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EXPERIENCE IN THE EXPANSION OF ALUMINA PLANTS AND INDUSTRY IN THE DEVELOPING COUNTRIES[1/]

by

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1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO.

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SUMMARY

The importance of an aluminium industry to the development of the economy of a country is indicated in this paper. The pattern of growth of the demand of aluminium and its production in the world has been discussed, world reserves of bauxite have been mentioned briefly.

Developments in the production of bauxite, alumina and aluminium in various countries of the world with particular reference to the developing countries have been described. The production of bauxite in the developing countries has been between 70 to 80 per cent of the world production during the last ten years. Barely one fifth of this bauxite is converted into alumina in these countries; the rest is exported to the developed countries.

The author deals with the status of the alumina and aluminium industry in developing countries and the possibilities of its expansion in the future. The capacity for alumina in the developing countries in 1966 was 3.46 million short tons, that is, 26.6 per cent of the total world capacity (excluding the capacity of centrally planned economy countries) of 13 million tons. It is estimated that by 1971 the capacity for alumina in the developing countries will increase to 5.5 million short tons, that is, 33 per cent of the total capacity as mentioned above of 16.7 million short tons. The export trade of the developing countries in bauxite, alumina and aluminium has also been indicated.

The paper describes the development of the alumina industry in India from its inception 25 years ago, its rapid growth during the last ten years and further expansion envisaged. The installed capacity for alumina in India by the end of this year will be 257,000 tons and is likely to increase to 889,000 tons by 1974. The types of bauxite used and the technology of the processes employed have also been given.

The paper further deals with the experience gained in the expansion of alumina industry in India with respect to design of the plant, availability of equipment; pilot plant study of bauxite, space; installation of equipment, and training of technical and operating personnel. These are briefly summarized below.

Alumina industry in India has been developed in technical collaboration with aluminium producing countries from the advanced countries. India thus got the benefit of the latest know-how from the advanced countries. Indian engineers are now playing a major role in the design and technology of the new plants and expansions. Most of the equipment required for the construction of an alumina plant is now manufactured in the country. It has been experienced that the data collected from laboratory scale tests on bauxite do not give an entire picture to the designer. It is therefore necessary that before taking up the design of a new plant or expansion, composite samples of bauxite should be collected from the mines and their behaviour studied in a pilot plant.

In an alumina plant which is initially designed for small capacity, adequate space should be provided for future expansion to raise the capacity to an economic size. In order to avoid loss of production from the existing plants, the units for expansion should be built up first and inter-connexions with the older units made by planning a schedule of shut-down of the latter for change-over and simultaneous maintenance. It is also felt that during the erection of the expansion capcity, supervision requires strengthening to ensure that the construction crew does not hamper the operation of the old plant. It is essential that technical and operating personnel should receive intensive training before the start-up of a new plant.

It is felt that an annual capacity of 200,000 to 250,000 tons is an economic size for an alumina plant. The cost of investment for such a plant is about $US 125 per annual ton. Finally it is concluded that there is great scope for the expansion of alumina and aluminium industry in the developing countries.

Contents

I. Aluminium: the metal of the age

1. During the latter part of the nineteenth century aluminium was only a costly curiosity of emperors and scientists. During the last three-quarters of a century, however, aluminium has made gigantic strides to establish itself not only as an essential and inexpensive industrial metal of today but also as a metal of challenge in the markets of the future.

2. The reason behind this grand transformation of aluminium is its unique characteristics developed through long years of research and engineering. Some of those are lightness, high strength/weight ratio, good corrosion resistance, non-magnetic and non-sparking properties, non-toxic character, good formability (including high malleability and ductivity), high thermal and electrical conductivity, extreme brightness and high reflectivity for radiant heat and light. Few materials, if any, possess a greater range of utilitarian characteristics than aluminium. The price stability of aluminium in comparison with other major metals over long periods is also remarkable. During the period 1939 to 1960 the international price of aluminium increased by 92 per cent only, while that of copper, lead and zinc increased by 390 per cent, 380 per cent and 540 per cent respectively.

3. Endowed with so many advantageous characteristics, aluminium lends itself to effective and economic use in a wide range of markets such as electrical cables and appliances, building and construction, transportation, aircraft, domestic kitchen ware, canning and packaging, steel deoxidizing, defence and ordnance, aluminizing paints, coinage, miscellaneous equipments (for food, textiles, chemicals, sewage, mining, nuclear applications etc.). Aluminium today has become the leader of the non-ferrous metals and has consolidated its position in the industrial world by successfully competing with and displacing numerous conventional metals and materials from their established markets.

4. Aluminium industry is thus playing an increasingly important role in the industrial and technological revolution of the modern world. In the developing countries, it assumes even greater significance. A rapidly developing country normally needs to double its power producing capacity almost every five years. The electrical industry, in turn, needs large amounts of copper. Many of the developing countries do not have deposits of copper ore at all, whereas others like India have rather inadequate ore reserves of copper. Some of these countries are, however, endowed with sizeable bauxite deposits and sufficient low-cost power potential. In such a situation, production of alumina and aluminium metal would assist greatly the economic and industrial progress of such developing countries.

