II BACKGROUND

Aluminium is a strong durable material that is corrosion resistant, a good conductor of electricity and heat and a good reflector. It is non-magnetic and non-toxic. It has an enormous range of applications in building and construction, the electrical industry, consumer goods (e.g. utensils), transport containers and packaging, machinery and communications.

Aluminium is the most abundant metal in nature, representing about 8.2 per cent of the earth's crust. Bauxite is the principal commercial raw material for aluminium production, and consists of hydrated aluminium oxide (alumina) mixed with impurities in the form of iron oxide, silica, titania and other minerals. There are three major forms of bauxite - Gibbsite, or alumina trihydrate ($Al_2O_3 . 3H_2O$) which contains alumina up to 65 per cent alumina, and Boehmite, or alumina alpha monohydrate ($Al_2 O_3 . H_2O$) and Diaspore, or beta monohydrate (also $Al_2 O_3 . H_2O$) which contain alumina up to 85 per cent Although Boehmite and Diaspore contain a larger percentage of aluminium oxide as compared to gibbsite, they are more difficult to process (because they are harder and not easily soluble in caustic soda in the Bayer process for the manufacture of alumina which is the first step in the production of aluminium).

Bauxite mined in Surinam, Guyana, Brazil and Western Australia are only or mostly of trihydrate variety. The European bauxite (Greece, Yugoslavia, Hungary, U.S.S.R.) are, on the other hand, predominantly of monohydrate variety. Jamaican and Guinean bauxite contain both trihydrate and monohydrate. In India, the characteristics of bauxite deposits differ from location to location. In the mines of Shevoroy hills and Kolli hills (Tamil Nadu), Phutkapahar (Madhya Pradesh) and Panchapatmali hills (Orissa) bauxite is mostly of gibbsite (trihydrate) variety. On the other hand, in the mines of Raktidadar and Nanhoodadar, bauxite has a high proportion of diaspore (monohydrate) mixed with gibbsite. The characteristics of bauxite obtained from various mines in India also differ in regard to the silica content.[2]

There are three stages in the production of aluminium. In the first stage, bauxite is mined, and then crushed and beneficiated in preparation for the refining process. In the second stage, bauxite is processed into alumina at refineries using the Bayer process, invented by Karl Joseph Bayer in 1888. This is a chemical process which separates aluminium oxide or alumina from the impurities in the bauxite. In the third stage, alumina is convened into aluminium in electrolytic smelters using the method developed by Carles Martin Hall and Paul Heroult in 1886. During smelting, alumina is reduced to aluminium in a series of large electrolytic cells called "pot-lines". Molten aluminium is siphoned off from the bottom of the cells and either continuously cast into commercial shapes or batch cast into ingots for rolling or direct sale.

Aluminium is technically obtainable also from non-bauxite sources, such as nepheline syenite and alunite, but at present the Bayer bauxite process has substantial cost advantage over the alternative processes. In consequence, nearly 95 per cent of the alumina produced in the world is from bauxite source and over 90 per cent of such alumina produced uses the Bayer's process.

All bauxite mined and alumina produced do not finally get converted into aluminium. Some amounts of bauxite and alumina are consumed by refractory, abrasive, chemical and other industries. In 1985, the total production of alumina in the world was 25.5 million tonnes of which 2.3 million tonnes (9.2%) was of special grade (used in the production of abrasives, refractory, ceramics, spark plug, synthetic gems, tooth paste, etc). The proportion of special grade alumina in total alumina production was nearly 50 per cent in East Asian countries, while the ratio was only about 2 per cent in South Asian countries. It should be pointed out that smelter grade alumina, which is essentially meant to produce aluminium metal, is sometimes used by chemical industries in place of special grade when the latter variety is not easily obtainable indigenously or for cost reasons. Presently in India, the abrasive manufacturers are buying smelter grade alumina and processing it further for self-use and for sale to other abrasive manufacturers.[3]

In addition to primary aluminium smelters (converting alumina into aluminium) which is the main source of supply of the metal, there are smelters that process new scrap (waste from fabrication) and used aluminium scrap into secondary aluminium. The proportion of demand for aluminium being satisfied by the secondary industry is growing steadily because the energy cost of producing primary aluminium is very high and the recycling of aluminium requires less than 5 per cent of the energy needed to produce primary ingot. Presently, secondary aluminium in India is estimated to form about 10 per cent of total consumption, whereas in industrialised industries it accounts for about 30 per cent (U.S.A 30%, Japan 30%, Italy 35% and West Germany 32% in 1986).[4]

