Development of Light Metal Industry in India

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DURING the last decade, considerable strides have been made in the technology of light metals, such as, aluminium, magnesium and titanium, etc., and billions of pounds of these light alloys are being utilised in the aircraft, automotive, electronic and other industries, both as cast and wrought products. Magnesium has earned a key role in the production of high speed planes, missiles and rockets and in the age of sputniks and explorers, magnesium has got a bright future by virtue of its light weight and its amenability to heat-treatment when alloyed with other elements, zinc, zirconium, etc. Titanium and its alloys have also acquired great importance as wonder metal of the present age due to their excellent corrosion resistance properties and light weight combined with strength. Beryllium—another member of the light metal family which was till recently regarded as a rare metal, has been found as valuable alloy in atomic reactors as a moderator and reflector along with graphite and heavy water, and as a possible structural material in aircraft, missiles and space vehicles. Nuclear scientists and aircraft technicians have found hopes for increasing the use of beryllium and demand for the metal is stimulating interest in finding new deposits of beryllium.

The paper reviews the trend in world production of aluminium, magnesium, titanium, beryllium, etc. and makes a critical assessment of Indian light metal industry and scope for its development in the context of raw material resources and in the background of production pattern followed in other countries.

Aluminium

Aluminium is the most plentiful metallic element present in the earth's crust constituting no less than 8% of the solid covering the globe, the proportion of iron being only 5% and other metals not even 0·1%. Though aluminium is so abundant in nature, it might appear strange that its successful smelting has been achieved so recently. The reason for this paradoxical situation was due to the fact that the successful liberation of aluminium from its oxide had to await the advent of electricity in large quantities and the consequent development of the electrolytic cell. It was not till 1886 that Hall in the U.S.A. and Heroult in France invented the electrolytic method of producing aluminium on a commercial scale. The lower cost of production made all the earlier methods obsolete; subsequent improvements in the production of alumina and in the design and efficiency of the reduction finance have reduced the price of aluminium from £60 per pound in 1854 to about £9 per cwt. in recent years which makes it competetive with many or most of the non-ferrous metals. Produced commercially for the first time in the decade before the turn of this century, it has caught and passed copper, lead and zinc and now is second only to steel industry.

The history of world alumiuium production during the last three decades[1], has been one of large surpluses alternating with acute shortages. Production has jumped sharply during war time, slumped at war end, then again peace time uses have increased and production has increased previous war peak. World production rose sharply from 705,000 tons in 1939 to 1,946,000 tons in 1943 at the peak of war period. By 1946, it had dropped to pre-war level. However, since 1946 production has been increasing rapidly until it is nearly 4 million tons today. The largest producers are U.S.A., U.S.S.R. and Canada, which together account for 80 per cent of the world production. The following table will furnish the production of aluminium in different countries of the world (excluding India)[2]:

The world trade in aluminium is mainly between five couuntries—U.S.A., U.K., and W. Germany are main importers and Canada and Norway main exporters[3], Unlike steel, world trade in aluminium is mainly in the form of ingots. Large capital requirement for aluminium (ten times more than that of steel) have resulted in a concentration of production between a few large operators. Similar considerations tend to result in larger and larger plants. Aluminium Ltd., which has interest in smelting operation in Canada, Norway, India and other countries, is the largest single force in world primary aluminium trade. However, in the last few years, Russia has emerged in the world aluminium market. The increase of primary aluminium production in Russia and East European countries from 90,000 tons in 1947 to nearly 750,000 tons in 1959 has made them fastest growing producers in the world. While considerable development has taken

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World production of Aluminium ('000 tons).

	1955	1956	1957	1958	1959
Australia	1·2	9·1	10·6	10·9	11·4
U.S.A.	1,397·9	1,499·1	1,471·2	1,397·8	1,743·7
Canada	546·9	553·9	497·1	566·2	535·2
Fed. Rep. Germany	134·9	145·0	151·4	134·6	148·7
France	127·4	147·4	157·3	166·2	170·3
Norway	70·6	90·5	94·1	119·4	142·6
Italy	60·5	62·4	65·1	63·0	73·8
Japan	56·6	65·0	66·9	82·2	98·6
Austria	56·3	58·6	58·5	56·0	64·7
U.K.	24·4	27·6	29·4	26·5	24·5
Switzerland	30·0	30·0	31·0	31·0	33·8
U.S.S.R.	424·0	450·0	490·0	540·0	558·0
Hungary	37·0	34·3	25·6	40·0	43·0
World total	3,100·0	3,300·0	3,300·0	3,400·0	3,925·0

place in the western countries regarding production and development of aluminium, the history of aluminium in India can be traced only a couple of decades ago when it was first produced in 1943 utilising imported alumina. Since the time of its production, the aluminium industry in India has made significant progress. Manufacture of virgin metal which commenced in 1943 with 1,275 tons, rose to 17,250 tons in 1959. It has been given a place of pride in the Third Five Year Plan period when a target production of 82,500 tons of aluminium is envisaged.

Raw material resources of India

The main raw materials for the aluminium industry are bauxite, electrical power, petroleum coke, cryolite, fluorspar, caustic soda, etc.

