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(Part- III : MINERAL REVIEWS)

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ZIRCON

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GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

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50 Zircon

Zircon ($ZrSiO_4$) is found usually as a constituent in heavy mineral sand assemblages, which include ilmenite, rutile, leucoxene, monazite and garnet in varying proportions. Zircon sand and baddeleyite (an oxide-ZrO_2) are used via their salts to extract zirconium and hafnium. Normally, all zirconium compounds contain between 1.4% and 3% hafnium. Zircon is very stable at high temperature and has excellent thermal shock resistance, low thermal conductivity and chemical inertness. It finds use chiefly in industries like ceramic, refractory, abrasive, foundry, chemical and speciality alloys. Gem variety of zircon is used in jewellery.

RESOURCES

Zircon occurs in close association with other heavy minerals such as ilmenite, rutile and monazite in beach sands, along the coastal tracts of the country. Its concentration in the deposits is about 0.6-18.7% of the total heavy minerals. Indian zircons analyse 63-66% ZrO_2. AMD has carried out reconnaissance investigation in parts of Gujarat, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Odisha and West Bengal during 2008-14. The resource estimation in these areas is almost complete. The resources of zircon are placed at 33.71 million tonnes as per Department of Atomic Energy (DAE). The statewise break-up of the resources is given in Table-1.

As per National Mineral Inventory (NMI), IBM as on 1.4.2010, the total resources of zircon are placed at 3.13 million tonnes.

Table – 1 : Resources of Zircon

(In million tonnes)

State	Resources*
Total	**33.71**
Andhra Pradesh	11.94
Bihar/Jharkhand	0.08
Gujarat	0.01
Kerala	7.83
Maharashtra	0.01
Odisha	3.25
Tamil Nadu	10.20
West Bengal	0.39

Source: *Department of Atomic Energy, Mumbai.*
** Inclusive of indicated, inferred and speculative categories.*

EXPLORATION & DEVELOPMENT

Exploratory agencies comprising GSI, Directorate of Geology, Odisha and AMD carried out exploration in the beach sand deposits which contain heavy minerals such as ilmenite, rutile, monazite, rare earths, zircon and garnet. For details, the review on 'Ilmenite and Rutile' may be referred.

PRODUCTION AND PRICES

Production of zircon decreased to 18,891 tonnes in 2014-15 from 20,626 tonnes in the preceding year. The production of zircon is given in Table-2. Prices of zircon as furnished by IREL, KMML and V. V. Mineral are given in Table- 3.

Table – 2 : Production of Zircon 2012-13 to 2014-15

(In tonnes)

Year	Production of Zircon*
2012-13	21,125
2013-14	20,626
2014-15	18,891

** Indian Rare Earths Ltd reported production of 10,915 tonnes, 8,778 tonnes and 10,673 tonnes during 2012-13 , 2013-14 and 2014-15, respectively.*

Table – 3 : Prices of Zircon, 2012-13 to 2014-15

(₹ per tonne)

Period	Grade	Price	Remarks
IREL			
2012-13	Q	109417	Ex-works, bagged
	MK	109417	Ex-works, bagged
	OR	97917	Ex-works, bagged
2013-14	Q	71187	Ex-works, bagged
	MK	71187	Ex-works, bagged
	OR	63500	Ex-works, bagged
2014-15	Q	65775	Ex-works, bagged
	MK	65775	Ex-works, bagged
	OR	58750	Ex-works, bagged
KMML			
2012-13	Zircon Gr.I	70000	-
	Zircon Gr.II	66000	-
	Zircon Gr.III	60000	-
2013-14	Zircon Gr.I	74417	-
	Zircon Gr.II	65417	-
	Zircon Gr.III	76300	-
2014-15	Zircon Gr.I	70000	-
	Zircon Gr.II	60000	-
	Zircon Gr.III	60000	-
V.V. Mineral			
2012-13	"	11700	-
2013-14	NA	-	-
2014-15	NA	55618	-

