

ZIRCON



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(Part-III : Mineral Reviews)



55th Edition

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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. Ministry of Mines vide notification No. S.O. 2356(E) dated 11.7.2016 inserted entry 12 beach sand minerals (which includes zircon) in Part B of the First Schedule to the MMDR Act, 1957.

RESERVES/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

Table – 1(A): 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.*

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(A).

As per National Mineral Inventory (NMI), IBM as on 1.4.2015, the total reserves/resources of zircon are estimated at 3.42 million tonnes, of which about 1.16 million tonnes (34%) are placed under reserves category and balance 2.26 million tonnes (66%) are placed under remaining resources category. Reserves/Resources are located in Kerala (81%), Odisha (14%) and Tamil Nadu (5%) Table -1(B).

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 18,437 tonnes in 2015-16 from 18,891 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. Minerals are given in Table- 3.

Table – 2: Production of Zircon

2013-14 to 2015-16

(In tonnes)

Year	Production of Zircon*
2013-14	20,626
2014-15	18,891
2015-16	18,437

** Indian Rare Earths Ltd reported production of zircon 8,778 tonnes, 10,673 tonnes and 10,785 tonnes during 2013-14 , 2014-15 and 2015-16, respectively.*

**Table-1(B): Reserves/Resources of Zircon as on 1.4.2015
(By Grades/States)**

Grade/State	Reserves				Remaining resources				Total resources (A+B)			
	Proved STD111	Probable STD121 STD122	Total (A)	Feasibility STD211	Pre-feasibility STD221 STD222	Measured STD331	Indicated STD332	Inferred STD333		Reconnaissance STD334	Total (B)	
All India: Total	1012205	146085	1158290	655020	-	105773	81741	377825	1044554	-	2264913	3423203
By Grades												
Unclassified	1012205	146085	1158290	655020	-	105773	81741	377825	1044554	-	2264913	3423203
By States												
Kerala	972624	-	972624	649938	-	-	81741	338525	716279	-	1786483	2759107
Odisha	-	146085	146085	0	-	-	-	39300	303491	-	342791	488876
Tamil Nadu	39581	-	39581	5082	-	105773	-	-	24784	-	135639	175220

Figures rounded off.

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**Table – 3: Prices of Zircon,
2013-14 to 2015-16**

(₹per tonne)

Period	Grade	Price	Remarks
IREL			
2013-14	Q	75500	Ex-works, bagged
	MK	75500	Ex-works, bagged
	OR	67500	Ex-works, bagged
2014-15	Q	67750	Ex-works, bagged
	MK	67750	Ex-works, bagged
	OR	60500	Ex-works, bagged
2015-16	Q	63800	Ex-works, bagged
	MK	63800	Ex-works, bagged
	OR	57000	Ex-works, bagged
KMML			
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	-
2015-16	NA		
V.V. Mineral			
2013-14	"	28256	-
2014-15	NA	59036	-
2015-16	NA	34565	-

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, leucosene, monazite, sillimanite and garnet. Beach sand deposits containing these minerals are obtained from coastal tracts of Manavalakurichi 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 2013-14 to 2015-16 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. 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 and Zirconium Complex (ZC) at Pazhayakayal, near Thoothukudi, Tamil Nadu.

NFC Hyderabad produced 404 tonnes, 542 tonnes and 625 tonnes of zirconium oxide during 2013-14, 2014-15 and 2015-16, respectively. ZC, Pazhayakayal, produced 402 tonnes, 259 tonnes and 502 tonnes of ZrO₂ in 2013-14, 2014-15 and 2015-16, 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.

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Table – 4: Plantwise Capacity and Production of Zircon ore, 2013-14 to 2015-16

(In tonnes)

Company	Location	Specification	Installed capacity (tpy)	Production		
				2013-14	2014-15	2015-16 (P)
Total			57000	21125#	20626.3	18437#
Indian Rare Earths Ltd	Manavalakurichi, Kanyakumari distt., Tamil Nadu	65% ZrO ₂ +HfO ₂ (min)	10000	-	2078.3	
	Chavara, Kollam distt., Kerala	65% ZrO ₂ +HfO ₂ (min)	17500	10915*	2132	10785
	Orissa Sand Complex, Ganjam distt., Odisha	64.25% ZrO ₂ (min)	5000	-	4576	
Kerala Minerals & Metals Ltd	Chavara, Kollam distt., Kerala	Zircon Gr.I 64.0% (min) Zircon Gr.II 62% (min)	6500	3960	4768	5346
V. V. Mineral	Keeraikarantattu, Tirunelveli distt.,Tisaiyanvilai, Tamil Nadu	66% min (ZrO ₂ +HfO ₂)	18000 (654,000 - of heavy minerals)	8205	8218	2306

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

Total includes 10,915 tonnes & 10,785 tonnes of Zircon during the year 2013-14 & 2015-16 from IREL, Plantwise break up is not available.