II. World demand and production of aluminium

5. Commercial production of aluminium started only towards the end of the nineteenth century in the United States. In 1886 the total output of aluminium in the world was only 17 tons. Since the beginning of the twentieth century the production of aluminium has more than doubled in every decade in free enterprise economy countries. Their production was 0.25 million tons in 1928, 0.72 million tons in 1940, 1.77 million tons in 1952, 4.78 million tons in 1964 and over six million tons at present. The total world production is now about 7.5 million tons. The world consumption (1)1/ of aluminium outside the centrally planned economy countries of Eastern Europe and Asia rose on an average by 8.6 per cent a year from 1952 to 1960 and by 10.1 per cent per year from 1960 to 1964. The rate of consumption during 1964 to 1975, is expected to increase within the same limits, that is, between 8 to 10 per cent per year.

6. In order to meet the increasing demand of aluminium all over the world, aluminium companies are engaged in massive expansion programmes. In 1966, rated capacities of primary aluminium plants in countries other than those with centrally planned economies were 5.4 million tons; after the planned expansions this capacity would reach 7.2 million tons in 1971. The number of countries producing aluminium increased from seventeen in 1959 to twenty in 1965 and it is expected (based on announced expansions) that by 1971, there will be at least 28 countries in the aluminium field. The rated capacities (2) for production of primary aluminium in countries other than those with centrally planned economies in 1966 and as planned by 1968 and 1971 are given in table 1.

III. Bauxite, alumina and aluminium industry in the developing countries

Bauxite

7. World reserves of high-grade bauxite (3) in 1963 were estimated at 5,760 million tons with an additional 8,740 million tons of lower grade resources. The main deposits are in the United States and Mexico in North America; Jamaica in the Caribbean area; Guyana, Brazil and Surinam in South America, Guinea and Ghana in Africa, Hungary, Yugoslavia, France and Greece in Europe, India and China (Mainland) in Asia, and Australia.

8. The combined reserves of the over-all Caribbean area (4) are estimated to be 1,200 million tons. The bulk of the African (4) reserves of bauxite are in Guinea, estimated to be in excess of 2,000 million tons. The data for production of bauxite in the world excluding centrally planned economy countries of Eastern Europe and Asia for 1953-1955, 1960 and 1964 are given in table 2. In 1964 the production of bauxite

1/ Numbers in parentheses indicate references.

in the developing countries was 20.6 million tons against the total production[1/] of 26.9 million tons (excluding the production of centrally planned economy countries). The main producers are Jamaica, Surinam, Guyana and Guinea. The output of bauxite in the developing countries has been between 70 to 80 per cent of the world production during the last ten years. Barely one fifth of this bauxite is converted into alumina in these countries and the rest is exported to the developed countries.

Table 1

Rated capacities of primary aluminium plants in countries other than those with centrally planned economies in 1966 and planned expansion by 1968 and 1971

(in short tons)

	1966	1968	1971
United States	2,767,500	3,137,400	3,510,900
Canada	886,500	971,100	1,057,500
Mexico	19,800	39,600	64,400
Brazil	39,500	63,800	102,200
Surinam	29,700	59,400	59,400
Venezuela	-	9,900	9,900
Cameroon	51,500	51,500	51,500
Ghana	-	103,500	103,500
United Arab Republic	-	-	39,600
South Africa	-	-	41,600
Formosa	19,800	33,300	33,300
India a/	93,700	141,300	270,000
Japan	340,700	434,700	516,600
Korea	-	-	13,500
Australia	88,200	103,500	155,300
Austria	86,700	86,700	95,700
France	352,800	352,800	352,800
Germany (Federal Republic of)	256,500	256,500	256,500
Iceland	-	-	29,700
Italy	131,800	131,800	230,800
Netherlands	31,700	59,400	59,400
Norway	370,600	478,800	507,600
Spain	65,000	104,400	115,200
Greece	61,900	72,000	79,200
Sweden	32,000	50,000	50,000
Switzerland	61,400	61,400	61,400
United Kingdom	37,100	37,100	37,100
Yugoslavia	50,500	50,500	50,500
Total	5,874,900	6,890,400	7,955,100

a/ Figures for India have been changed.

Table 2

Production of bauxite (gross weight)
(in thousands of metric tons)

	1953-55 average	1960	1964	1965
Developing countries:	9,491	17,934	20,616	
Guyana a/	2,377	3,422	2,508	2,873
Guinea	417	1,378	1,433	1,600
Jamaica	2,015	5,841	7,824	8,705
Surinam	3,253	3,455	3,996	4,360
Others	1,429	3,838	4,855	
Developed countries:	3,854	5,398	6,270	
Australia	6	71	902	
France	1,312	2,067	2,436	2,651
United States a/	1,816	2,030	1,632	1,683
Others	720	1,230	1,300	
Total b/	13,345	23,332	26,886	
Developing countries (per cent)	(71.1)	(76.9)	(76.7)	
Developed countries (per cent)	(28.9)	(23.1)	(23.3)	

a/ Data represent dried equivalent of crude ore.

b/ Excluding the centrally planned economy countries of Eastern Europe and Asia.