Source: *Department of Atomic Energy, Mumbai.*

MINING AND PROCESSING

Indian Rare Earths Ltd (IREL), a Government of India Undertaking, KMML, a Kerala State Government Undertaking and V.V. Mineral, a Private Sector company are engaged actively in mining and processing of beach sands in India. Zircon is recovered by these companies as a co-product of mining/dredging of heavy mineral sands which include ilmenite, rutile, leucoxene, monazite, sillimanite and garnet. Beach sand deposits containing these minerals are obtained from coastal tracts of Manavala-kurichi in Tamil Nadu, Chavara in Kerala and Gopalpur in Odisha. As such, no deposit is being worked exclusively for zircon alone. For details regarding mining and processing, etc., review on 'Ilmenite and Rutile' may be referred. Plantwise capacity and production of zircon during 2012-13 to 2014-15 are given in Table- 4.

INDUSTRY

IREL has set up a dry grinding mill at Chavara, Kerala to produce Zirflour for its application in the ceramic industry. A wet grinding mill was also set up at Chavara to produce micro-zir for its specialised application as opacifier. IREL, Chavara, produced 598 tonnes and 866 tonnes Zirflour during 2013-14 and 2014-15, respectively, against an installed capacity of 6,000 tpy. Besides, IREL established a small chemical plant at Manavalakurichi, Tamil Nadu to produce zircon frit, zirconium chloride, etc., primarily for making supply of zircon frit to Department of Atomic Energy's Nuclear Fuel Complex (NFC), Hyderabad. A pilot plant (3.5 tpy capacity) was set up at Orissa Sand Complex (OSCOM) to produce a whole range of zirconia stabilised with CaO, MgO and rare earths.

The NFC, Hyderabad has different types of production facilities which include the zirconium oxide plant for processing of zircon to pure zirconium oxide and zirconium sponge plant for conversion of zirconium oxide to pure sponge metal at NFC, Hyderabad and Zirconium Complex (ZC) at Pazhayakayal, near Thoothukudi, Tamil Nadu.

NFC Hyderabad produced 500 tonnes, 404 tonnes and 542 tonnes of zirconium oxide during 2012-13, 2013-14 and 2014-15, respectively. ZC, Pazhayakayal, produced 335 tonnes, 402 tonnes and 258 tonnes of ZrO_2 in 2012-13, 2013-14 and 2014-15, respectively.

Besides, the Zircaloy Fabrication Plant produces various zirconium alloy tubings and sheet, rod and wire products. The plant also has facilities for reclamation of zircaloy mill-scrap. Zircon sand is processed through caustic fusion, dissolution, solvent extraction (to remove hafnium), precipitation and calcination to obtain zirconium oxide. The pure oxide is then subjected to high temperature chlorination, reactive metal reduction and vacuum distillation to obtain homogeneous zirconium sponge. The sponge is briquetted with alloying ingredients and melted in vacuum to produce zircaloy ingots. The alloy ingots are extruded to convert into seamless tubes, sheets and bars. The total installed capacity and production of zirconium oxide and zirconium sponge plants at NFC and ZC are furnished in Table - 5.

Table – 4 : Plantwise Capacity and Production of Zircon, 2012-13 to 2014-15

(In tonnes)

Company	Location	Specification	Installed capacity (tpy)	Production		
				2012-13	2013-14	2014-15 (P)
Total			**57000**	**21125#**	**20626.3**	**18891**
Indian Rare Earths Ltd	Manavalakurichi, Kanyakumari distt., Tamil Nadu	65% ZrO_2+HfO_2(min)	10000	-	2078.3	3166.35
	Chavara, Kollam distt., Kerala	65% ZrO_2+HfO_2(min)	17500	10915*	2132*	1737.9*
	Orissa Sand Complex, Ganjam distt., Odisha	64.25% ZrO_2(min)	5000	-	4576	5769
Kerala Minerals & Metals Ltd	Chavara, Kollam distt., Kerala	Zircon Gr.I 64.0% (min) Zircon Gr.II 62% (min)	6500	3960	3635	-
V. V. Mineral	Keeraikaranthattu, Tirunelveli distt., Tamil Nadu	66% min (ZrO_2+HfO_2)	18000 (654000 - Total Heavy Minerals)	6250	8205	8218