** Besides, 598 tonnes, 886 tonnes & 507 tonnes of zirflour is reported in 2013-14, 2014-15 & 2015-16, respectively.*

Table – 5 : Production at Zirconium Oxide and Sponge Plants of DAE at NFC and ZC 2013-14 to 2015-16

(In tonnes)

Plant/Location	Installed capacity (tpy)	Production		
		2013-14	2014-15	2015-16
Zirconium Oxide Plant, NFC, Hyderabad	600	403.801	541.808	625.089
Zirconium Sponge Plant, NFC, Hyderabad	400	250.120	-	-
Zirconium Oxide Plant, ZC, Pazhayakayal	500	401.501	258.285	502.000
Zirconium Sponge Plant, ZC, Pazhayakayal	250	115.140	115.140	-

Source: Department of Atomic Energy, Mumbai.

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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). The third 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 °C, zircon is found to be an outstanding refractory material. Zirconia and Zirconium chemicals can be used for a variety of uses. Yttria-stabilized 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 accords 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. Zircon compounds have a very low toxicity and are not perceived as a potential environmental hazard. They are even said to have some medicinal properties and are now increasingly preferred in the manufacture of food products and pharmaceuticals too. It is also widely used in television and computer screens, resistance to corrosion and erosion makes zircon products ideal for use in the Chemical Industry and in desalination plants. Zircon flour is manufactured by milling zircon sand. It is used in ceramic frits, foundry mould coatings, ceramic shells for investments casting, refractories, friction products, insulating fibres and glass. Zircon opacifier are used in refractories and friction products. Zirconium metal, or sponge is used mainly in the Nuclear Industry with a requirement for minimum content of hafnium.

Consumption of zircon/zircon flour increased to 28,600 tonnes in 2015-16 from 11,800 tonnes in 2014-15. Consumption of zircon/zircon flour during 2013-14 to 2015-16 is furnished in Table- 6. Ceramic Industry was a major consumer of zircon/zircon flour accounting for 51% consumption in 2015-16, followed by Refractory Industry (31%).

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**Table – 6: Consumption * of Zircon/Zirflour
2013-14 to 2015-16
(By Industries)**

Industry	(In tonnes)		
	2013-14	2014-15 (R)	2015-16 (P)
All Industries	8400	11800	28600
Ceramic	1600	5300	14600
Chemicals	1500	1400	2400
Foundry	1100	1100	1300
Refractory	4200	4000	10300
Others# (Alloy steel, iron & steel, & paint)	++	++	++

Figures rounded off.

** includes actual reported consumption and/or estimates made wherever required. Due to paucity of data, coverage may not be complete.*

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. Recently, vide notification No.S.O.2356(E) dated 11.07.2016, zircon covered under beach sand minerals and being inserted after entry 11 of Part B of the First Schedule to the MMDR Act, 1957. As per the Foreign Trade Policy, 2015-20, the export and import of zirconium ores and concentrates under ITC (HS) Code 26151000 are freely allowed.

WORLD REVIEW

World reserves of zirconium are placed at 75 million tonnes in terms of ZrO₂. Australian mineral sand deposits hold the world's largest reserves of zirconium (64%), followed by South Africa (19%). The world production of zirconium minerals was estimated at 1.34 million tonnes in 2015. Australia, South Africa, USA and Mozambique 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)**

Country	Reserves
World: Total (rounded)	75000
Australia	48000
China	500
India	3400
Mozambique	920
South Africa	14000
USA	500
Other countries	7200

Source: Mineral Commodity Summaries, 2017.

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

Country	(In '000 tonnes)		
	2013	2014	2015
World: Total	1104	1323	1341
Australia	498	582	598
Brazil ^b	25	24	25 ^e
China ^e	34	34	34
India	19	19 ^e	19 ^e
Indonesia ^e	49	21	21
Kenya	-	40	26
Madagascar	23	27	25 ^e
Mozambique	31	51	52
South Africa ^e	292	393	390
Ukraine ^e	35	35	35
USA ^e	80	70	60
Other countries	19	28	57

Source: World Mineral Production, 2011-15.

^b Including caldasite rock containing zircon and baddelyite.

Australia

Iluka Resources produced 351,000 tonnes of zircon from its operations in Australia, an increase of 6% compared with that of 2014. Production was 297,000 tonnes from its operations in the Eucla Basin, South Australia, and the Perth Basin, Western Australia, and 54,000 tonnes from its operations in the Murray Basin.

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MZI Resources Ltd completed construction of its Keysbrook project and began mining heavy-mineral concentrates in October. By year end, Keysbrook had produced 1,775 t of zircon and had shipped 1,000 tonnes to China.

In New South Wales, Alkane Resources Ltd continued to develop its Dubbo Zirconia project and planned to produce hafnium, niobium, rare-earth, tantalum and zirconium products. Based on recoveries developed from the demonstration pilot plant, 25,200 tonnes per year of combined output was expected, including zirconium carbonate (equivalent to 16,300 t/yr of ZrO₂) and more than 200 t/yr of hafnium oxide. Ore reserves were sufficient to support a 35-year mine life. Alkane received State and Federal environmental approvals in 2015 and was expecting to begin construction in 2016 with production to begin in 2018.