Bauxite: Bauxite is found in many places in India. The total bauxite resources of India are estimated at 250 million tons out of which about 25 million tons are reported to be of high-grade, 50% Al_2O_3 and over[4]. One important bauxite-bearing mountainous belt extends from Lohardaga, Bihar, in the east through the districts of Jashpur, Surguja, Koira and Rewa, up to Balaghat, Mandla area in Madhya Pradesh in the west. The deposits at Lohardaga are at present being exploited for use in alumina plants of Indian Aluminium Company and Aluminium Corporation of India Ltd. Another bauxite-bearing belt extends from the north of Bombay city along the Western Ghats through Kolhapur up to Belgaum and beyond. Resources of bauxite of various grades in this region are estimated to be about 30 million tons. A third belt which may prove to be of importance is located along the coastal run of Gujerat[5]. A rich bauxite belt in the Vindhya mountains in U. P. has also been located where Messrs Hindustan Aluminium is building up its 20,000 tons aluminium smelting plant.

There are several other bauxite deposits in India, e.g. Katni area in Madhya Predesh, the Eastern Ghats, north of Visakhapatnam, Shevaroy Hills in the Madras, Sambalpur in Orissa, in Bhopal and in Kashmir State.

Bauxite found at various places in India varies in composition and properties and presents certain chemical peculiarities which are not generally found in bauxites elsewhere in the world[6]. In North and South America, nearly all bauxites are trihydrates. In Europe, practically all bauxite is of monohydrate type, generally high in iron oxide. In Africa, bauxite is of trihydrate type, similar to that of America. In India, unhappily, there is no uniformity in this respect. Although Indian bauxite is mainly of the trihydrate type, varying amounts of monohydrates are often found mixed with the trihydrate. This lack of uniformity applies to most of the constituents of the Indian bauxite, such as, water and iron oxide, titania, silica, etc. Thus bauxite found in Lohardaga area is high in titania (10%) but those in Gujerat, Shevaroy and Kashmir are relatively low in titania (2-4%)[7]. The Kashmir bauxite with low percentage of loss on ignition is essentially a monohydrate bauxite (diaspore), difficult to digest in caustic soda and thus not very suitable for treatment by Bayer's process. The bauxite in the Lohardaga-Balghat belt appears to be a mixture of monohydrate and in trihydrate, with trihydrate predominating to the extent of 70-80%. The bauxite's solubility in caustic soda is fair, but the most easily soluble bauxites are the trihydrate varieties and it is believed that Gujerat and Shevaroy bauxites are of this type. Typical analysis of various Indian bauxite deposits are given in the following table :

	Lohardaga	Belgaum	Katni	Shevaroy	Gujerat	Kashmir
Al_2O_3%	53–58	53–58	53–58	50–55	58–62	70–80
Fe_2O_3%	8–80	6–8	5–7	4–6	2–6	1–3
TiO_2%	8–10	6–8	5–7	1–3	1–3	1–3
SiO_2%	1–3	1–3	1–3	15–20	1–2	5–10
$R.SiO_2$	1–2	1–2	—	2–4	0–1	—
L.O.I.	25	27	27	27	33	12

Impurities like Fe_2O_3 and TiO_2 are insoluble in caustic soda and are left behind as insoluble red mud which is filtered off, washed and dumped outside. These impurities, however, do not interfere in processing of bauxite, except that if they are in large percentages, the amount of red mud produced will be large, requiring bigger sized mud-handling equipment and resulting in increased soda loss to the red mud pond. Also with more impurities the tons of bauxite required to produce one ton of alumina will increase resulting in increased bauxite mining cost.

When it comes to silica as an impurity in bauxite, one has to be careful since the chemical form in which silica is present in bauxite can materially affect soda and alumina losses during digestion. If silica is present as SiO_2-quartz, it is normally harmless, since it is insoluble in caustic soda and does not interfere in Bayer's process. If silica, however, is present in bauxite as an aluminium-silicate, it will combine with soda and alumina during digestion of bauxite forming insoluble sodium alumino-silicate which is then eliminated from the process into the red mud increasing soda and alumina losses. Since soda is an expensive material, it renders the process uneconomic. Normally it is not economical to process bauxite containing more than 7% reactive silica. For every pound of reactive silica 1 to 2 lb of alumina and the same quantity of soda (Na_2CO_3) are lost. Most of the Indian bauxites contain relatively low percentage of reactive silica (about 2%), although it is believed that Shevaroy bauxite contains higher percentage of reactive silica.

