R & D efforts will have to be initiated to meet the domestic demand of vanadium pentoxide and ferrovanadium.

As more than 90 % of vanadium is used in steel production, its demand is correlated to gross crude steel production. Use of vanadium in the manufacturing of rebar in China and other emerging markets have picked up, as these countries are increasingly adopting western standards in the fabrication of high strength rebar used in construction activities.