Alumina

9. Most of the developing countries that have bauxite deposits now manufacture alumina, but only a small portion of the alumina is used for the manufacture of aluminium in the country of origin; the balance is exported to the developed countries. The alumina (2) capacities of various countries in 1966 and plans for 1967 to 1971 are given in table 3. The capacity for alumina in the developing countries in 1966 was 3.46 million short tons, that is, 26.6 per cent of the total world capacity of 13 million short tons (exclusive of centrally planned economy countries). By 1971 it is estimated that the capacity for alumina in the developing countries will increase to 5.5 million short tons, that is, 33 per cent of the total capacity of 16.7 million short tons. Jamaica is the largest alumina producer with a capacity of 820,000 short tons per year and this is likely to be more than doubled by 1971. Among the other developing countries, Surinam in South America and Guinea in Africa have built up large alumina capacities. Guyana, Brazil, India and Yugoslavia are planning substantial expansion in their alumina capacity (table 3).

Table 3

Estimated alumina capacities, 1966-1971
(excluding centrally planned economy countries)
(in thousands of short tons)

	1966	1967	1968	1969	1970	1971
United States	5,400	6,100	6,100	6,100	6,100	6,100
Canada	1,100	1,100	1,100	1,100	1,100	1,100
Total North America	6,500	7,200	7,200	7,200	7,200	7,200
Virgin Islands	200	200	200	200	200	200
Jamaica	820	820	900	1,470	1,890	1,890
Total Caribbean	1,020	1,020	1,100	1,670	1,090	2,090
Brazil	60	85	130	130	130	130
British Guyana	350	630	630	630	630	630
Surinam	790	790	790	790	790	790
Total South America	1,200	1,505	1,550	1,550	1,550	1,550
Guinea	540	540	540	540	540	540
Total Africa	540	540	540	540	540	540
Formosa	40	70	70	70	70	70
India a/	160	290	290	360	460	540
Japan	700	700	730	750	780	780
Korea	-	-	-	27	27	27
Australia	420	1,020	1,020	1,020	1,020	1,020
Total Asia and Oceania	1,320	2,080	2,110	1,227	2,357	2,437
France	920	970	970	970	970	970
Germany (Federal Republic of)	570	570	570	570	570	570
Greece	200	200	200	200	200	200
Italy	300	300	300	300	300	300
Netherlands	-	-	-	-	-	-
Norway	17	17	17	17	17	17
Sweden	8	8	8	8	8	8
United Kingdom	110	110	110	110	110	110
Yugoslavia	230	230	230	230	690	690
Total Europe	2,355	2,405	2,405	2,405	2,865	2,865
Grand total	12,935	14,750	14,905	15,592	16,602	16,682

a/ Estimated figures for India have been changed.

Aluminium

10. The availability of an abundant supply of cheap electric power, finance and general industrial development are the major factors that govern the growth of the aluminium industry in a country and for these reasons, the production of aluminium has so

far taken place predominantly in developed countries. The world production (6) of primary aluminium, excluding the centrally planned economy countries of Eastern Europe and Asia, during 1953-1955, 1960 and 1964 is shown in table 4. The production of aluminium in the developing countries in 1964 was 188,000 tons only and amounted to hardly 4 per cent of the world production. Until 1965 primary aluminium was produced only in five developing countries (6) - Brazil, the Cameroons, Yugoslavia, India and China (Taiwan) - with a total capacity of about 225,000 tons. At the end of 1965 an aluminium smelter with a capacity of 50,000 tons per year started operation in Surinam. Other developing countries such as Venezuela, Ghana, United Arab Republic, South Africa and Korea are also establishing aluminium smelters as shown in table 1. The Tema smelter in Ghana with an initial capacity of 100,000 tons per year is scheduled to start production this year. By 1971 the aluminium capacity in the developing countries is likely to increase to 0.92 million short tons, that is, 11.5 per cent of the estimated other than centrally controlled economies' capacity of 7.96 million short tons.

Table 4

Production of primary aluminium
(in thousands of metric tons)

	1953-55 average	1960	1964	1965
Developing countries	19	113	188	
Developed countries:	2,355	3,503	4,613	
Australia	1	12	80	
Canada	520	691	764	
France	120	239	316	340
Germany (Federal Republic of)	124	169	220	238
Japan	52	133	265	292
Norway	62	165	262	276
United States	1,294	1,828	2,316	2,499
Others	182	266	390	
Total a/	2,374	3,616	4,801	
Developing countries (per cent)	(0.8)	(3.1)	(3.9)	
Developed countries (per cent)	(99.2)	(96.9)	(96.1)	

a/ Excluding countries of Eastern Europe and Asia with centrally planned economies.

11. In most of the developing countries the use of aluminium is still in its early stages and the consumption is relatively very small as compared to that in more advanced countries of the world. For example, the per capita consumption (7, 8)

of aluminium in India is 0.2 kg, in Mexico 0.31 and in Brazil 0.46 kg, as compared to 15.8 kg in the United States, 9.1 kg in Switzerland, 8.5 kg in the Federal Republic of Germany, 7.7 kg in the United Kingdom and 4 kg in Italy and Japan. The consumption of aluminium in the developing countries (6) increased at an average rate of 23.8 per cent per year during 1952 to 1960 and 14 per cent per year during 1960 to 1964. Despite this rapid growth, the total consumption of aluminium in these countries by 1964 was under 250,000 tons, representing only 5 per cent of the world production as shown in table 5.