Technology

Bauxite Mining

Most of the bauxite produced in the world is mined by open-cast methods. There are basically three stages in bauxite mining: extraction, crushing and drying. Extraction involves removal of overburden by bulldozers, drag-lines and large-wheel excavators, with the use of explosives for hard terrains. Then, the bauxite is removed by similar methods, and the overburden is replaced to restore the surface of the mines for re-use as forest or agricultural land. The bauxite removed from the mines generally requires crushing (for which crushers are used) for ease of processing. This is followed by drying which may be done at mine- site or at the refinery. The treatment of bauxite ore prior to refining is usually restricted to washing and cleaning to remove sand and some clay. Mine capacities range from approximately 80 thousand tonnes per annum (tpa) to 10 million tpa. The smallest scale operations are in India and China where a few mines operate at 50 to 60 thousand tpa. About 80 per cent of the mines in developed countries have capacities greater than 5 lakh tpa and 15 mines have capacity of over one million tpa.[5] The largest bauxite mine in India is the recently developed Panchapatmali mine of Orissa, which has a capacity of 2.4 million tpa. The Gandhamardhan bauxite project (Orissa) which is currently awaiting environmental clearance is to have a capacity of 6 lakh tpa.

Alumina Production

Bauxite is refined into alumina almost exclusively by the Bayer process. Bayer alumina plants consist of two facilities operating in series: a hydrate plant and a calcination plant. The hydrate plant transforms bauxite into alumina hydrate in a process involving the following four major operations [6]:

1. Grinding and slurring where the crushed ore is fed to ball or rod mills and caustic soda, lime, hot water and spent liquor are added to it, forming a slurry that goes into the digestors.
2. Digestion of the slurry containing bauxite and caustic soda at elevated temperatures and pressure. At this stage, bauxite is dissolved, forming a solution of sodium aluminate, while the reactive silica combines with alumina forming an insoluble sodium aluminium silicate and consuming caustic soda and alumina in the process. (Having a high proportion of reactive silica in the bauxite is, therefore, disadvantageous).
3. Filtration and settling of the insoluble impurities (called red mud) separating them from the sodium aluminate solution which is pumped into precipitators.
4. Precipitation of the sodium aluminate which is seeded with aluminium hydrate crystals, causing about 50-60 per cent of the alumina hydrate to disassociate from the soda and precipitate out as crystals. The mixture is pumped to at least three stages of thickeners which separate the crystals from the caustic solution. The coarsest product is sent to the calcination department; the products of the previous two stages are recycled to the precipitators for seed to

control particle size; and the caustic solution (spent liquor) is recycled for further use.

The calcination of alumina hydrate to alumina ($Al_2 O_3$) involves the removal of moisture and of the chemical bonded hydroxide by roasting the hydrate at 1150 to 1250oC. Before the 1950s, rotary kilns were used for this purpose, but afterwards there has been widespread use of fluid bed calciners, which use 33 per cent less fuel, and are cheaper to install and maintain. Most Indian alumina plants, however, continue to use rotary kilns for calcination.

Aluminium Production

The Hall-Heroult electrolytic reduction process is used for smelting alumina into aluminium. In the smelter, alumina is dissolved in cells (pots) containing a molten electrolyte bath consisting mostly of cryolite (sodium aluminium fluoride). Excess aluminium fluoride and calcium fluoride (fluorspar) are added to lower the melting point and improve operation. A pot consists of an outer iron shell with inner carbon lining which serves as cathode. This surrounds an inner container or block of baked carbon (anode). An aluminium reduction plant has a large number (50-200) electrolytic cells electrically connected in a series (known as potlines).

The passage of direct current through the electrolyte decomposes the dissolved alumina. Aluminium metal is deposited at the cathods and therefore collects at the bottom of the cell (below the cryolite bath) from where it is siphoned periodically (and transported to holding furnaces which feed the casting machines). Oxygen is released at the anodes where it reacts with carbon, forming a mixture of carbon dioxide and carbon monoxide. Thus, the anodes are consumed and must be replaced regularly.[7] The smelting process is continuous. Alumina is added, anodes replaced, and molten aluminium periodically siphoned off without interrupting current to the cells.

