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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, 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.

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 19,017 tonnes in 2013-14 from 21,125 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 – 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.*

Table – 2 : Production of Zircon 2011-12 to 2013-14

(In tonnes)

Year	Production of Zircon*
2011-12	25,996
2012-13	21,125
2013-14	19,017

** Indian Rare Earths Ltd reported production of 14,583 tonnes, 10,915 tonnes and 8,778 tonnes during 2011-12 , 2012-13 and 2013-14 respectively.*

Table – 3 : Prices of Zircon, 2011-12 to 2013-14

(₹per tonne)

Period	Grade	Price	Remarks
IREL			
2011-12	Q	90700	Ex-works, loose
	MK	90700	Ex-works, loose
	OR	83300	Ex-works,loose
2012-13	Q	109417	Ex-works, loose
	MK	109417	Ex-works, loose
	OR	97917	Ex-works, loose
2013-14	Q	71187	Ex-works, loose
	MK	71187	Ex-works, loose
	OR	63500	Ex-works, loose
KMML			
2011-12	Zircon Gr.I	118000	-
	Zircon Gr.II	114000	-
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	-
V.V. Mineral*			
2011-12	Premium	94546	-
	Standard		
2012-13	"	11700	-
2013-14	NA		

Source: *Department of Atomic Energy, Mumbai.*
Q: Quilon; MK: Manavalakurichi; OR: Odisha.
** Price of zircon-sillimanite is quoted by V. V. Mineral at ₹11,500 per tonne during 2010-11, ₹27,848 per tonne during 2011-12 and ₹58,000 per tonne during 2012-13.*

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 2011-12 to 2013-14 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 1,161 tonnes and 598 tonnes Zirflour during 2012-13 and 2013-14 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 545 tonnes, 500 tones and 404 tonnes of zirconium oxide during 2011-12, 2012-13 and 2013-14 respectively. ZC, Pazhayakayal, produced 311 tonnes, 335 tonnes and 402 tonnes of ZrO_2 in 2011-12, 2012-13 and 2013-14 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, 2011-12 to 2013-14

(In tonnes)

Company	Location	Specification	Installed capacity (tpy)	Production		
				2011-12	2012-13	2013-14
Total			**57000**	**25996#**	**21125#**	**19017#**
Indian Rare Earths Ltd	Manavalakurichi, Kanyakumari dist., Tamil Nadu	65% ZrO_2+HfO_2(min)	10000	-	-	-
	Chavara, Kollam dist., Kerala	65% ZrO_2+HfO_2(min)	17500	-	-	-
	Orissa Sand Complex, Ganjam dist., Odisha	64.25% ZrO_2(min)	5000	-	-	-
Kerala Minerals & Metals Ltd	Chavara, Kollam dist., Kerala	Zircon Gr.I 64.0% (min) Zircon Gr.II 62% (min)	6500	5213	3960	-
V. V. Mineral	Keeraikaranthattu, Tirunelveli dist., Tamil Nadu	66% min (ZrO_2+HfO_2)	18000 (654000 - Total Heavy Minerals)	6200*	6250*	8205*

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

 # Total includes 14,583 tonnes, 10,915 tonnes and 8,778 tonnes of Zircon in the year 2011-12, 2012-13 and 2013-14 respectively from IREL, Plantwise breakup is not available.

** Besides, 1,886 tonnes, 1,161 tonnes & 598 tonnes of zirflour is reported in 2011-12, 2012-13 & 2013-14, respectivcely.*

Table – 5 : Production at Zirconium Oxide and Sponge Plants of DAE at NFC and ZC 2011-12 to 2013-14

(In tonnes)

Plant/Location	Installed capacity (tpy)	Production		
		2011-12	2012-13	2013-14
Zirconium Oxide Plant, NFC, Hyderabad	600	545.180	500.130	403.801
Zirconium Sponge Plant, NFC, Hyderabad	400	351.405	250.120	-
Zirconium Oxide Plant, ZC, Pazhayakayal	500	311.051	335.410	401.501
Zirconium Sponge Plant, ZC, Pazhayakayal	250	100.358	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.

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 7,400 tonnes in 2013-14 from 7,300 tonnes in 2012-13. Consumption of zircon/zirflour during 2011-12 to 2013-14 is furnished in Table- 6.

Table – 6: Consumption of Zircon/Zirflour 2011-12 to 2013-14 (P) (By Industries)

(In tonnes)

Industry	2011-12	2012-13 (R)	2013-14(P)
All Industries	**6900**	**7300**	**7400**
Ceramic	1700(16)	1600(16)	1600(16)
Chemical	1200(2)	1200(2)	1200(2)
Foundry	200(11)	400(13)	400(14)
Refractory	3800(8)	4100(10)	4200(10)
Others* (Alloy steel & paint)	-	++(1)	++(2)

***Source**: Department of Atomic Energy, Mumbai.*
** 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 2013. 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**
Hafnium*	**660**
Australia	
Zirconium	51000
Hafnium*	230
China	
Zirconium	500
Hafnium*	NA
India	
Zirconium	3400
Hafnium*	42
Mozambique	1100
South Africa	
Zirconium	14000
Hafnium*	280
USA	
Zirconium	500
Hafnium*	68
Other countries	
Zirconium	7200
Hafnium*	NA