Source: *Respective Producers and Department of Atomic Energy, Mumbai.*

 # Total includes 10,915 tonnes of Zircon during the year 2012-13 from IREL, Plantwise break up is not available.

** Besides, 1,161 tonnes, 598 tonnes & 866 tonnes of zirflour is reported in 2012-13, 2013-14 & 2014-15, respectively.*

Table – 5 : Production of Zirconium Oxide and Sponge at Plants of DAE in NFC and ZC 2012-13 to 2014-15

(In tonnes)

Plant/Location	Installed capacity (tpy)	Production		
		2012-13	2013-14	2014-15
Zirconium Oxide Plant, NFC, Hyderabad	600	500.130	403.801	541.81
Zirconium Sponge Plant, NFC, Hyderabad	400	250.120	-	-
Zirconium Oxide Plant, ZC, Pazhayakayal	500	335.410	401.501	258.28
Zirconium Sponge Plant, ZC, Pazhayakayal	250	115.140	115.140	-

***Source**: Department of Atomic Energy, Mumbai.*

Besides, Bhalla Chemical Works Pvt Ltd operates three plants; two of which are located in Gurgaon, Haryana to manufacture zirconium derivatives (ZrO_2), based on imported zircon ore (capacity 10,000 tpy) and zirconium silicate opacifiers (capacity 5,000 tpy). One plant of the company in Rajasthan manufactures zirconium oxychloride crystals and special zirconias (capacity 10,000 tpy).

USES & CONSUMPTION

Zircon's exceptional qualities of hardness and durability make it a must-use for the manufacture of ceramics and refractory tiles and also for a range of other high-tech applications such as armour plating on military aircraft, heat shield in space shuttles and potentially as solid oxide fuel cells in hydrogen powered vehicles and in many industrial and chemical applications. Owing to its chemical inertness, very low heat conductivity, high specific gravity, low expansion, good resistance to abrasion, high melting point and no shrinkage on being heated up to 1750^0 C, zircon is found to be an outstanding refractory material.

Zirconia and zirconium chemicals can be used for a variety of uses. Yttria-stablized zirconia (YSZ) is used in the manufacture of oxygen sensors that control combustion in automobile engines and furnaces.

In foundry industry, zircon is used as facing for foundry moulds as it increases the resistance to metal penetration and affords a uniform finish to castings. Zircon sand is preferred to silica sand because of its uniform size, higher melting point, low thermal expansion and resistance to molten metal, acidic chemicals, slag, etc. Zircon containing 64% ZrO_2 is used generally for foundry applications.

In ceramic industry, finely ground high-grade zircon and zirconium dioxide are used as opacifier in melts for vitreous enamelling and as pigment in ceramic glazes. Zirconium oxide is considered as a potential ceramic material for high temperature applications like engine components. Usually, zircon containing 65% ZrO_2 is preferred in ceramics. The toughened zirconia finds its use in ceramic coatings in jet aircraft engines and in other applications where strength and high temperature oxidation resistance are important. Zirconia ceramics are also used in automobile sensors for the microprocessor control of engines.

In chemical industry, its property of high resistance to corrosion is used where dry chlorine, hydrochloric acid and caustic alkalies are involved. Abrasive and grinding wheels made from zircon sands are used for polishing optical glasses. Zircon powder is used as a medium in waterjet cutting machines.

Zirconium and zirconium powders are used in ammunition, primers, detonation caps, flashlight mixtures, radio tubes and in various heating elements. Hafnium-free zirconium metal is used as cladding material in atomic reactors due to its low absorbing cross section for thermal neutron. Green, blue, indigo, red,orange coloured zircon is used as a natural gemstone and also processed to produce cubic zirconia - a synthetic gemstone resembling diamond.

Consumption of zircon/zirflour increased to 8,500 tonnes in 2014-15 from 8,300 tonnes in 2013-14. Consumption of zircon/zirflour during 2012-13 to 2014-15 is furnished in Table- 6.