The bauxite resources of India and determination of its amenability to purification by Bayer's process led to consideration of the red mud which is treated as a waste product by the aluminium smelting industries. The red mud contains ferric oxide, titania, silica together with Al_2O_3 and soda which are tied up with reactive silica. Its average analysis is furnished below :

			Red mud
L.O.I.	..	...	11–12%
Total SiO_2	...	...	4–5 %
Fe_2O_3	...	...	20–24%
TiO_2	...	...	24–26%
Al_2O_3	...	...	18–20%
Na_2O	...	...	4–5 %

With the present rate of production of alumina, about 29,000 tons of red mud is obtained every year which is dumped as waste. Red mud (granulated type) is utilised in other countries as a catalyst for synthetic petroleum production, pig iron manufacture, etc. As it contains considerable percentage of TiO_2 and Fe_2O_3, one of the profitable uses may be ultilising TiO_2 and Fe_2O_3 of the leached red mud in the production of ferro-titanium by Thermit process which will be of considerable importance to India particularly in view of the proposed Alloy, Tool and Special Steel Plants to be established during the Third Five Year Plan period. Other probable uses may be smelting red mud with coke and soda ash in an electric furnace to recover all the Fe_2O_3 as saleable pig iron and to obtain a slag richer in TiO_2 and Al_2O_3 from which Al_2O_3 can be removed by digesting with dilute alkali solution and the residue may be suitable for TiO_2 pigment manufacture.

Electrical power: Electric power is another essential requisite of this industry. Normally about 10 units of electrical energy are required for each pound of aluminium. An aluminium plant must, therefore, obtain large blocks of electrical power, and it is essential that such power should be available at a very low cost. Power in India cannot be produced at costs comparable to those in America or Europe, since the very high costs of equipment, all of which has to be imported, impose a burden which is not adequately compensated by any special advantage. There are instances where bauxite has to be transported thousands of miles to enable the smelting to be done at a site where cheap power is available. With the advent of the various thermal and hydro-electric power projects it has been possible for the aluminium industries to expand their production capacity. But even then with the present installed capacity of 3,223,000 kW (thermal and hydro-electric) the quantity will not be sufficient to meet the requirement of aluminium industries for producing cheap aluminium[8].

The present rate of power in India is also high which is Rs. 165 to Rs. 125 per kW year as compared to Rs. 85 to Rs. 125 per kW year in other countries. It will therefore be difficult for the aluminium industry to meet the country's ever-increasing demand of cheap aluminium unless the power problem is solved. Considering all these factors, a proposition may be made to study the possibilites of reducing the power consumption in the cell. Several developments have been made in the cell design and operating methods to reduce the power consumption and for more efficient working of the cell. One of the methods advocated is the use of prebaked anodes in place of self-baking existing types of anodes[9]. While the latter type has the advantage that no pressing equipment is necessary, it is associated with the following disadvantages :

1. The lesser specific current density of anode lies at about 0·7 amp./cm² compared with 0·80–1·00 amp./cm² of the prebaked anode, demanding larger cell and greater floor space and thereby higher investment costs for the same level of productivity of aluminium.
2. The quality of anode material has a direct influence on the working rate of the cell. The control of the quality in the anode with prebaked type is easier to carry out than with self-baking anodes. Irregularities in the anode for the latter type require several weeks for correction, whereas with prebaked type qualitatively bad or damaged anode may be replaced within the shortest time.

The economy to be effected by using the prebaked anodes is however to be weighed against the fabricating and other costs associated with it.

The improvements in cathode lining has also drawn the attention of the technologists for a considerable period. The life expectation of a cathode lining for cell with an amperage of 80–100,000 is on the average 3 years. Life expectation of larger cells is still shorter. Prebaked block carbon lining which is more expensive but guarantees a longer cell life, is becoming common in many aluminium production centres. For a long time, attempts have been undertaken to impove the material utilised in the lining to reduce the costs caused by relining. Endeavours in this direction have been undertaken for several years with oxide bonded or nitride bonded silicon carbide sides.

A further development which is being pursued especially by the Engligh aluminium industry is lining the cathode floors with permanent conduction materials, mainly zirconium and titanium borides and carbides. Although it is possible to achieve longer life with the product it is quite impossible at this time to produce this material at an economic price and therefore they do not possess any great industrial application.

Petroleum coke: Next to bauxite and electric power, carbon electrodes are important raw materials for which petroleum coke is required. For every ton of metal produced, electrode paste consumed is 0·65 ton which in turn calls for 0·75 ton of green petroleum coke or 0·5 ton of calcined petroleum coke. The requirement of green petroleum coke by the end of the Third Five Year Plan will be of the order of 100,000 tons per year. At present, Assam Oil Company of Digboi is the only producer of petroleum coke. It is understood that the two proposed public sector oil refineries being set up at Gauhati and Barauni will produce raw petroleum coke with a capacity of 39,000 tons and 67,000 tons and are expected to be in operation in 1962 and 1963 respectively.

Cryolite and fluorspar: At present both the materials are imported. Although there is no deposit of cryolite, synthetic cryolite may be made in the country. Large deposits of fluorspar have been reported from Dungarpur district in Rajasthan. It has been estimated from the deposit so far prospected that about 2·5 million tons of fluorite ore containing about 20-30% CaF_2 exist. Further prospecting is expected to increase the reserve considerably. Fluorspar deposits also occur at Nandgaon and Kairagarh in Madhya Pradesh. The existing deposits in Rajasthan are quite extensive and the material if beneficiated (CaF_2-85%) can meet the entire requirement of the country.

Caustic soda: The target of production by 1965-66 has been kept at 300,000 tons per year. It is expected that the indigenous production would be able to meet the demand of the aluminium industry.

