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GOVERNMENT OF INDIA
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19 Vanadium

Vanadium is a scarce element. It occurs in association with titaniferous magnetite and recovered as a by-product during iron & steel manufacture. Vanadium is also concentrated in many end-products of organic material including coal and crude oil, oil shale & tar sands. In addition, vanadium present in bauxite can also be recovered as vanadium sludge from red mud during the production of alumina.

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 ferro-magnesium-rich rocks, such as pyroxenite, anorthosite and gabbro.

As per UNFC system, the total estimated resources of vanadium ore as on 1.4.2010 are placed at 24.72 million tonnes with an estimated V_2O_5 content of 64,887 tonnes. Out of the total resources, the reserves are 0.41 million tonnes having 1,603 tonnes of V_2O_5 content while the remaining resources are 24.31 million tonnes having 63,284 tonnes of V_2O_5 content (Table-1).

Table – 1: Reserves/Resources of Vanadium as on 1.4.2010 (By Grades/States)

(In tonnes)

	Reserves			Remaining Resources					
				Prefeasibility		Indicated	Inferred	Total	Total
Grade/State	Proved STD111	Probable STD122	Total (A)	STD221	STD222	STD332	STD333	(B)	resources (A+B)
All India: Total									
By Grades									
Ore	**293539**	**117416**	**410955**	**1720000**	**4000000**	**232000**	**18355933**	**24307933**	**24718888**
Contained V_2O_5	**1144.8**	**457.92**	**1602.72**	**2835**	**5600**	**487.2**	**54362.25**	**63284.45**	**64887.17**
By States									
Karnataka									
Ore	–	–	–	500000	4000000	–	14884430	19384430	19384430
Contained V_2O_5	–	–	–	700	5600	–	43197.55	49497.55	49497.55
Maharashtra									
Ore	293539	117416	410955	–	–	–	58708	58708	469663
Contained V_2O_5	1144.8	457.92	1602.72	–	–	–	229	229	1831.72
Odisha									
Ore	–	–	–	1220000	–	232000	3412795	4864795	4864795
Contained V_2O_5	–	–	–	2135	–	487.2	10935.74	13557.94	13557.94

Figures rounded off.

PRODUCTION

Vanadium sludge is separated as a by-product during the Bayer process for production of alumina hydrate. 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. Nalco is not producing vanadium sludge commercially. However, it could be extracted successfully in lab-scale studies. The sludge extracted during lab-trials typically analysed 9.35% V_2O_5.

Production of ferro-vanadium during 2007-08 to 2011-12 is given in Table-2.

Table – 2: Production of Ferro-Vanadium 2007-08 to 2011-12

(In tonnes)

Year	Production
2007-08	1585
2008-09	1501
2009-10	1389
2010-11	1521
2011-12	2459

Source: *Indian Ferro-alloys Producers' Association.*

USES

It is used primarily as an alloying element in iron & steel industry and to some extent as a stabiliser in titanium and aluminium alloys 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 a wide range of products, from low carbon flat rolled steels, high strength plates and structural steels to pipes, reinforcing bars, forging steels, rail steels and tool steels. Most of the vanadium (about 80%) is used in the form of ferro-vanadium as a means of introducing vanadium into steel. 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 vanadium pentoxide 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 up to 5% vanadium. Non-metallurgical applications include 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 175,000 gauss.

New uses include vanadium secondary batteries for power plants and rechargeable vanadium redox battery (VRB) for commercial applications. 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 effect, 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

Ferro-vanadium 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 for ferro-vanadium production and gap is met by imports. The reported consumption of ferro-vanadium during 2009-10 to 2011-12 by various units in the organised sector is given in Table-3.

Table –3 : Reported Consumption of Ferro-Vanadium, 2009-10 to 2011-12 (By Industries)

(In tonnes)

Industry	2009-10	2010-11(R)	2011-12(P)
All Industries	**569**	**942**	**1171**
Foundry	6(2)	4(1)	4(1)
Alloy steel	78(5)	52(5)	26(5)
Iron & steel	485(10)	886(10)	1141(11)

Figures in parentheses denote the number of units reporting consumption in organised sector.*
*(*includes actual reported consumption and/or estimates made, wherever required).*

WORLD REVIEW

The world reserves of vanadium in 2011 were about 14 million tonnes of metal located mainly in China, Russia, South Africa and the USA and are expected to last till next century at the current rate of consumption (Table-4). Most of the reserves are of titaniferous magnetite from which vanadium could be extracted as a by-product of iron. The resources are also available in crude oil, tar sands, phosphate rock, uraniferous sandstone and siltstone. In all these cases, extraction depends on economic recovery of the product.