Table – 6: Consumption * of Zircon/Zirflour 2012-13 to 2014-15 (By Industries)

(In tonnes)

Industry	2012-13	2013-14 (R)	2014-15 (P)
All Industries	**7300**	**8300**	**8500**
Ceramic	1600(16)	1600(16)	1600(15)
Chemical	1200(2)	1400(3)	1400(3)
Foundry	400(13)	1100(15)	1300(17)
Refractory	4100(10)	4200(10)	4200(11)
Others# (Alloy steel & paint)	++(1)	++(2)	++(2)

***Source**: Department of Atomic Energy, Mumbai.*
**Paucity of data, hence consumption may not be complete.*
 # Including electrode, abrasive and other industries.
***Note**: Consumption relates to sales figures of IREL.*

POLICY

Zircon was earlier classified as a 'prescribed substance', as per notifications issued under Atomic Energy Act, 1962. From the revised list notified vide S. O. No. 61(E), dated 20.1.2006, zircon has been deleted, subject to the condition that the mineral shall remain a prescribed substance till the policy on exploration of beach sand minerals notified on 6.10.1998, is adopted/revised/modified by Ministry of Mines or till 1.1.2007, whichever occurs earlier and shall cease to be so thereafter.

As per the Foreign Trade Policy, 2009-2014 and the effective policy on export and import, zirconium ores and concentrates under HS Code 26151000 can be imported/exported freely.

WORLD REVIEW

World reserves of zirconium are placed at 78 million tonnes in terms of ZrO_2. Australian mineral sand deposits hold the world's largest reserves of zirconium (66%), followed by South Africa (18%). The world production of zirconium minerals was estimated at 1.2 million tonnes in 2014. Australia, South Africa, Indonesia and USA are the principal producers of zirconium minerals (Tables - 7 and 8). Zircon finds its application in ceramics, zirconia, chemicals, refractory and foundry & castings which accounts for zircon's total world estimated consumption.

Table – 7 : World Reserves of Zirconium (By Principal Countries)

(In '000 tonnes)

Country	Reserves
World: Total (rounded)	
Zirconium	**78000**
Australia	
Zirconium	51000
China	
Zirconium	500
India	
Zirconium	3400
Mozambique	
Zirconium	1100
South Africa	
Zirconium	14000
USA	
Zirconium	500
Other countries	
Zirconium	7200

Source: *Mineral Commodity Summaries, 2016.*

Table – 8 : World Production of Zirconium Minerals (By Principal Countries)

(In '000 tonnes)

Country	2012	2013	2014
World: Total	**1433**	**1027**	**1183**
Australia	605	388	400[e]
Brazil	20	21	20[e]
China[e]	34	34	34
India	21	20[e]	20[e]
Indonesia[e]	109	49	21
Madagascar	23	23	27
Mozambique	47	31	51
South Africa[e]	393	292	393
Ukraine[e]	35	35	35
USA[e]	115	115	115
Vietnam[e]	21	7	7
Other countries	10	12	60

Source: *World Mineral Production, 2010-14.*
e : *Estimated*

Australia

IIluka produced 333,000 tonnes of zircon from its operations in Australia, an increase of 35% compared with that of 2013. Production was 240,000 tonnes from its operations in the Eucla Basin, South Australia, and the Perth Basin, Western Australia, and 93,000 tonnes from its operations in the Murray Basin.

China

China imported 816,039 tonnes of zircon concentrates in 2014, a decrease of 4% from that of 2013. The leading import sources, Australia and South Africa, accounted for 51% and 24%, respectively, of total imports.

Kenya

In February, Base Resources Ltd began producing zircon concentrates from its Kwale heavy-mineral sands project and by year-end has produced 15,000 tonnes of concentrates. During a mine life of 13 years, Base Resources expected to produce 30,000 tonnes per year of zircon (Base Resources Ltd, 2014).

Madagascar

World Titanium Resources Ltd (WTR) estimated ore reserves at its Ranobe deposit in the Toliara Sands Project in southwest Madagascar to be 161 Mt containing 8.2% heavy minerals. WTR expected to produce 44,000 tonnes per year of zircon/rutile concentrate during a mine life of 21 years.