Two types of reduction plants are currently in use - (i) prebaked anode plants and (ii) Soderberg (self-baking) anode plants. The Soderberg anode system produces anodes continuously by feeding unbaked carbon paste (made from calcined petroleum coke and coal tar pitch) into a casing at the top of the smelter pot. The heat of the pot bakes the paste as it moves into the pot, providing a constantly renewed anode. In the prebaked anode system, solid anodes are made in a separate process[8] and lowered progressively into the bath as they are consumed. The prebaked anode system has a number of advantages over the Soderberg anode system, including lower consumption of anode, easy recovery of fluorines from the cell, exhaust gases and lesser pollution problems. However, in India, most smelters use the Soderberg paste method.

The smelting process is highly power intensive. Power cost is the most important cost item in the production of aluminium. Considerable R & D efforts have therefore been made in the past to reduce power requirement in aluminium production. Originally, when the Hall-Heroult process was developed in 1886, the power requirement per tonne of aluminium was about 40,000 kwh. With better cell design and operational improvement, the power requirement was reduced to about 20,000 kwh per tonne by 1925, and to-day it has come down to as low as 12,800 kwh per tonne of aluminium production at the most efficient. In India,

where smelters have electrolytic cells of early fifties design, the power consumption norms are 17 to 19 thousand kwh per tonne of aluminium production.[9]

With the possibilities of further energy saving in the Bayer- Hall-Heroult process of aluminium production getting more and more limited, R & D efforts have been directed towards developing new routes of aluminium production. Notable among them are Alcoa's Chloride process, the Toth process and the direct reduction process. In the Alcoa chloride process bauxite is converted into aluminium chloride, which is then electrolysed. It offers an energy saving of 30% to 9000 kwh per tonne of aluminium. Also, it does not require scarce cryolite and fluoride, and dispenses with expensive C.P. coke consumption. The Toth process is based on a series of chemical reactions and does not require electrolysis.

The main advantage of this process is that it does away with the use of electricity altogether. The direct deduction process adopts a totally enclosed blast furnace route to reduce bauxite with coke to produce aluminium and silicon alloy (alusil). Thus, expensive electricity is substituted by cheaper thermal energy. It should be noted that the processes discussed above are still in the development stage and have not yet been commercialised.

Fabrication

Molten aluminium metal obtained from smelters are transferred to melting and holding furnaces, where it is combined with recycled scrap and alloying elements (copper, magnesium, silicon and manganese). The molten aluminium alloy is treated and then cast into ingots or billets. For the manufacture of wire rods, the molten metal is directly transferred to the casting machines. From the ingots or billets, aluminium products are made through processes such as rolling, extruding, forging and drawing.[10]

World Aluminium Industry

From a very small production level of 13 tonnes per annum about 100 years ago, the world aluminium industry has reached today a production level of over 17 million tonnes per annum. Analysis of production figures for aluminium (primary metal) for the last four decades brings out that in the 1950s and 1960s the world aluminium industry experienced a rapid growth at the rate of about 10 per cent per annum. The world production of aluminium was 1.5 million tonnes in 1950. It rose to 10.3 million tonnes in 1970.[11] There was a marked slowdown in the growth rate of the world aluminium production after 1970. Between 1970 and 1980, the growth rate was 4.6 per cent per annum. In 1980, the production level reached 16.1 million tonnes. The growth of the world aluminium production has been very slow in the 1980s (See Table 2.1). Between 1980 and 1982, production fell by about 2.2 million tonnes. The production level reached in 1980 was surpassed only in 1987. A signfificant increase took place in 1988 when the production level reached 17.3 million tonnes. Between

1980 and 1988, the growth rate in production was 0.9 per cent per annum, well below the growth rate achieved in the 1970s.

The progressive deceleration of aluminium production from the end of 1960s may be attributed, among other factors, to: (1) rise in energy prices and the consequent rise in the cost of producing aluminium, (2) the scope of substitution of aluminium for other materials in electric cables, packaging, construction and transportation getting increasingly exhausted in the main OECD consuming markets, and (3) secondary metal (scrap recovery) taking an increasing share of total consumption.[12]

There is a high degree of vertical and horizontal integration in the world aluminium industry. A large part of the world's productive capacity of bauxite, alumina and aluminium is owned and operated by six multinational corporations: ALCOA, ALCAN, Kaiser, Reynolds, Pechiney and Alusuisse. Till the end of the sixties, these six companies together controlled over 70% of the world production of aluminium. Their share has declined significantly since then. In 1980, the share of the six companies in total world capacity of aluminium smelting was 41%. In bauxite mining and alumina refining, the share of these companies was 54% and 56% respectively in 1978/79.[13] In the 1980s, the share of the six companies has declined further. In 1985, their share in world capacity of aluminium smelting was 35 per cent.