Production, consumption and demand of aluminium

At present the factories producing aluminium metal are managed by the Indian Aluminium Co. and the Aluminium Corporation of India. The Indian Aluminium Co. has its works at four different parts of the country—the alumina factory with the thermal station at Muri (Bihar), the aluminium smelter at Alupuram (Kerala) and Hirakud (Orissa), and the rolling mills at Belur (W. Bengal). The present capacity of the alumina plant is 18,000 tons and the smelter 15,500 tons ingots per year. The Aluminum Corporation of India Ltd. has a composite and integrated factory with a power house, an alumina plant, a smelter, a petroleum coke calcining plant and rolling mills at Jaykaynagar in Asansol, West Bengal. The present installed capacity of the factory is 4,400 tons of alumina and 2,200 tons of aluminium ingots. The following tables will give the production, import and consumption of aluminium in India in recent years.

Year	Production (tons)	Import (tons)	Total consumption (tons)
1951	3,840	10,500	15,000
1952	3,590	7,100	13,000
1953	3,760	4,800	12,500
1954	4,890	12,400	20,000
1955	7,225	15,800	27,000
1956	6,500	14,000	26,000
1957	7,780	17,300	33,000
1958	8,180	19,200	35,000
1959	17,250	19,000	40,000
1960	18,000*	17,000*	45,000*

* Estimated.

To meet the domestic demand mostly from the indigenous production, the expansion of the aluminium industry has been given a dominant place in the industrial programme under the Third Five Year Plan. A target of 82,500 tons by 1965-66 is expected to be achieved as a result of the following projects which have been already recommended for implementation:

(1) Expansion of the Indian Aluminium Company plant in Hirakud by 10,000 tons a year.
(2) Establishment of a 20,000 tons smelter in Rihand (Hindusthan Aluminium Co.)
(3) Establishment of a 20,000 tons smelter in Konya (Messrs Tendulkar Industries)
(4) Establishment of a 10,000 tons smelter near Salem (Madras Aluminium Co.)
(5) Expansion of the plant of the Aluminium Corporation of India by 5,000 tons a year.

Processing industries[10]

Aluminium rolling mill: In the field of semi-manufacturing sectors, there were eight rolling mills in 1958, total capacity being 17,800 tons a year. The present capacities of the rolling mills of the Aluminium Corporation of India Ltd. and the Indian Aluminium Co. Ltd. for rolled products, namely, plates, sheets, circles, strips and foils, are 2,500 and 7,300 tons respectively. Their production during 1957 was 1,786 and 7,283 tons respectively. At present, there are eleven units in the organised sector, besides a good number of small units scattered all over the country engaged in rolling non-ferrous metal including aluminium depending upon the availability of the raw materials. According to the Development Wing, the production of aluminium sheets and circles by the organised sector, amounted to 13,583 tons in 1958 and 15,931 tons in 1959. Full information on small-scale sector is not available. Aggregate capacity of some 45 small units as estimated by the Traffic Commission is said to be of the order of 4,635 tons per year.

Further expansion programme of the rolling industry includes one of the Aluminium Corporation to increase its capacity for sheets and circles to 3,900 tons/year and also to go in for production of new articles, such as, aluminium foils (480 tons annual capacity) and aluminium extrusion (annual capacity 960 tons) by 1962. The Indian Aluminium Co. plans to install new equipment to produce heavier foil stock coils weighing 1,500 lb each and also to expand its capacity.

Aluminium wire rod and cable: The main aluminium conductor manufacturing unit in the country is the

Aluminium Industries Ltd. at Kundara in Kerala State which started manufacture in February, 1950. This Company set up with the technical collaboration with Aluminium Laboratories Ltd., Montreal, has pioneered in this country the application in a big way of aluminium and steel cored aluminium conductors. Production of aluminium conductors at Kundara has progressively stepped up from 1,500 tons in the first year to over 4,000 tons in recent years. The factory has a capacity of over 7,000 tons per year of plain aluminium and steel and aluminium conductors. The other cable manufacturing units in India like the Indian Cable Company Ltd. at Tatanagar, the National Insulated Cable Company of India Ltd. at Shamnagar near Calcutta, also report manufacture of aluminium conductors in their plants. Messrs Electrical Manufacture Company Ltd. at Dum Dum have commissioned their plant in recent years for the manufacture of aluminium conductors with an estimated annual capacity of 2,500 tons.

Aluminium foil : Messrs Venesta Foils Ltd. is the only unit at present manufacturing aluminium foils. Its capacity for the manufacture of foils and container sheets is about 3,500 tons per year. The firm has also a plan to increase its capacity to 4,100 tons during 1961 and further by 2,000 tons during the Third Five Year Plan. Besides, Messrs Aluminium Corporation of India has been granted licence to manufacture 480 tons of aluminium foils. The production of foils amounted to 1,964 tons in 1958 ; 2,429 tons in 1959 and 1,342 tons during January to May, 1960.

Powder and paste : The Indian Aluminium Co. Ltd.'s aluminium paste plant at Kalwa, 26 miles from Bombay City, commenced production in December, 1951. The plant is designed to produce 300 tons of pastes per annum and 300 tons of powder in addition to the quantity required for the paste industry.