China

China imported 1.05 tonne of zircon concentrates in 2015, an increase of 30% from that of 2014, but the average value decreased by 10% to \$752 per metric tonne.

By the end of 2015, major zirconium metal producers were reportedly operating at reduced capacity due to overcapacity issues. Other producers had stopped producing zirconium sponge and were liquidating existing stock. The Shanghai Hafeng New Materials Science and Technology Co.Ltd applied for a national patent based on a new zirconium and hafnium separation technology. Shanghai Hafeng also announced the planned construction of a new operation with an annual capacity of 200,000 t/yr of zirconium and 3,000 t/yr of hafnium, to be built in Jiangsu. No timetable was given for start of construction.

Kenya

Base Resources Ltd reported that it produced 26,000 tonnes of zircon from its Kwale operation in 2015, the first full year of production. The production target for 2016 was 27,000 to 30,000 tonnes of zircon.

Mozambique

Kenmare Resources plc produced 51,800 tonnes of zircon at its Moma Mine in 2015, an increase of 2% from that of 2014.

Senegal

Mineral Deposits Ltd reported that it produced 45,200 tonnes of zircon at its Grande Cote project in 2015, the first full year production. The company planned to increase zircon production in 2016. At full production levels, Mineral Deposits expected to produce 85,000 t/yr of zircon over a 25-year mine life.

South Africa

Tronox Ltd expected to begin operations at its Fairbreeze Mine in 2016. During a 12-year mine life, the Fairbreeze Mine was expected to produce 60,000 t/yr of zircon.

Mineral commodities Ltd reported that it produced 44,489 tonnes of zircon-rutile concentrate, grading 72.88% zircon and 13.44% rutile, at their Tormin Mine in 2015, an increase of 4% from that of 2014.

FOREIGN TRADE

Exports

Exports of zirconium ores and concentrates decreased to 4,859 tonnes in 2015-16 from 12,230 tonnes in the previous year. Exports were mostly to China (61%), Japan (21%) and Netherlands (12%). Exports of zirconium and scrap sharply increased to 236 tonnes in 2015-16 as against 8 tonne in 2014-15. Exports were mostly to Iran (99%). While, exports to Germany, UAE, China were negligible (Tables- 9 and 10).

Imports

Imports of zirconium ores and concentrates increased to 53,208 tonnes in 2015-16 from 47,656 tonnes in the previous year. Main suppliers were Australia (92%) and South Africa (4%). Imports of zirconium and scrap were at 37 tonnes in 2015-16 against 9 tonnes in the previous year. Imports were mainly from China (57%), Germany (16%) and USA (11%) (Tables- 11 and 12).

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

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	12230	488129	4859	241901
China	10464	355528	2944	113742
Japan	776	51948	1026	68516
Netherlands	280	18505	560	37810
Belgium	26	1776	130	8783
France	286	19755	78	5328
Chinese Taipei/Taiwan	70	3906	60	3634
Oman	-	-	24	1777
Malaysia	-	-	28	1643
UAE	10	687	5	346
Bulgaria	2	132	3	197
Other countries	316	35892	1	125

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

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	8	6755	236	25879
Iran	-	-	234	20827
Germany	++	1831	++	4740
UAE	1	117	1	128
China	-	-	1	107
Australia	1	647	++	55
USA	-	-	++	22
Canada	++	207	-	-
Japan	++	109	-	-
Oman	++	69	-	-
Pakistan	1	50	-	-
Sigapore	5	3604	-	-
Sudan	++	121	-	-

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

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	47656	3331466	53208	3691652
Australia	43810	3074827	49056	3421394
South Africa	2395	156201	1935	132219
USA	97	13022	198	40855
Kenya	-	-	314	19584
Indonesia	-	-	225	16162
Sri Lanka	-	-	664	10519
Thailand	52	3494	156	10323
China	-	-	40	8894
Senegal	-	-	108	7467
Vietnam	175	12039	111	6652
Other countries	1127	71883	401	17583

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

Country	2014-15		2015-16 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	9	30970	37	74877
USA	1	4795	4	25953
Germany	1	3998	6	13612
China	4	6161	21	10021
Italy	2	8760	2	8270
France	++	1395	1	7958
Malaysia	1	1918	2	4304
Japan	-	-	1	3223
Switzerland	++	3301	++	1052
UK	++	184	++	377
Singapore	-	-	++	67
Other countries	++	458	++	40

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FUTURE OUTLOOK

The development of digital printing of ceramic tile pattern has 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.

As a major producer, Iluka expected the zircon market would continue to remain over supplied and that production would decrease in 2016. TZ Minerals International Pty Ltd, a major industry analyst of the zircon and titanium mineral sands industry, expected global zircon demand to increase by 3% to 4% per year from 2015 to 2020.