Until the decade of the forties, bauxite, alumina and aluminium were produced mainly in Europe, the Soviet Union, the United States and to a lesser extent in the Guinas (only bauxite). Thus, during this period, the entire production cycle remained principally concentrated in the industrial nations nearer to the major metal markets. Cost considerations drove the aluminium companies to seek new sources of supply of bauxite after the Second World War, which was reflected in the rise of Guyana and Surinam as the main producers of bauxite, supplying primarily to North America. The industry got increasingly internationalised with the emergence of new important bauxite producers : Jamaica in 1950s and Australia and Guinea in the 1960s.[14]

Escalating energy cost in the seventies and the consequent rise in transportation cost have led to significant restructuring of the world aluminium industry. There has been an increasing transfer of alumina production from developed countries to the bauxite producing countries.[15] The sharp rise in thermal electricity prices in energy importing countries, coupled with the stagnation in consumption in the 1980s, have led to the closures of aluminium smelters in Japan, U.S.A. and Western Europe. Japan has been the most striking case, where aluminium smelting capacity has been reduced to less than one-fourth (from 1.4 million tonnes in 1980 to 0.3 million tonnes in 1986). In this period, production capacity of aluminium in USA has been reduced from 4.97 million tonnes to 3.8 million tonnes. Unless a major breakthrough occurs in the technology of aluminium production and/or in low cost power generation, the geographical distribution of aluminium smelting capacity is likely to change in future towards the developing regions of Asia and Africa with large unutilised potentials of hydro-electric power and to other regions having abundant natural gas supply or cheap hydro- electric power.

While some countries were closing down aluminium smelters, some others were installing new smelting capacities. Indeed, in the decade ending 1982, there was a substantial expansion in the world capacity of smelting aluminium.[16] As a result of the continued new investment and deceleration in demand for primary aluminium, there has been a sharp fall in capacity utilization. According to one estimate, capacity utilisation in aluminium smelters in non-socialist countries was 77 per cent in 1983 as against 93 per cent in 1973. Despite adverse world market conditions, investment in additional aluminium smelting capacity has continued in the 1980s. The world annual production capacity of aluminium was 17.4 million tonnes in 1982. In the next six years, the capacity got raised to 18.8 million tonnes.

Recently, there has been a significant improvement in capacity utilisation in aluminium production. In 1988, the average rate of capacity utilisation in aluminium smelters in market economy countries was over 94 per cent which is the highest rate achieved since 1974.

Substantial expansion in production capacity for aluminium is expected in the 1990s. From 18.8 million tonnes in 1988, the world capacity of aluminium smelting is expected to increase by the mid-1990s to about 25 million tonnes (and may even reach 27 million tonnes).

World Market

Although the share of the six multinationals in aluminium industries has declined over time, they continue to dominate international trade in bauxite, alumina and aluminium. The major part of international trade in bauxite and alumina takes place as internal transfers between affiliates of the six companies mentioned above. The remaining part of the trade in bauxite and alumina is mostly done on the basis of long-term contracts.

Since most of the aluminium production in the world takes place in developed countries and consumed by affiliated fabricators, there is only a limited spot market for aluminium metal. While more free metal is entering the market as new producers emerge, the six companies continue to dominate price setting of aluminium. Since 1978, aluminium has been traded on the London Metal Exchange (LME), which provides a source of spot price quotations. However, the volume traded on LME, while growing, still represents a very small percentage of total sales.

The price of aluminium ingot has been relatively stable over time and has not increased as much as the prices of competing metals. In part, this is due to the big producers' strategy to discourage new entrants by keeping the price low and increasing it only in line with costs. Also, the fact that there has been reasonably close matching of capacity to demand has contributed to price stability. Between 1960 and 1973, the price of aluminium in London market rose from $513 to $669 per tonne, reflecting a barely 2 per cent increase per annum. Between 1973 and 1978 there was a sharp increase in the price of aluminium by 56%, i.e., an annual growth rate of about 9%. After 1978, there have been fluctuations in aluminium price from year to year, reflecting primarily short-term excess demand and excess supply situations, but the trend growth rate has been low. Between 1978 and 1986, the increase in aluminium price was from $1045 to $1152 per tonne, implying a growth rate of about 1% per annum. There have been sharp increases in aluminium price in 1987 and 1988. The price was $1560 per tonne in 1987 and over 2500 US$ per tonne in 1988.17From 1978 to 1987, the spot price for alumina remained mostly in the range $100 to $150 per tonne. There was a sharp increase in the prices of alumina in 1988. From $150 per tonne in the beginning of the year, the spot price briefly touched $700 per tonne. In mid-1988, the average price paid for alumina by world smelters was about $200 per tonne.[17]