Table 5

Consumption of aluminium
(in thousands of metric tons)

	1953-55 average	1960	1964
Developing countries	60	156	239
Developed countries:	2,204	3,094	4,540
United States	1,407	1,541	2,635
Canada	79	110	160
European Economic Commission	312	703	889
United Kingdom	235	360	359
Japan	45	151	262
Others	126	229	335
Total a/	2,264	3,250	4,779
Developing countries (per cent)	(2.7)	(4.8)	(5.0)
Developed countries (per cent)	(97.3)	(95.2)	(95.0)

a/ Excluding the centrally planned economy countries of Eastern Europe and Asia.

Exports

12. There is a considerable surplus of bauxite and alumina in most of the developing countries, while the large aluminium producing countries such as the United States, Canada, Norway, Sweden, the United Kingdom, the Federal Republic of Germany and Japan have either insignificant or no bauxite reserves. Consequently the exports of bauxite and alumina from the developing countries to the developed countries are expected to continue although a shift towards a relatively greater export of alumina will take place. Exports of alumina from these countries have more than trebled during 1959 to 1964. During 1964 to 1975 bauxite exports (1) from the developing countries are expected to rise from about 16 million tons to about 24 million tons while

alumina exports are expected to increase from 1.5 million tons to about 8 million tons or amounting in value to an increase of more than $US 450 million at 1964 prices. Exports of aluminium from developing countries have also risen from 49,000 tons in 1959 to 73,000 tons in 1964 and are further expected to rise to about 300,000 tons by 1975 representing an increase of about $US 90 million at 1964 prices. Thus the value of exports from developing countries would increase with a shift in exports from bauxite to alumina and aluminium, as well as the total volume of exports.

IV. Alumina industry in India

Present and future status

13. In view of the inadequate ore deposits of other non-ferrous metals like copper, lead and zinc, and the potentialities of aluminium to replace copper and other non-ferrous metals, the demand for aluminium has increased at a very rapid rate in India during the last 15 years. The consumption of aluminium has grown from 11,000 tons in 1950 to 47,500 tons in 1960, 102,000 tons in 1965 and 130,000 tons in 1967. Productio of aluminium has increased in the corresponding period from 3,600 tons in 1950 to 18,2 tons in 1960, 68,000 tons in 1965, and about 100,000 tons in 1967. The shortfall is met by imports. According to current estimates, the demand for aluminium is likely to rise to 250,000 tons by 1970-1971 and 450,000 tons by 1975-1976, and most of it is expected to be supplied from domestic production.

Expansion of capacity

14. India is endowed with sizeable deposits of bauxite totalling over 250 million ton out of which over a 100 million tons are of metal grade (above 45 per cent alumina). In order to meet the growing demand for aluminium in the country, a substantial expansion of the capacity of alumina and aluminium industries has been planned. The capacity for production of alumina during 1967 and as planned by 197[illegible] is given in table 6. The production of alumina in India has increased from about 4,000 tons in 1943 to 150,000 tons in 1966. The installed capacity for alumina will be 257,000 tons by the end of 1967. With the implementation of the proposed expansions at Renukoot, Mettur and the new units at Belgaum, Korba, Koyna and in Gujarat, the total capacity by 1974 is likely to be 889,000 tons. A map of India showing the location of bauxite deposits, power stations above 100,000 mega watts, alumina plants and aluminium smelte is given in figure 1.

15. In India fortunately most of the bauxite deposits are reasonably near centres of power generation and therefore a trend towards building integrated alumina-aluminium facilities has developed. Accordingly all alumina plants in India except the one of M/s. Indian Aluminium Company at Muri (Bihar) are part of the aluminium smelter complexes. This trend is likely to continue in the future.

Table 6

Alumina production capacity in India
(in tons per year)

Company	Plant location	Installed 1967	Expansion or new units: Approved	Expansion or new units: Likely date of implementation
Aluminium Corporation of India	Asansol (West Bengal)	15,000	10,000	1970-1971
Indian Aluminium Co.	Muri (Bihar)	72,000	-	
Indian Aluminium Co.	Belgaum (Mysore)	-	72,000	1971
Hindustan Aluminium Corporation	Renukoot (U.P.)	150,000	120,000	1970-1971
Madras Aluminium Co.	Mettur (Madras)	20,000	30,000	1970-1971
Bharat Aluminium Co.	Korba (M.P.)	-	200,000	1971-1972
Bharat Aluminium Co.	Koyna (Maharashtra)	-	100,000	1972-1973
Gujerat Mineral Development Corporation	Gujerat	-	100,000	1972-1974
	Total	257,000	632,000	
	Grand total	889,000		