Capsules, food containers, etc. : Aluminium Capsule Ltd. a subsidiary of Messrs Larson & Tubro Ltd., are manufacturing aluminium capsules since 1948 in Bombay and have a capacity of 500 lakhs of capsules per annum. The Metal Box Co. Ltd. at Calcutta have started large-scale production of aluminium collapsible tubes for tooth paste and drug industries and aluminium containers for packing industries.

Utensils : The utensil industry has been consuming so far the major percentage of aluminium either produced in this country or imported from abroad. The demand for this industry of approximately 8,000 to 10,000 tons per annum, which has been steady till 1952 has diminished to some extent due to the falling demand in foreign and home markets for finished utensils. The principal utensil manufacturers are : Messrs Jeewanlal (1929) Ltd. and Messrs Aluminium Manufacturing Co. Ltd. Besides, there are a number of manufacturers including innumerable small entrepreneurs. It would not be out of place to mention that such small units have led to the slump in the aluminium utensil industry by flooding the market with pots and pans of sub-standard quality made from scrap of doubtful purity which may be dangerous to health.

Future trends in application of aluminium in India

A recent U. N. study[11] indicates that about half the aluminium consumed throughout the world is in direct competition with steel (plain carbon, alloy and stainless steel). In India, however, aluminium has barely begun to compete with steel and its main competition is with non-ferrous metals which are in critically short supply. With the expansion of the aluminium industries in the country, the metal will find varied application the trend of which will be broadly as follows :

(1) In the railways, both for passenger and goods wagon where use of light materials increases pay loads and results in economic operation and maintenance.

(2) In motor vehicles mainly for cladding and framework of bus and truck bodies.

(3) In building and construction for various non-structural application, such as, roofing sheets, side-cladding, extrusions for door and window frames, pre-fabrication and scaffolding. For structural purposes the use of aluminium although recent, is likely to make much progress. Aluminised hardwares will also find considerable application as telegraph poles.

(4) In electrical cables, while the consumption of steel reinforced aluminium cables for long distance power transmission continues to grow with growing thermal and hydro-power grids, a vast field exists for long-voltage aluminium conductors. Also there is possibility of using aluminised steel wires as telephone and telegraph transmission lines. Aluminium wire itself may be used in low horse-power electric motors.

(5) In packaging new applications for foil such as heat sealable foils, bottle caps and scales, gravure printed foil, etc.

The table on page 23 will give an idea of the present capacity and estimated consumption in 1965-66 of aluminium under various categories of uses.

Recommendations for aluminium industry in India

Price factor plays an important part in the development of demand for any product. It is more so in India where great stress is laid on the initial cost as opposed to long term economics. Aluminium costs 30 to 40% more in India than in any other developed country. Further, the price differential between aluminium and other competiting materials is far more unfavourable in India than elsewhere. If aluminium is to establish itself especially in the next few years, when the supply of steel is expected to increase, it is essential that price should be brought down. But the Indian Aluminium Industries are faced with many adverse operating and other conditions e.g. high processing cost of bauxite, high charges for electric power, freight, etc., which stand in the way of decreasing the production cost. While the reduction in cost of power (Rs. 165 per kW year as compared to Rs. 85 to Rs. 125 per kW year in other

Industry	1955 (tons)	1960 (tons)	Estimate by the Development Council for non-ferrous metal (tons)	Present estimate of the Development Wing (tons)
Building and construction	480	3,000	5,000	6,000
Transportation and aluminium alloys ...	2,350	7,000	15,000	20,000
Household and other commercial supplies	11,650	11,000	20,000	30,000
Electrical industries ...	8,980	16,000	35,000	50,000
Food, farming and sugar industries ...	15	1,000	2,500	5,000
Canning and packing ...	2,580	3,000	7,500	10,000
Miscellaneous	1,345	4,000	5,000	9,000

countries), improved transport facilities and reduction in freight charges, etc. should be considered by the respective State Governments and Ministry of Railways, the industries may consider the following suggestions for lowering the production costs :

(1) To increase the existing plant capacities to 60,000 tons/year. It has been estimated that unit costs of production of a 50,000 tons smelter may be lower by 15% than those of a 20,000 tons plant. By having larger size plants, operating costs will be correspondingly reduced and this will ensure that aluminium holds its ground in competition with other metals.[12]

(2) Recently an announcement has been made by the Aluminium Ltd. of Canada (Alcan) regarding a basically new process of manufacturing aluminium metal directly from the bauxite thus by-passing the present alumina from bauxite extraction step and eliminating the big investment required by the conventional Bayer's process. In essence, instead of separating impurities in the alumina extraction plant, Al_2O_3 is reduced to metal in the presence of all the impurities in the ore, then the metal is distilled out. Messrs Alcan does not reveal how the bauxite is reduced, and they are trying the new process on experimental scale installing a plant with 8,000 tons annual capacity. The new facilities are believed to be available in two years' time[13]. The adoption of the new technique for the future aluminium plants of the country will have substantial bearing on lowering the production cost of alumina.