Source: *Mineral Commodity Summaries, 2010 & 2015.*

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

(In '000 tonnes)

Country	2011	2012	2013
World: Total	**1611**	**1512**	**1252**
Australia	762	605	610[e]
Brazil #	23	20	20[e]
China[e]	33	33	33
India[e]	26	26	26
Indonesia[e]	127	109	49
Mozambique	44	47	31
South Africa	383	468[e]	292[e]
Ukraine[(e)]	35	35	35
USA	115	115	115
Vietnam[e]	24	21[e]	7[e]
Other countries	39	33	34

Source: *World Mineral Production, 2009-13.*
Notes: *#Including caldasite rock containing zircon and baddeleyite.*

Australia

Illuka Resources Ltd produced 246,000 tonnes of zircon, recording a decrease of 20% as compared to production in 2012. Production included 186,000 tonnes from Eucla Basin, South Australia, and Perth Basin, Western Australia. Production from Murray Basin, Victoria was 60,000 tonnes.

Feasibility studies were conducted by Image Resources for its Atlas and Boonanarring deposits in the Perth Basin, Western Australia. The study called for the production of 35,000 tpy of Zircon and 110,000 tpy of ilmenite during 10 years. Image Resources was seeking funding and offtake partners in order to begin mining operation in 2015.

China

Longnan Xinneng Zircon Co. Ltd commissioned its zirconium sponge production and produced more than 300 kilogram of sponge by the year end. Longnan expected to produce 1,000 tpy of zirconium sponge, 20 tpy of hafnium sponge, and 2,000 tpy of zirconium and hafnium alloys by the end of 2014.

Kenya

The Base Resources Ltd began production of heavy mineral concentrates at its Kwale Project and its first production of zircon began in April 2014. Production at Kwale was expected to be 30,000 tpy of zircon during the first 7 years of operation.

Madagascar

World Titanium Resource Ltd (WTR) estimated ore reserves at its Ranobe deposit in Toliara Sands Project in southwest Madagascar to be 161,000 Mt with 8.2% heavy minerals. WTR expected to produce 407,000 tpy of ilmenite and 44,000 tpy of ziron/rutile concentrate over a mine life of 21 years. Production was scheduled to begin in the third quarter of 2015.

Mozambique

Kenmare Resources plc's production of zircon at its Mona mine in 2013 was 31,400 tonnes, a decrease of 33% from 2012 because of plant expansion activities and power outages in November and December.

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 18,036 tonnes in 2013-14 from 31,600 tonnes in the previous year. Exports were mostly to China. Exports of zirconium and scrap sharply increased to 3 tonnes in 2013-14 as against one tonne in 2012-13 (Tables- 9 and 10).

Imports

Imports of zirconium ores and concentrates increased substantially to 50,945 tonnes in 2013-14 from 34,600 tonnes in the previous year. Main suppliers were Australia and South Africa. Imports of zirconium and scrap were 21 tonnes in 2013-14 against 11 tonnes in the previous year. Imports were mainly from China and USA (Tables- 11 and 12).

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

Country	2012-13		2013-14	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**31600**	**962127**	**18036**	**648740**
China	27988	551343	15816	470359
Iran	1668	196860	334	29984
Japan	443	48122	1034	72959
Kenya	10	1371	10	1306
Oman	2	227	13	527
Netherlands	130	8844	520	38965
Kuwait	-	-	105	19523
France	-	-	156	11962
UAE	484	47289	28	1767
Hong Kong	-	-	20	1371
Other countries	875	108071	++	17

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

Country	2012-13		2013-14	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**1**	**343**	**3**	**2876**
Germany	-	-	++	1287
Japan	-	-	1	729
Singapore	-	-	1	679
USA	++	106	++	70
Sri Lanka	-	-	1	45
Uganda	-	-	++	44
Pakistan	-	-	++	23
Other countries	1	237	-	-

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

Country	2012-13		2013-14	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**34652**	**3932536**	**50945**	**3772861**
Australia	29093	3345414	43081	3259244
South Africa	2266	266468	2788	189473
Ukraine	1008	98768	1820	124629
Nigeria	886	21803	1402	36585
Malaysia	178	16359	416	34008
Korea, Rep. of	240	35473	300	27428
Italy	398	61760	250	24377
Spain	215	32568	213	20064
Sri Lanka	-	-	250	17843
Hong Kong	-	-	108	11011
Other countries	368	53923	317	28199

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

Country	2012-13		2013-14	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**11**	**31476**	**21**	**68530**
USA	1	5544	6	36700
China	6	8077	11	13845
Germany	++	1313	1	7449
Italy	2	6357	2	6982
Switzerland	-	-	++	1518
Japan	++	2946	++	920
Malaysia	-	-	1	684
Hungary	-	-	++	141
UK	++	264	++	135
France	++	7	++	94
Other countries	2	6968	++	60

FUTURE OUTLOOK

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.