Technology of alumina manufacture in India

The Bayer process

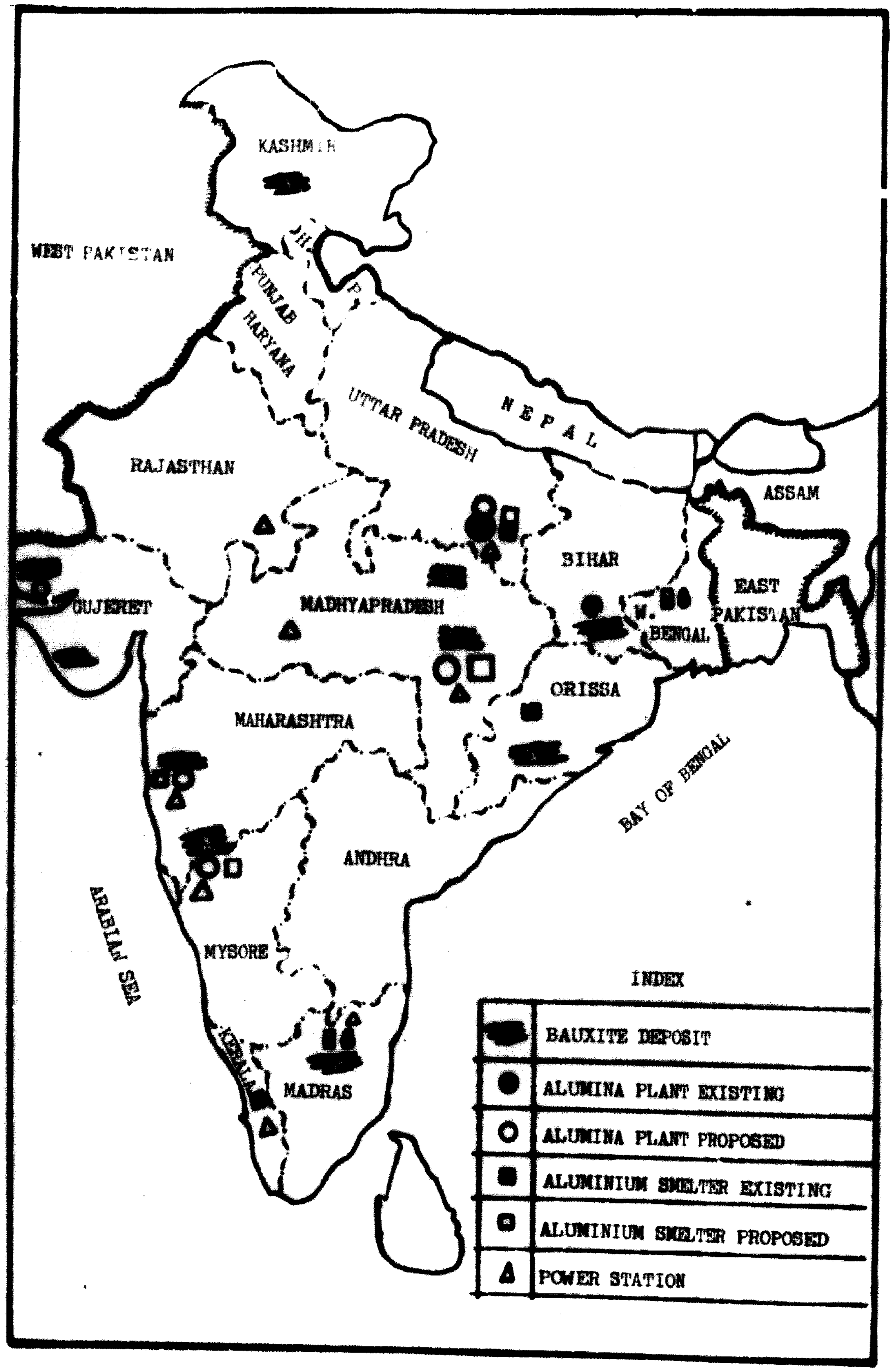
16. Practically all the alumina is produced in India by the Bayer process. The essential features of this process have remained the same since it was first discovered by Karl Bayer in 1888. It involves the digestion of bauxite with caustic soda to extract aluminium trihydrate leaving behind the impurities as an insoluble residue, the precipitation of aluminium trihydrate from alkali solution by dilution and cooling, and finally calcination of aluminium trihydrate to produce anhydrous aluminium oxide. The basic reactions are:

Digestion

$$Al_2O_3 \cdot 3H_2O + 2\ NaOH = 2\ NaAl_2O_2 + 4H_2O$$

Figure 1

Aluminium industry in India



Precipitation

$$2NaAlO_2 + 4H_2O = Al_2O_3.3H_2O + 2NaOH$$

Calcination

$$Al_2O_3.3H_2O = Al_2O_3 + 3H_2O$$

Bauxite is generally a mixture of the trihydrate ($Al_2O_3.3H_2O$) and monohydrate ($Al_2O_3.H_2O$) of aluminium together with certain impurities mainly iron (Fe_2O_3), titanium (TiO_2), silica and vanadium (V_2O_5). The analysis of Indian bauxites from various deposits is given in table 7. Aluminium hydrates differ not only in their X-ray spectra but also in their chemical and physical properties. Aluminium trihydrate is soluble in lower concentrations of caustic soda (150 g/l expressed as soda) and at a lower temperature (140° C). Bauxite deposits in Saurashtra contain chiefly the trihydrate.

Table 7
Analysis of Indian bauxite

	Lohardaga (Bihar)	Belgaum (Mysore)	Amarkantak (M.P.)	Yercaud (Madras)	Saurashtra (Gujerat)	Kashmir
Al_2O_3	53-58	53-58	53-58	42-47	58-62	70-80
Fe_2O_3	8-10	6-8	5-7	7-9	2-4	1-3
TiO_2	8-10	6-8	5-7	Traces	1-3	1-3
SiO_2	1-4	1-4	1-3	15-20	1-2	5-10
$R.SiO_2$	1-3	1-3	-	2-4	0-1	-
Loss on ignition	25	27	27	27	23	12

17. The alpha monohydrate dissolves at a higher concentration of caustic soda (200 g/l expressed as Na_2CO_3) as well as a higher temperature (240° C). The bauxites of Bihar and Madhya Pradesh are a mixture of trihydrate and alpha monohydrate, the latter ranging from 10 to 25 per cent. The bauxites of Kashmir contain chiefly diaspore or beta monohydrate which is not soluble under the conditions of operation of the Bayer process. Indian bauxites in general contain a high percentage oftitania (TiO_2) and 0.15 to 0.20 per cent of vanadium pentaoxide (V_2O_5). As both these impurities have an adverse effect on the electrical conductivity of aluminium metal, special precautions are taken in the process to separate them from the sodium aluminate liquor.