Indian Aluminium Industry

The aluminium industry in India started with the production of household utensils from imported sheets and circles. A sizeable utensils industry was built up from 1929 onwards but indigenous manufacture of aluminium metal was attempted only in 1937. A public limited company - Aluminium Corporation of India (ALUCOIN) - was formed to set up an integrated plant near Asansol (West Bengal) for the manufacture of aluminium metal, utilising the bauxite available from Ranchi and Plamau districts of Bihar. Production of aluminium started in 1944. The initial installed capacity for aluminium ingot was 2000 tonnes per annum (tpa).

Another company - Aluminium Production Company of India Ltd. - was incorporated in 1938 as a private limited company. In 1944, it was converted into a public limited company under its present name, Indian Aluminium Company Ltd. (INDAL). The company commenced operations in 1941 with the fabrication of imported ingots into sheets and circles at Belur (West Bengal). Production of aluminium from imported alumina started in 1943 at Alwaye (Kerala) with an installed capacity of 2500 tpa, and production of alumina from indigenous bauxite in 1948 at Muri (Bihar) with an installed capacity of 6500 tpa. At present, this company has three smelters at Alwaye (Kerala), Hirakud (Orissa) and Belgaum

(Karnataka). The installed capacities of these three smelters are 20, 24 and 73 thousand tpa respectively, i.e. 117 thousand tpa in total. The company also has semi-fabrication capacity of about 50 thousand tpa at different locations in the country. The company has foreign collaboration with ALCAN (Canada), which holds 50.5% equity share (in 1986).

The Hindustan Aluminium Company (HINDALCO)[18] was registered as a public limited company in 1958. It started with an initial capacity of 20 thousand tpa of aluminium metal production. The alumina plant and smelter were located at Renukoot in Uttar Pradesh. The unit has now expanded to 120 thousand tpa of installed capacity. It has achieved the distinction of being the largest single integrated aluminium smelter plant in India. The present licensed capacity of the firm for rolling and extrusions is about 34 thousand tpa, and the licensed capacity for all semi- fabricated products is about 55 thousand tpa. The company has foreign collaboration with Kaiser (USA), which has an equity participation of 26.7% (in 1986).

The Madras Aluminium Company Ltd. (MALCO) was set up in 1960 as a public limited company. Production of alumina and aluminium commenced from 1965. The unit was located at Muttur (Tamil Nadu). The initial installed capacity of the smelter was 10 thousand tpa, which has now expanded to 25 thousand tpa. The company has licensed capacity for semi-fabrication of 17.5 thousand tpa. The Company has foreign collaboration with Montecatini (Italy), which has an equity participation of 27%.

The public sector entered the aluminium industry with the setting up of the Bharat Aluminium Company Ltd. (BALCO) in 1965. The company established an integrated aluminium complex at Korba in Madhya Pradesh. The company had technical collaboration with Chemokomplex (Hungary) for the alumina plant and with Tsvetmetromexport (USSR) for the smelter. The alumina plant was commissioned in April, 1973 and the first phase of the smelter (25,000 tpa capacity) in May 1975. At present, BALCO has installed capacity of 1 lakh tpa of aluminium production.

The company has semi-fabrication capacity of 82 thousand tpa at Korba and 6.4 thousand tpa at Bidhanbag.[19]

Another big aluminium unit has recently come up in the public sector. This is the aluminium complex set up in Orissa by the National Aluminium Company (NALCO). The project comprises of a bauxite mine of 2.4 million tpa capacity at Panchapatmali (Koraput district), an alumina plant of 8 lakh tpa capacity at Damanjodi (Koraput district), a 2.18 lakh tpa smelter at Angul (Dhenkanal district), a captive power plant of 600 MW capacity (5 units of 120 MW each) at Angul and related port facilities at Vishakapatnam for export of alumina and import of caustic soda. The company has technical collaboration with Pechiney (France).

