77 Vanadium

Vanadium is a rare element even though its concentration in the earth's crust is more than those of some common metals. It occurs in trivalent form; i.e., V^{+++} in the earth's crust but it being geochemically similar to trivalent iron; i.e., Fe^{+++}, it generally substitutes the ferric ion and consequently forms few minerals of its own. Thus, there is a direct relation between vanadium and iron. 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 oil. In addition, vanadium present in bauxite can also be recovered as vanadium sludge from red mud during the production of alumina. On an average, it contains 0.26 to 0.4% V_2O_5.

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 1.4.2005 are placed at 24.85 million tonnes with an estimated metal content of 65,390 tonnes. Out of the total resources, the reserves are 6.32 million tonnes having 10,770 tonnes of metal content while the remaining resources are 18.53 million tonnes having 54,620 tonnes of metal content (Table-1).

Table - 1 : Reserves/Resources of Vanadium as on 1.4.2005 (By Grades/States)

(In tonnes)

Total	Reserves				Remaining resources				
	Proved STD111	Probable STD121	Probable STD122	Total (A)	Measured STD331	Indicated STD332	Inferred STD333	Total (B)	Total resources (A+B)
All India : Total									
By Grades									
Ore	**490663**	**1720000**	**4108000**	**6318663**	**1382875**	**263000**	**16883350**	**18529225**	**24847888**
Metal	**1913.58**	**2835**	**6021.2**	**10769.78**	**7162.2**	**552.3**	**46905.99**	**54620.49**	**65390.27**
By States									
Karnataka									
Ore	–	500000	4000000	4500000	–	–	14884430	14884430	19384430
Metal	–	700	5600	6300	–	–	43197.55	43197.55	49497.55
Maharashtra									
Ore	490663	–	108000	598663	–	–	–	–	598663
Metal	1913.58	–	421.2	2334.78	–	–	–	–	2334.78
Orissa									
Ore	–	1220000	–	1220000	1382875	263000	1998920	3644795	4864795
Metal	–	2135	–	2135	7162.2	552.3	3708.44	11422.94	13557.94

Figures rounded off.

PRODUCTION

VISL was mining and treating vanadium-bearing magnetite from Masanikere deposit near Bhadravati in Karnataka in the past. The ore containing about 1.04% V_2O_5 was used for producing ferro-vanadium. However, VISL has now restricted the production of pig iron and special steels.

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.

Vanadium sludge is separated as a by-product during the Bayer process for production of alumina hydrate. Production of vanadium sludge was reported by four alumina plants. 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.

Production of ferro-vanadium during 2003-04 to 2007-08 is given in Table-2.

Table - 2 : Production of Ferro-Vanadium 2003-04 to 2007-08

(In tonnes)

Year	Production
2003-04	769
2004-05	826
2005-06	877
2006-07	1139
2007-08	1585

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

USES

Vanadium, a whitish, soft and ductile metal, has great affinity for oxygen. It offers excellent resistance to hydrochloric acid or sulphuric acid, but cannot withstand nitric acid.

It is used primarily as an alloying element in iron & steel industry and to some extent as a stabilizer 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 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. New uses include vanadium secondary batteries for power plants and vanadium redox rechargeable battery for commercial applications.

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

The consumption of ferro-vanadium during 2005-06 to 2007-08 by various units in the organised sector is given in Table-3.

Table - 3 : Reported Consumption of Ferro-Vanadium, 2005-06 to 2007-08 (By Industries)

(In tonnes)

Industry	2005-06(R)	2006-07	2007-08(p)
All Industries	**711**	**668**	**671**
Foundry	8 (4)	8 (4)	8(4)
Alloy steel	148 (8)	148 (8)	148(8)
Iron & steel	555 (9)	512 (9)	515 (9)

Figures rounded off.
Data collected on non-statutory basis.
Figures in parentheses denote the number of units reporting consumption in organised sector.

WORLD REVIEW

The world reserve base of vanadium in 2007 was about 38 million tonnes located mainly in China, South Africa, Russia and the USA (Table-4). Most of the resources 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 Resources of Vanadium (By Principal Countries)

(In '000 tonnes of vanadium content)

Country	Reserve base
World : Total (rounded)	**38000**
China	14000
Russia	7000
South Africa	12000
USA	4000
Other countries	1000

Source: *Mineral Commodity Summaries, 2008.*

The world production of vanadium in 2007 was estimated at 69,000 tonnes. Major producing countries were Russia, South Africa and China (Table-5).

Highveld Steel, Vanadium Corporation and Xstrata were the leading producers of vanadium in various forms like slag, chemicals and ferro-vanadium in South Africa and Panzhihua Iron & Steel and Chengde Iron & Steel Company in China. A major part of South African production comes from titaniferous magnetite ore. One of the main contributing factors being the use of vanadium in reinforcing bar steels, at the Chinese demand for vanadium increased.

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

(In tonnes of metal content)

Country	2005	2006	2007
World : Total	**65000**	**66000**	**69000**
China[e]	17000	17500	18500
Kazakhstan[e]	1000	1000	1000
Russia[e]	24000	24000	25000
South Africa	22604	23800	24000[e]

Source: *World Mineral production, 2003-2007.*
Note : *Include vanadium in slag product but exclude vanadium recovered as a by-product of refining and burning of heavy oil.*

FOREIGN TRADE

Exports of vanadium and scrap increased to 6,169 tonnes in 2007-08 from 1,300 tonnes in the previous year. exports were mainly to Turkey (Table - 6).

Imports of vanadium and scap decreased in 2007-08 to 100 tonnes from 7,799 tonnes in the previous year. Imports were from Germany and UK (Tables - 7).

Table - 6 : Exports of Vanadium & Scrap (By Countries)

Country	2006-07		2007-08	
	Qty (t)	Value (Rs.'000)	Qty (t)	Value (Rs.'000)
All Countries	**1300**	**1478**	**6169**	**506**
Turkey	–	–	6076	299
Israel	–	–	50	107
Saudi Arabia	–	–	40	82
Germany	–	–	3	18
Morocco	300	369	-	-
UAE	1000	1109	-	-

Table - 7 : Imports of Vanadium & Scrap (By Countries)

Country	2006-07		2007-08	
	Qty (t)	Value (Rs.'000)	Qty (t)	Value (Rs.'000)
All Countries	**7799**	**26211**	**100**	**27**
UK	400	201	10	14
Germany	1	2	90	13
Australia	2092	7607	–	–
Austria	54	370	–	–
Russia	5250	18027	–	–
USA	2	4	–	–

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 high growth registered in automobile sector led to increased use of vanadium in steels. 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 Orissa through R&D efforts to meet the domestic demand of vanadium pentoxide and ferro-vanadium.