The double digestion process

18. In India the expansion in alumina capacity has been accompanied by developments in the technology of the process also. In their alumina plant at Muri, M/s. Indian Aluminium Company has adopted recently a double digestion process for Lohardaga bauxite. At first the trihydrate is extracted from bauxite under less severe conditions, that is, a caustic soda concentration of 150 g/l as soda and a temperature of below 150° C. The mud left behind containing the alpha monohydrate is digested under relatively severe conditions of digestion (caustic soda 500 g/l as soda, and 200° C). In this process, the efficiency of extraction of alumina is about 92 per cent. A schematic flow sheet of the process adopted at Muri is given in figure 2.

Digestion - Hindustan Aluminium Corporation

19. M/s. Hindustan Aluminium Corporation is using bauxite mainly from Lohardaga and partly from the Amarkantak area and has adopted a single stage digestion process. The digestion of bauxite is carried out in autoclaves in caustic soda with a concentration of 200 g/l expressed as Na_2CO_3 at a temperature of 240° C and a pressure of 37 kg/sq cm. In the precipitation division, the concentration of sodium aluminate liquor is brought to 180 g/l and the temperature of the liquor after precipitation is brought to 60° C. The efficiency of the extraction is nearly 96 per cent. A flow sheet of the process is given in figure 3.

Digestion - Madras Aluminium Company

20. M/s. Madras Aluminium Company is using bauxite from Yercaud (Shevaroy hills) and Saurashtra in the proportion of three to one. They are also using a single stage digestion process which is carried out at a caustic soda concentration of 320 g/l expressed as Na_2CO_3, a temperature of 140° C, and a pressure of 5 kg/sq cm. The efficiency of extraction is about 90 per cent.

Digestion - Aluminium Corporation of India

21. M/s. Aluminium Corporation of India is using bauxite from Lohardaga in Bihar. The bauxite is digested at a caustic soda concentration of nearly 500 g/l expressed as Na_2CO_3, a temperature of 175 to 180° C and a pressure of 8 kg/sq cm. The efficiency of extraction is about 87 per cent.

V. India's experience in the expansion of the alumina industry centre

22. The first plant for the manufacture of alumina in India was started in 1942 at Asansol by the Aluminium Corporation of India. The plant was designed by Dorr Oliver for a capacity of about 5,000 tons alumina per annum. As no operating data were available, experiments were conducted in the plant research laboratory and the operating conditions were stabilized gradually. Subsequently, the plant was expanded to a capacity of 15,000 tons with the technical assistance of the Swiss Aluminium Company of Switzerland.

Figure 2

Schematic flow sheet
(Representing Bayer process for making alumina
at Indian Aluminum Co. Ltd., - Muri)