Another way of expanding the industries and side-stepping the effect of shortage of power, is to develop the finishing side of the industry. It may be an interesting proposition to export processed alumina to countries like Norway, Switzerland and Japan who have established smelting industries without any bauxite resources of their own, and to import aluminium ingots on toll basis from them for processing the metals in Indian Mills to turn out various finished and semi-finished products. Such a step may prove beneficial till the country's output of electrical power is increased considerably and can be obtained at a much cheaper rate.

The above factors when given due consideration will, apart from bringing down the manufacturing cost of aluminium, also help in finding a larger export market for Indian aluminium products. At present, India is exporting aluminium semis worth Rs. 120,000 and domestic utensils worth about Rs. 45 lakhs to South East Asia, the Middle East and African countries. A larger export trend cannot be expected at this stage as the industry itself is not in a position to meet the internal demand and needs tariff protection.

The latest enquiry by the Tariff Commission[14] into the circumstances of the aluminium industry has led to the findings that the industry is still in a developmental stage inasmuch as various schemes for expansion of the existing units have just been taken in hand. Since in its estimatiom, these schemes will take anything from three to five years for completion, the Commission has recommended the continuance of protection to aluminium ingots, bars, etc., for a further period of four years, that is, till the end of 1964. It has also recommended that the rate of protective duty be fixed at 25 per cent ad valorem, for developmental considerations although according to the findings, a duty of not more than 18 per cent would be required to equate the domestic ex-works price of the ingots with the landed cost ex-duty of the imported product. As for aluminium manufactures like sheets, circles, etc. they do not, in theory, need any protective duty, because there are no unfavourable differences between their domestic ex-works prices and the landed cost ex-duty of the imported products. But they would need compensatory protection so long as the raw materials, namely, ingots, bars, etc. are in the protected category. The Commission has therefore recommended that protection to these aluminium manufactures, namely, sheets, circles, etc. be also continued till the end of 1964 at the same rate of duty as recommended for ingots, e.g. 25 per cent ad valorem as against the effective rate of duty of 35 per cent ad valorem.

The Government, however, has not accepted the Commission's recommendation for a reduction in the rate of duty from 35 per cent to 25 per cent, though it has accepted the other recommendation for the continuance of protection for a further period of four years. Apparently, the Government thinks that the needs of the developmental phase would justify the maintenance of the protective duty at the existing level of 35 per cent ad valorem. At the same time, it has not ruled out the possibility of a reduction in the duty if a further study shows that consumers of aluminium require some relief or incentive and that such reduction will secure the developmental objective. For the present, the Government's decision to continue to maintain the existing duty is as realistic as it is understandable for more than one reason.

Magnesium

Magnesium is the eighth most abundant element and the fourth most plentiful metal in the earth's crust, where it is present to the extent of 2·2 per cent. Sea water contains 0·13% magnesium metal, so that one cubic mile of sea water represents $5\frac{1}{2}$ million tons of the metal combined as a salt. The reasons for the very late appearance in our history of this metal so lavishly provided by nature are the same as those given for the tardy arrival of aluminium. Both these light metals awaited the development of industrial electrolysis; but whereas aluminium is made solely by that method, alternative procedures for reduction of magnesium are practised now alongside the electrolytic process. The largest tonnage of magnesium today is however extracted from the sea water, adopting electrolysis method, by Dow Chemical Company of U.S.A. and Norsk Hydro-Elektrisk Kvoclsto-Fakticselskap of Norway.

The United Kingdom was the first country in Europe to produce magnesium in small quantity for photographic purposes[15]. Germany began to produce magnesium commercially on an industrial scale, and to develop alloys for use as engineering materials. The results of the German work, supported by that of U.K., France and Italy, gave Europe the lead for some years in the production and use of the metal for engineering purposes. Between the years 1929 and 1938, in addition to aircraft and military application a fairly wide range of products for civilian use became firmly established.

From about 1939 onwards, the Dow Chemical Company of America began steadily to increase production of magnesium and its alloys and the efforts of that company, stimulated by the great demand of World War II, enabled U.S.A. rapidly to become the leading producer and consumer of magnesium in the world—a position which she still holds today.

In 1938, the world's annual production of magnesium was only 32,000 tons, as per the breakdown given below:

Germany	about	20,000 tons
U.K.	,,	5,000 tons
U.S.A.	,,	2,500 tons
France	,,	2,500 tons
Japan	,,	1,000 tons
Switzerland	,,	500 tons
Russia	,,	500 tons
Total		32,000 tons

The enormous increase in the demand for magnesium metal for war purposes, already visible in Germany, was met by the rapid expansion of production facilities in U.K. and still greater and more rapid expansion facilities in U.S.A. The approximate total quantity of magnesium produced by all countries for the year 1939–40 was 32,000 tons; the comparable figure for the period of 1943–44 was 228,000 tons, more than seven times that of 1939–40. Unfortunately the valuable properties of the metal were so little known that such tonnages could not be absorbed for civilian purposes, and so the fall in post-war production was even sharper than the war-time rises in consumption, which has again come down to about 100,000 tons in 1959. The world production figures for magnesium in different countries are given in the following table[16]:

World production of magnesium metal, by countries, in short tons.