The setting up of mining facility and alumina plant for the NALCO project has been accomplished in accordance with the time schedule of implementation. But, considerable teething problems have been faced in regard to smelter. Phase I of the smelter was scheduled to be completed by December 1986 and Phase II by September 1987. Completion of the first phase of the smelter has taken two years more than scheduled, and the full capacity of both phases of 2.18 lakh tpa is expected to be achieved only during 1990-91.

In 1987-88, NALCO's production of aluminium metal was 25 thousand tonnes. With the completion of phase I of the smelter, the production increased in the following year, 1988-89, to 78.8 thousand tonnes. In its very first year of commercial production, NALCO earned foreign exchange by exporting 76.8 thousand tonnes of alumina. During 1988-89, NALCO exported 380 thousand tonnes of alumina and 15 thousand tonnes of aluminium metal, earning Rs.235 crores of foreign exchange.

talled capacity for aluminium production (primaryetal) in different companies and the industry as a whole for selected year in the past is shown in Table 2.2. It is seen from the table that the total installed capacity has increased from 5 thousand tonnes in 1950 to 3.62 lakh tonnes in 1987.

With the completion of the NALCO project, there will be an addition to the total installed capacity by 2.18 lakh tonnes. Also, HINDALCO is building its sixth potline which will take its aluminium smelting capacity to 1.5 lakh tonnes. Thus, the projected total installed capacity for 1990-91 is 6.1 lakh tonnes.

Currently, large expansions in capacity are being planned by the major domestic producers of aluminium. NALCO hopes to add new production lines and take its capacity from 218 thousand tonnes to 330 thousand tonnes. HINDALCO aims at raising its capacity from 120 thousand tonnes to 150 thousand tonnes in 1990 and has plans to raise it subsequently to 250 thousand tonnes (with matching expansion in alumina capacity and downstream rolling and extrusions). BALCO has plans for raising its capacity from 100 thousand tonnes to 150 thousand tonnes. If these expansion plans get approved and materialised the country's production capacity of aluminium will go up to 8.72 lakh tonnes by the mid-1990s.

Time-series on installed capacity and production in the aluminium industry for the period 1970-71 to 1988-89 are presented in Table 2.3, in which capacity utilisation rates are also given. It is seen from the table that in this period the growth in aluminium production has been slower than the growth in installed capacity for aluminiu. This is reflected in a significant downward trend in the rate of capacity utilisation, as the last column of the table brings out.

Company-wise capacity utilisation figures for the period 1976-77 to 1988-89 are presented in Table 2.4. It is seen from the table that BALCO has made a remarkable improvement in the rate of capacity utilisation from 25.1% in 1976-77 to 96.5% in 1986-87. Capacity utilisation in HINDALCO has also improved substantially. On the other hand, there has been a marked decline in the rates of capacity utilisation in INDAL and MALCO. The rate of capacity utilisation in INDAL and MALCO has been quite low in recent years. This is attributable largely to inadequate and irregular power supply to these units.

Table 2.5 shows trends in the availability of aluminium in India which is an indicator of the level of consumption of aluminium in the country. In 1950-51, apparent consumption of aluminium (in terms of availability) was about 15 thousand tonnes. In the next twenty yeas, there was a rapid growth in the consumption of aluminium in India. Thus, in 1970-71, apparent consumption of aluminium was 174 thousand tonnes, which gives a growth rate of 13% per annum. This rapid growth in domestic demand for aluminium was met by increasing production of aluminium in the country, and the dependence on imports wa greatly reduced. In 1950-51, imports constituted 72.5% of the availability. In 1970- 71, this ratio was only 3.7%. In comparison with the 1950s and 1960s, the growth in aluminium consumption in the 1970s was much slower. Thus, between 1970-71 and 1979-80, the growth rate in availability was 3.6% per annum. The growth rate of aluminium consumption was a little higher in the 1980s. Between 1979-80 and 1987-88, the growth rate in availability was 4.6% per annum. However, in this period there was greater dependence on imports.[20]

Table 2.6 shows the consumption pattern of aluminium for selected years. It is seen from the table that in 1950 nearly half of the consumption of aluminium in the country was for household and consumer durables (mostly utensils). This proportion fell sharply over time. In 1984, only about a fifth of the total consumption of aluminium was for this purpose. On the other hand, the use of aluminium for electrical applications gained substantial in importance from 20 per cent of total consumption in 1950 to 50 per cent of total consumptin in 1984. This has come about through the increasing substitution of copper conductors by aluminium, and the rapid growth of the power sector. It may be mentioned in this connection that in recent years the off-take of electrical conductor (EC) grade aluminium has been quite depressed because State Electricity Boards (who are the main consumers) ave been facing severe financial constraints and in their investment programmes, relatively greater emphasis is being put on generation than on transmission and distribution, compared to the investment pattern prevailing in the 1970s.