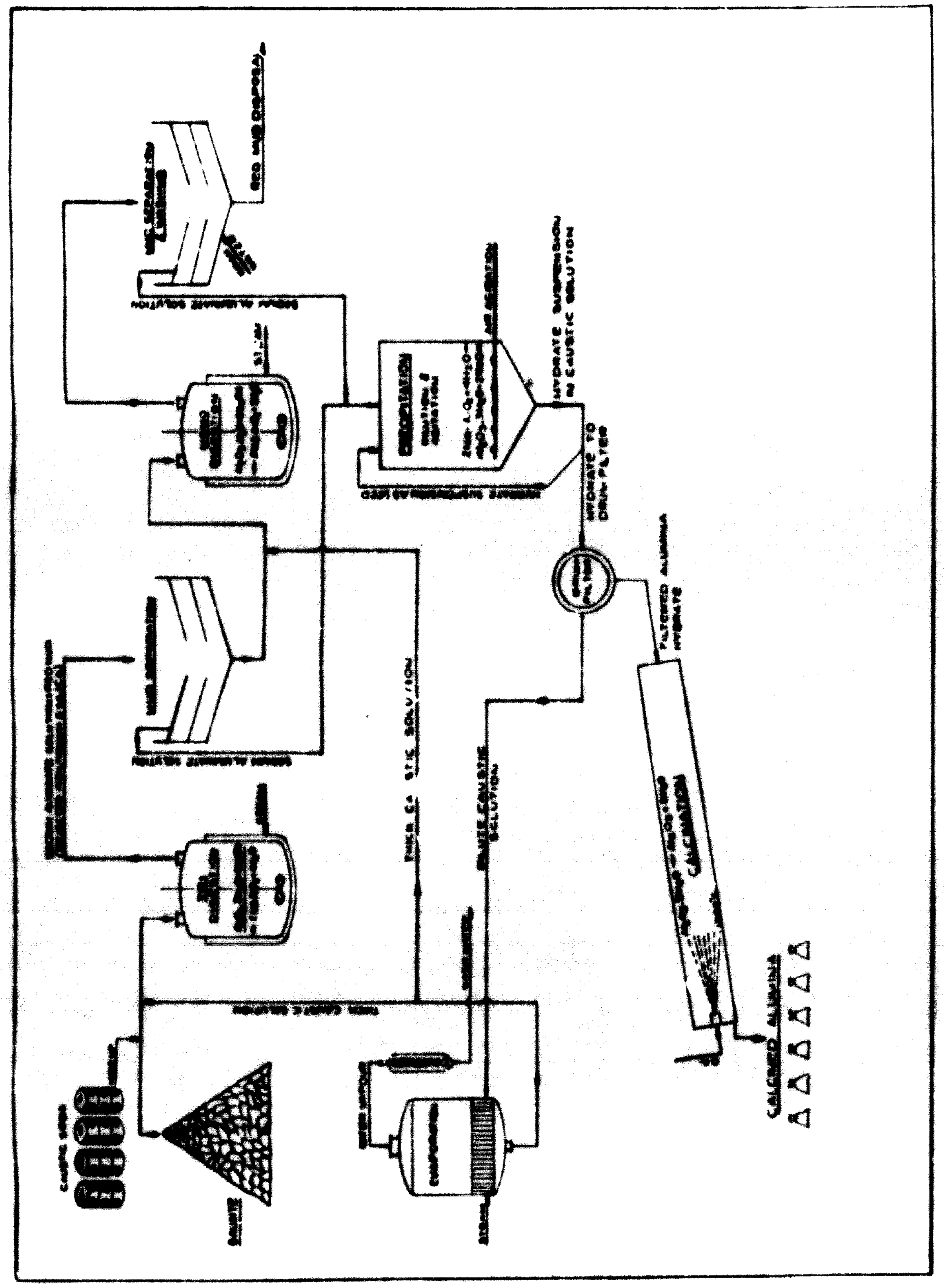
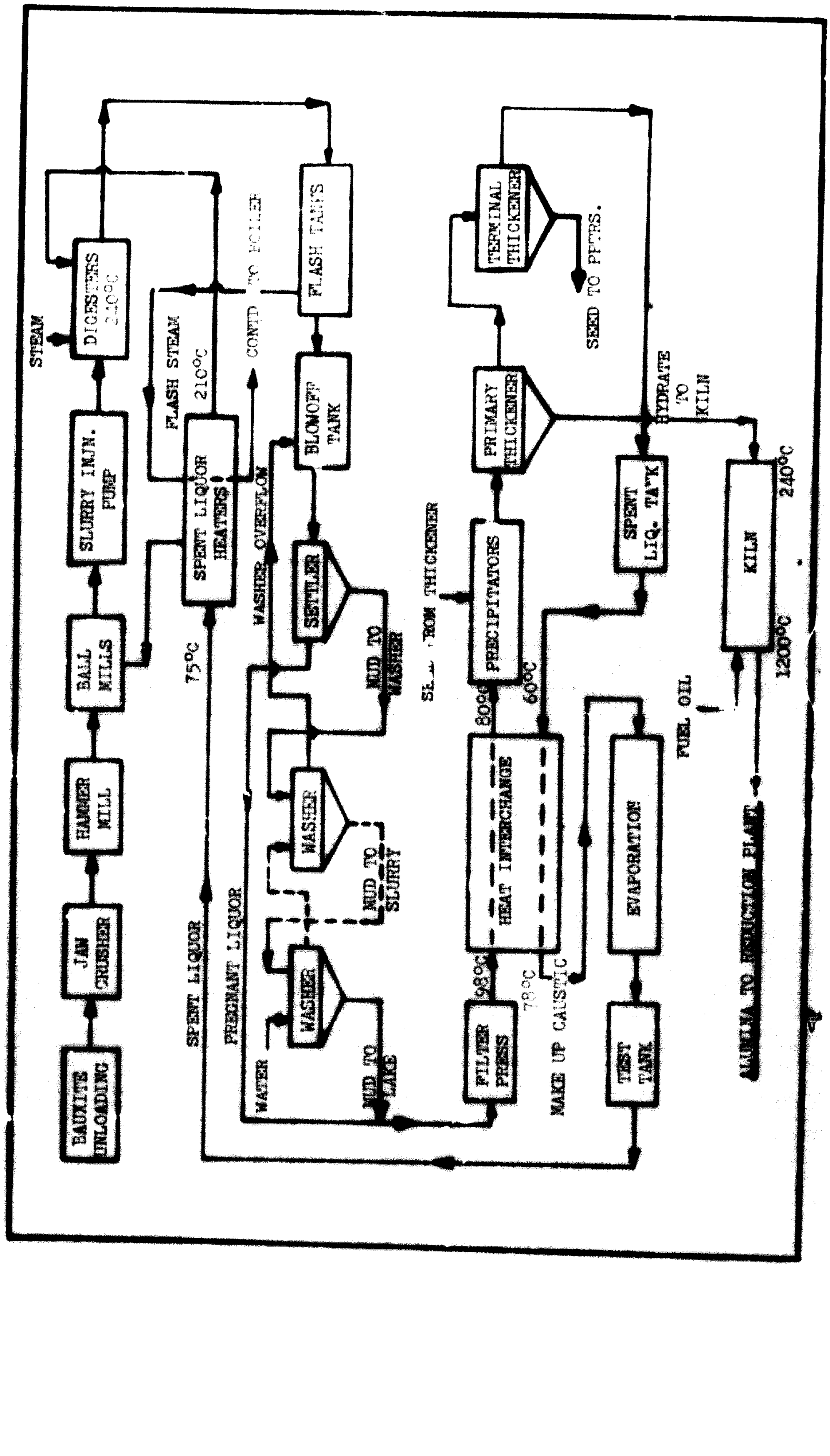