	1950 to 1954 (average)	1955	1956	1957	1958	1959
Canada	4,982	7,700	9,606	8,385	6,796	5,817
China	—	—	—	—	1,100	1,100
France	989	1,670	1,660	1,750	1,897	1,931
Germany, West	154	144	194	260	208	214
Italy	956	3,161	4,097	4,162	4,607	4,630
Japan	23*	148	86	472	1,106	1,655
Norway	1,942	7,433	8,185	9,504	10,226	10,250
Poland	61*	103	158	150	165	165
Switzerland	231	—	—	—	—	—
U.S.S.R.	38,000	45,000	45,000	45,000	45,000	45,000
United Kingdom	5,081	6,054	4,009	3,831	2,691	2,458
United States	65,046	61,135	68,346	81,263	30,096	31,033
World Total (estimate)	118,400	132,800	141,600	155,000	103,900	104,300

* One year's production.

Scope for development of magnesium metal industry in India

Magnesium is not being produced in India and the country's entire requirements are solely met by import both as virgin metal and fabricated components. Considering the raw material resources for the production of magnesium metal, India can be considered to be in a happy position so far as the ores of the metal are concerned.

The occurrence of dolomite is very widespread and the best known deposits exist in Birmitrapur and Panposh areas of Sundergarh district of Orissa, which account for 97 per cent of India's total production[17]. The resources of the ore in these areas are estimated at 250 million tons. The output of dolomite was 325,000 tons in 1959. Indian dolomites containing MgO–20 to 26%, CaO–30%, insoluble less than 3% and alkalies trace, are quite suitable for magnesium production employing silico-thermal process.

Magnesite, the other magnesium bearing mineral, also occurs in many places in India but so far only the Salem, Mysore, and Almora deposits appear to be workable. Reserves of the Chalk Hills[18, 19] deposits are roughly estimated at 90,000,000 tons analysing over 96 per cent $MgCO_3$ (46·4% Mg). Annual mine output is about 30,000–40,000 tons, part of it being used for refractories and a large quantity being exported. The Almora reserves are estimated at least 20,000,000 tons.

There are certain inherent difficulties associated with the extraction of magnesium metal from magnesite by pyro-metallurgical technique. The reduction of MgO is to be effected at a much higher temperature than that required for dolomite, e.g. 1150–1200°C. The magnesite is also to be reduced by carbon and magnesium has to be recovered by shock-cooling treatment as otherwise a back reaction results with the formation of magnesium oxide and carbon. Magnesium is obtained in a powder form, pyrophoric in nature and has to be carefully remelted and then used.

The present demand for virgin metal on a very liberal estimate is of the order of 200 tons/year. To meet this requirement and also the needs in the near future, the adoption of silico-thermal process of reducing dolomite seems to be the most convenient process of manufacturing magnesium under the existing raw material conditions. But scope also exists in India for the production of magnesium metal by electrylysis from magnesium chloride which is obtained as a bye-product in the chemical industries and does not have any commercial market. Depending on the demand for the metal, availability of power, etc. choice is to be made on adoption of the specific techniques. The electrolysis process which is a continuous one, can be adopted advantageously when the demand is quite large.

In the field of manufacture of light metals and alloys, including alloys of magnesium, there are a number of industries engaged in their production, total output of which is of the order of 1,000–1,500 tons.

Considering the raw materials position, India has great potentiality in manufacturing magnesium metal the demand for which is increasing tremendously in this supersonic age. Production of this metal is therefore essential in the building up and expansion of India's aircraft, automobile, defence and other engineering industries and it is expected that magnesium production will find a prominent place in the industrial programme under the aegis of the Five Year Plans.

Titanium, Beryllium and Zirconium

None of the above metals are at present produced in India although extensive deposits of the major raw materials occur in the country.

Titanium which was considered as a "wonder metal of the future" a few years back due to its excellent mechanical properties, good corrosion resistance and high strength to weight ratio, has recently been eclipsed and the demand has fallen. Various reasons have been put forward, one main reason being assigned to the less production of military aircraft.

The high cost of titanium[20] and its non-availability for civilian use have restricted the growth of this industry the world over. The price of titanium sponge, however, has gradually come down from 5 dollars per lb in 1954 to 2 dollars per lb. The present price of mill product is about 11·50 dollars a lb, which is quite prohibitive for large scale application.

U.S.A. is the leading manufacturer of titanium sponge with an output of 14,600 short tons. Japan ranked second with production of 2,800 tons and United Kingdom third with an estimated output of 1,700 tons. Relatively small quantities of metal are produced in France and Germany.

Three major grades of master alloys of titanium with iron ore are made for use as iron and steel addition[21] e.g. high, medium, and low, carbon ferro-titanium alloy which can be conveniently produced.