Table 2.1

World Production of Aluminium (primary) in the 1980s

Year	Aluminium Production (million tonnes)
1981	15.7
1982	13.9
1983	14.3
1984	15.9
1985	15.5
1986	15.5
1987	16.3
1988	17.3

Source : Radhakrishna and Kalra (1985), Vol.II,pp 1-4, and various issues of Minerals and Metals Review.

TABLE 2.2

Installed Capacity for Aluminium Production in India : ('000 tonnes)

Company	1950	1960	1970	1975	1980	1985	1987	1990-91 (Projected)
INDAL	2.5	35.0	66.0	96.0	96.0	117.0	117.0	117.0
ALUCOIN	2.5	7.5	9.0	9.0	-	-	-	-
HINDALCO	-	20.0	80.0	95.0	110.0	120.0	120.0	150.0
MALCO	-	10.0	12.5	25.0	25.0	25.0	25.0	25.0
BALCO	-	-	-	25.0	100.0	100.0	100.0	100.0
NALCO	-	-	-	-	-	-	-	218.0
TOTAL	5.0	72.5	167.5	250.0	331.0	362.0	362.0	610.0

TABLE 2.3

1980 Installed Capacity, Production and Capacity Utilisation in Aluminium Industry : 1970-71 to 1987-88

Year	Installed Capacity ('000 MT)	Production ('000 MT)	Capacity Utilisation (per cent)
1970-71	156	167	107.1
1971-72	173	181	104.6
1972-73	195	176	90.3
1973-74	195	148	75.9
1974-75	210	127	60.5
1975-76	246	187	76.0
1976-77	266	209	78.6
1977-78	291	179	61.5
1978-79	321	214	66.7
1979-80	321	192	59.8
1980-81	321	199	62.0
1981-82	321	207	64.5
1982-83	321	208	64.8
1983-84	362	220	61.0
1984-85	362	276	76.2
1985-86	362	264	72.9
1986-87	362	257	71.0
1988-89	471	357	75.8

* includes new pots installed by NALCO.

Source : Thangaraju and Kothari (1986) and various issues of Mineral and Metals Review.

TABLE 2.4

Trends in Capacity Utilisation of Primary Aluminium Producers : 1976-77 to 1987-88

(Per cent)

Company Year	BALCO	HINDALCO	INDAL	MALCO	Industry Average
1976-77	25.1	88.2	82.2	71.6	78.6
1977-78	31.6	57.8	68.5	74.9	61.5
1978-79	31.9	70.7	83.8	86.2	66.5
1979-80	30.5	71.5	66.4	88.4	59.8
1980-81	28.4	69.8	75.8	88.0	62.0
1981-82	34.8	63.1	70.5	55.4	64.5
1982-83	43.5	74.3	54.2	48.6	64.8
1983-84	60.4	75.0	47.0	26.4	61.0
1984-85	87.4	105.0	41.4	56.8	76.2
1985-86	96.5	100.5	32.3	38.8	72.9
1986-87	96.5	101.9	23.8	41.2	71.0
1987-88	91.0	102.3	25.8	34.0	66.0 *
1988-89	93.4	104.1	42.3	42.4	75.8 *

* including NALCO.

Source : Thangaraju and Kothari (1986), and various issues of Minerals and Metals Review.

TABLE 2.5

Availability of Primary Aluminium Metal in India

('000 tonnes)

Year	Production	Imports	Availability	Import- Availability Ratio (%)
1950-51	4.1	10.8	14.9	72.5
1960-61	18.3	25.4	43.7	58.1
1970-71	168.8	6.4	174.0	3.7
1971-72	181.5	21.2	202.7	10.5
1972-73	174.8	1.7	176.4	1.0
1973-74	147.8	1.6	149.5	1.1
1974-75	126.6	2.7	129.3	2.1
1975-76	187.3	5.1	185.1	2.8
1976-77	208.7	0.3	187.3	0.2
1977-78	178.5	9.0	186.9	4.8
1978-79	213.7	32.2	245.9	13.1
1979-80	191.8	51.1	239.5	21.3
1980-81	199.0	117.6	309.1	38.0
1981-82	206.8	28.7	232.1	5.7
1982-83	208.1	19.3	227.5	8.5
1983-84	221.0	18.0	239.0	7.5
1984-85	276.0	55.0	331.0	16.6
1985-86	265.0	25.0	290.0	8.6
1986-87	257.0	65.0	322.0	20.2
1987-88	278.0	65,0	343.0	19.0

Source : Compiled from Lal and Abroi (1986) and Minerals and Metals Review, August, 1988 (p.15).