Mozambique

Kenmare Resources plc's production of zircon at its Moma Mine in 2014 was 50,800 tonnes an increase of 62% from that of 2013.

South Africa

The Tronox Ltd received permits for its water use licence in order to develop the Fairvreeze mine in KwaZulu-Natal. The water use licence cleared the way for mine construction at Fairvreeze. Over a 12 year mine life the Fairvreeze mine was expected to produce 60,000 tpy of zircon.

FOREIGN TRADE

Exports

Exports of zirconium ores and concentrates decreased to 12,180 tonnes in 2014-15 from 18,036 tonnes in the previous year. Exports were mostly to China (86%) & Japan (6%). Exports of zirconium and scrap sharply increased to 8 tonnes in 2014-15 as against 3 tonne in 2013-14. Exports were mostly to Singapore (62%), Australia, Pakistan and UAE (13% each) (Tables- 9 and 10).

Imports

Imports of zirconium ores and concentrates decreased to 47,656 tonnes in 2014-15 from 50,945 tonnes in the previous year. Main suppliers were Australia (92%) and South Africa (5%). Imports of zirconium and scrap were 9 tonnes in 2014-15 against 21 tonnes in the previous year. Imports were mainly from China (44%) and Italy (22%) (Tables- 11 and 12).

Table – 9 : Exports of Zirconium Ores & Conc. (By Countries)

Country	2013-14		2014-15 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**18036**	**648740**	**12180**	**488129**
China	15816	470359	10464	355528
Iran	334	29984	82	10570
Japan	1034	72959	776	51948
Korea, Rep. of	-	-	40	2637
Netherlands	520	38965	280	18505
Kuwait	105	19523	24	14860
France	156	11962	286	19755
Vietnam	-	-	100	5608
Chinese Taipei/Taiwan	-	-	70	3906
Bangladesh	++	18	20	2217
Other countries	71	4970	38	2595

Table – 10 : Exports of Zirconium & Scrap (By Countries)

Country	2013-14		2014-15 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**3**	**2876**	**8**	**6755**
Germany	++	1287	++	1831
Japan	1	729	++	109
Singapore	1	679	5	3604
UAE	-	-	1	117
Australia	-	-	1	647
Sudan	-	-	++	121
Oman	-	-	++	69
Pakistan	++	22	1	50
Canada	-	-	++	207
Other countries	1	159	-	-

Table – 11 : Imports of Zirconium Ores & Conc. (By Countries)

Country	2013-14		2014-15 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**50945**	**3772861**	**47656**	**3331466**
Australia	43081	3259244	43810	3074827
South Africa	2788	189473	2395	156201
Ukraine	1820	124629	532	34248
Madagascar	25	1193	325	14869
Malaysia	416	34008	66	5326
Vietnam	75	5658	175	12039
Germany	-	-	52	7013
Spain	213	20064	72	6027
USA	68	9758	97	13022
Thailand	-	-	52	3494
Other countries	2459	128834	80	4400

Table – 12 : Imports of Zirconium & Scrap (By Countries)

Country	2013-14		2014-15 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**21**	**68530**	**9**	**30970**
USA	6	36700	1	4795
China	11	13845	4	6161
Germany	1	7449	1	3997
Italy	2	6982	2	8760
Switzerland	++	1518	++	3301
Malaysia	1	684	1	1918
Hong Kong	-	-	++	452
UK	++	135	++	184
France	++	94	++	1395
Korea, Rep. of	++	60	++	5
Other countries	++	1063	++	2

FUTURE OUTLOOK

The development of digital printing of ceramic tile pattern as the potential to increase demand since higher zircon content of the base tile is required to impart greater aesthetic appeal and optimize the cost of the digital printing process.

The Working Group on Mineral Exploration & Development (other than coal & lignite) for the 12th Five Year Plan (2012-17) has estimated the projected demand for next five years between 86,000 and 90,000 tpy at the GDP growth rate of 8%, 9% and 10%. The projected production is expected to remain at the level of 30,000-35,000 tpy with the balance to be met by way of imports.