High-carbon ferro-titanium containing 7 to 8 per cent carbon and '5–17 per cent titanium is made by reducing with coal or coke in a single arc electric furnace employing a high circuit density. Medium carbon ferro-titanium containing 3 to 5 per cent carbon and 16 to 20 per cent titanium is made in the same fashion as low-carbon except that some rutile is added in the feed. Low-carbon master alloys have 0·03 to 0·1 per cent carbon, 20 to 45 per cent titanium and are made by alumino-thermic reduction of ilmenite and rutile.

India occupies a unique position so far as the reserves and cheap production of titanium minerals are produced. The reserves are estimated over 200 million tons and the main deposits occur in the beach sand of Travancore. The ilmenite concentrates obtained from Travancore are usually 60 to 70 per cent purity, the rest being rutile, monazite, zircon, sillimanite, quartz, etc[22].

The majority of the titanium mineral produced in India are exported in raw form and a very small proportion of the order of 3,000 tons a year is utilised for the manufacture of titanium dioxide pigment by Messrs Travancore Titanium Products at Trivandrum[23] and a small quantity of about 1,000 tons is used for manufacture of arc welding rod electrodes. Although no possible scope now exists for the manufacture of titanium metal in India in the near future, there is great potentiality for starting production of ferro-titanium in the country in the background of alloy, tool and special steel plant which is being established during the Third Five Year Plan period.

Ferro-titanium can be conveniently produced on a small scale by alumino-thermic reaction. On a large scale, however, the smelting in electric furnace is to be conducted with a titania-rich slag.

Deposits of both beryllium and zirconium occur in India which was once the only source of world's supply of beryl. In 1957, India produced 1,150[24] metric tons of beryl out of a total world production of ten thousand metric tons. The present-day use of beryllium in the atomic energy has added more significance to this metal.

There is no production of beryllium metal or any alloys of beryllium in India at present. The Department of Atomic Energy of India is considering to set up a pilot plant for producing sintered beryllium oxide bricks for utilisation of a reactor material[25]. The plant will treat about 150 kilos of beryl ore and will produce 9 kilos of brick per day.

Only two firms in U.S.A., viz. The Beryllium Corporation of Reading and The Brush Beryllium Co. of Cleveland, Ohio, process beryl to beryllium metal and alloys. Both the firms have constructed new plants to process beryl to reactor grade beryllium.

The main source of zirconium is zircon sands. Indian zircon is obtained as a bye-product in the ilmenite concentration process and contains about 65% zirconium oxide. There is a good scope in India for the exploitation of the zirconium sands for the production of zircon refractories. This type of refractory which is not manufactured in India finds wide application in aluminium remelting furnace, glass tank furnace, etc. The increase of aluminium industries in India will open up a greater demand for the refractory, which can be profitably made with this raw material.

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DISCUSSIONS

Mr. D. N. Sen, NCL, Poona: Chlorination of bauxite sludge and preparation of rutile grade TiO_2 is an important means of utilising this waste product. While much importance has been given to light metals and zirconium no stress has been given to very light metals like lithium and sodium. These two elements, apart from their use in atomic energy, are of considerable use as reducing agents in chemical technology. Complex borohydrides and aluminohydrides of these elements are versatile reducing agents. Both these metals are not being produced in India and steps are to be taken to produce them. In this context I would like to know about the availability of spodumene and lepidolite in India.

Mr. P. K. Gupta (Author): I agree with Dr. Sen about the importance of lithium and sodium which have a multitude of applications particularly in the chemical industries. We have in this paper stressed the development of light metals from the metallurgical standpoint. In the background of the present position of the light metal industry in India, it is of paramount importance to develop aluminium, magnesium, titanium and beryllium industries. Production of metallic sodium and lithium and their alloys is of much lesser importance than that of the light metals described in this paper.

Regarding the deposit of lithium in India, very few and small occurrences of lithium are known. The largest occurrence of lepidolite is in Bastar in Madhya Pradesh. In Bastar lepidolite occurs in large masses, which, except for a little quartz, is free from impurities and has been found to analyse 3·34 per cent lithium.

Mr. K. S. Ganapati, Aluminium Mfg. Co. P. Ltd., Calcutta: The impression that Aluminium Mfg. Co. Ltd. produces aluminium utensils is to be corrected; we stopped manufacture of aluminium utensils more than 5 years ago and have no plans to start the utensil line.

It has been stated that the estimated consumption is about 45,000 tons whereas production plus import amount to 35,000 tons for the year 1960. Assuming that secondary aluminium would account for about 6,000 tons, there is still a gap of about 4,000 tons to be explained and I would request the author to clarify in this respect.

Mr. P. K. Gupta (Author): Regarding the production figures mentioned, I wish to point out that these are estimated figures and, as such, there is slight variation between the actual production and consumption.

Mr. K. C. Choudhuri, Research, Designs and Standards Organisation, Ministry of Railways, Chittaranjan: In connection with the utilisation of red mud which is a waste product, I would like to say that the Metallurgical and Chemical Section of R.D.S.O. has successfully developed primus and finishing paints using calcined red mud in CNSL (resin) media, which can replace red lead. The estimated cost of red mud paint is about half of that of red lead, although consuming capacity is not less than that of red lead (450 sq ft per gallon). Therefore there exists a great prospect of utilisation of red mud (bauxite residue).