TABLE 2.6

Consumption Pattern of Aluminium in India

(Per cent)

Use\Year	1950	1960	1970	1980	1984
Electrical	20	40	48	52	50
Household & consumer durables	52	24	28	18	18
Transportation	6	13	8	12	15
Canning and packaging	10	11	8	6	7
Building and construction	2	2	2	6	7
Machinery, equipment andothers	10	10	6	6	3
TOTAL	100	100	100	100	100

Source : Thangaraju and Kothari (1986).

NOTES

1. Brown and McKern (1987), p.22.

2. See Thangaraju and Kothari (1986), pp 19-26. For more details about mining of bauxite in general and in Indian context see Brown et.al. (1983) pp 6-11, Brown and McKern (1987), p 25- 26, Das Gupta (1985) and NCAER (1983), pp 70 - 94.

3. For more details about spccial grade alumina, see Ramaratnam (1987).

4. See Rao (1988), p 56.

5. Brown and McKern (1987), p 25-26.

6. Brown et.al. (1983), pp 11-13. Also see Radhakrishna and Kalra (1987), Vol.II, Appendix 7.1.

7. Although cathods are not consumed during metal production, they have a limited life of 4-5 years due to thermal and electrical stresses, and need to be replaced from time to time.

8. Ground C.P. Coke is mixed with hot coal tar pitch to bind it into a block and then pressed in a mould to form 'green' anode. This is then baked slowly at a temperature upto 1100-1200 C for about 15 days.

9. "Energy Conservation in India's Aluminium Plants", Minerals and Metals Review, August 1987, p 46.

10. For details of fabrication methods, see Thangaraju and Kothari (1986), pp 44-53.

11. Radhakrishna and Kalra (1987), Vol.I, p.6, 35, and Vol.II, p.1- 4.

12. Between 1976 and 1986, global consumption of primary aluminium increased at the rate of 1.6 per cent per annum, while the consumption of scrap increased at the rate of 5.2 per cent per annum (Minerals and Metals Review, August 1989, p.40). In 1988 total production of primary aluminium in non-socialist countries was about 14 million tonnes. The production of secondary aluminium in these countries was over 5 million tonnes.

13. Transnational Corporations in the Bauxite/Aluminium Industry, UNCTC, 1981, as cited in Lal and Abroi (1986).

14. Currently, Australia and Guinea are the top two bauxite producing countries in the world. Their production in 1988 was 36.2 and 16.8 million tonnes respectively. In terms of bauxite production, Brazil, Jamaica and U.S.S.R. are in the 3rd, 4th, and 5th place. In 1988, the production of these three countries were 7.7, 7.4 and 5.9 million tonnes respectively. Bauxite production in India was 2.8 million tonnes in 1987 and 3.4 million tonnes in 1988.

15. Since more bauxite is now refined to alumina in the country of origin, there has been a steady decline in the trans- ocean shipments of bauxite in the 1980s while alumina trade has been growing (Minerals and Metals Review, Annual 1989, p.49).

16. Brown and McKern (1987), pp. 13-14.

17. To protect their earnings against increasing volatity of aluminium prices and to secure fresh outlets for their metal, more and more major aluminium producers are moving downstream and investing in fabrication plants.

18. Recently, the company has changed its name to HINDALCO Industries Ltd.

19. Minerals and Metals Review, August 1986, p 10.

20. In 1987, imports of aluminium were 78.1 thousand tonnes, and the import-availability ratio was 22.7 per cent. There was a drastic reduction in imports of aluminium in 1988. Imports fell to 7.3 thousand tonnes, and the import-availability ratio came down to 2.1 per cent. This is attributable to a sharp rise in the international price of aluminium and a substantial increase in domestic production of aluminium (by 26.1 per cent). Imports of aluminium have increased again in 1989. In the first ten months of the year, imports of aluminium were 26 thousand tonnes, and the import-availability ratio was about 7 per cent.