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

(In '000 tonnes of vanadium content)

Country	Reserves
World : Total (rounded)	**14000**
China	5100
Russia	5000
South Africa	3500
USA	45
Other countries	NA

***Source:** Mineral Commodity Summaries,2013.*

The world production of vanadium in 2011 was estimated at about 67 thousand tonnes, excluding vanadium recovered as a by-product of refining and burning of heavy oils. Major producing countries were South Africa, China and Russia (Table-5).

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 are probably the only countries to recover significant quantities of vanadium from petroleum residues.

Australia

Atlantic Ltd was expected to begin production at Windimurra Vanadium Project (Perth, Western Australia) in early 2012 with a capacity of 6,300 tpy of contained vanadium.

Brazil

Largo Resources Ltd (Toranto, Ontario, Canada) was expected to commence its Maracas Vanadium Project located in Campo Alegre de Lourdes in the state of Bahia in March, 2012. The company set a production target for summer 2013 with expected production of 5,000 tonnes per year of ferro-vanadium.

Canada

Apella Resources Inc. (Vancouver) owned two vanadiferous magnetite deposits in Canada - The Iron Titaniferous Vanadium Project in Central Quebec and the Lac Dore Vanadium Project in Northern Quebec. The Lac Dore Vanadium Project is an advanced vanadium project and it was expected to be the largest in North America and the second largest in the world.

China

China's Panzhihua New Steel and Vanadium Co. Ltd (a subsidiary of Panzhihua Iron and Steel Group) is the major producer that operates from Panzhihua in Sichnan Province, the largest vanadium producing region of China. The second leading vanadium producer in China is the Chengde Xinxin Vanadium & Titanium Co. Ltd, associated with the steel and vanadiferous slag production in Hebei Province.

Madagascar

Energizer Resources Inc. (Toronto) estimated an indicated resource of 49.5 million tonnes (an average grade of 0.693% V_2O_5) for its Green Giant vanadium project. Green Giant vanadium deposit is a sedimentary hosted deposit, in contrast to most vanadium deposits which are magnetite hosted. The unique characteristic of this deposit would allow to produce high purity V_2O_5 which is required in battery power and in battery storage for both automotive and large scale applications.

South Africa

Xstrata plc's Rhovan facility recorded 8%, increase in FeV production and 4% increase in V_2O_5 production in 2011 as against 2010. Vameto Alloys increased V_2O_5 production by 5% in 2011 as compared to previous year. The company's primary end-product is Nitrovan vanadium, a speciality vanadium-nitrogen alloy which strengthens steel more efficiently than FeV.

Table – 5: World Mine Production of Vanadium (By Principal Countries)

(In tonnes of metal content)

Country	2009	2010	2011
World: Total (rounded)	**58000**	**67000**	**67000**
China[e]	20800	22000	23000
Kazakhstan[e]	1000	1000	1000
Russia[e]	22000	21000	21000
South Africa	14353	22606	21651

Source : *World Mineral Production, 2007-2011.*

Note : *Include vanadium in slag product but exclude vanadium recovered as a by-product of refining and burning of heavy oil.*

FOREIGN TRADE

No exports and imports of vanadium & scrap were reported in 2010-11. Exports of vanadium ores & concentrates during 2011-12 were 1250 tonnes valued at about ₹ 25.8 million to USA. (Table-6). Imports of vanadium ores and concentrates increased sharply to 109 tonnes in 2011-12 from 4 tonnes in the previous year. Imports were from Austria (Table-7).

Table – 6: Exports of Vanadium Ores & Conc. (By Countries)

Country	2010-11		2011-12	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**++**	**1**	**1250**	**25841**
U S A	-	-	1250	25841
Other countries	++	1	-	-

Table – 7: Imports of Vanadium Ores & Conc. (By Countries)

Country	2010-11		2011-12	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**4**	**1182**	**109**	**10605**
Austria	-	-	87	5302
Unspecified	-	-	22	5302
Other countries	4	1182	++	1

FUTURE OUTLOOK

The worldwide demand for vanadium is directly related to the demand for steel. In vanadium batteries, the consumption may increase in future.

The future Indian alumina plants, being mostly based on East Coast bauxite having a very low content of vanadium will 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 ferro-vanadium is expected to increase and this has to be met by imports. The accelerated growth in the forging industry and increased demand for die steels and tool steel paved the way for increased vanadium consumption. Steps are also necessary to utilise huge vanadium-bearing titaniferous ores available in Indian states; viz, Karnataka, Maharashtra and Odisha, through R&D efforts to meet the domestic demand of vanadium pentoxide and ferro-vanadium.