Figure 3

Alumina plant flow sheet
Single digestion



23. The second plant was built in 1948 by the Indian Aluminium Company at Muri with technical and financial collaboration of the Alcan Aluminium Ltd. (Canada). The plant was designed and built by Canadian experts with an annual capacity of 5,000 tons. The plant has been expanded in stages and finally brought up to a capacity of 72,000 tons per year in 1965. Hindustan Aluminium Corporation installed a 40,000-ton alumina plant in 1962 at Renukoot in collaboration with Kaiser of the United States. The expansion of this plant to a capacity of 150,000 tons is almost complete. The Madras Aluminium Company installed at Mettur a 20,000-ton alumina plant in early 1965 in collaboration with Montecatini of Italy and the plant is now under expansion to an annual capacity of 50,000 tons.

24. The aluminium industry in India is only 25 years old. Initially its progress was very slow but it has gained momentum in the last ten years. The bulk of India's capacity for production of alumina has been built up during the period 1960 to 1967. During this short period, India has gained varied experience in the expansion of older plants as well as in the installation of large new plants. The important features of this expansion have been described briefly below.

Design aspects

25. All the alumina plants in India have been built in technical collaboration with aluminium producing companies from advanced countries. The designs of plantr including the drawings were thus received mostly from the overseas technical consultants. This procedure had the advantage that although the aluminium industry in India was in the infant stage, the country received the benefit of the latest know-how from advanced countries. These designs, however, had to be modified and sometimes completely revised in order to treat successfully the local bauxite. Indian engineers are now playing a major role in the design and technology of new plants and expansions.

Equipment availability

26. In the past, most of the equipment for the alumina plants had to be imported. Today the situation has chaanged enormously. Fabrication facilities have developed considerably and most of the equipment like crushing and grinding mills, autoclaves, thickners, filters, decomposers, evaporators, boilers, and calciners are available locally. Only some components and equipment of intricate and sophisticated design and some control instruments still have to be imported. Some of the equipment fabricated indigenously has been used in the expansion of alumina plants implemented recently. Though there have been some teething troubles and breakdowns, these have been overcome successfully.

Space

27. It has been the experience that alumina plants, though designed mostly in the initial stages for smaller capacities, have to be expanded substantially in the future. In India when the first few plants were established, such expansions were not anticipated in the initial stages and consequently sufficient space was not provided to accommodate the later expansion. For economic reasons, it is not possible to discard the old units. Therefore after expansion, these plants have become very congested, leaving very little room for operation and maintenance work.

28. Generally, the main units in an alumina plant can give an output of 10 per cent or more than the rated capacity, if some balancing plants are added. However, unless provision is made for this purpose in advance, the extra production involving only limited additional investment cannot be accomplished. It is therefore necessary that in developing countries where the land is not expensive, adequate space for expansion, be provided not only for the alumina plant, but also for red mud ponds, cooling towers, bigger storage and handling facilities for bauxite, alumina, coal, oil etc. as well as for housing.

Pilot plant study of bauxite

29. Characteristics of bauxite such as its hardness, quantity of sandy material, settling properties of red mud, and presence of organic material change from place to place. It has been experienced by one of the plants that the data collected on laboratory scale tests do not give the entire picture to the designer, with the result that many problems arise during the operation of a plant when it is erected. If the hardness of bauxite is not assessed properly, the design of the grinding circuit would be inadequate to yield the desired amount of bauxite ground to the required degree of fineness. The presence of an appreciable quantity of sandy material in the bauxite gives a blasting effect in the high-pressure pipe lines, elbows, tees etc. and creates erosion problems, thereby necessitating shut-down of the plant from time to time for maintenance work. If provision is not made for the removal of organic matter in bauxite, it retards the precipitation process as well as the filtration operation and thereby affects production to a great extent.

30. It is, therefore, essential that before taking up the design of a new alumina plant or its expansion, composite samples of bauxite should be collected from the mines and their behaviour studied in a pilot plant.

Installation of equipment for expansion

31. During the expansion of an existing alumina plant, the operation of the old plant and the construction of new units go on side by side and some disturbance is bound to occur in the normal operation of the old plant. The schedule of working can, however, be planned in such a manner as to cause minimum loss of production. In India, the units for expansion of capacity were installed first and interconnexions with the older units were made by planning a schedule of shut-down of the latter for change-over and simultaneous maintenance.

32. It is also felt that during erection of the expansion capacity, supervision requires strengthening to ensure that the construction crew does not hamper the operation of the old plant.

Personnel training

33. The experience in India shows that training of technical and operating personnel is very vital wherever new facilities are installed or old plants are expanded incorporating new production techniques. This problem was satisfactorily solved by training initially a handful of Indian technicians abroad as well as by bringing overseas technicians to India for erection as well as initial start-up, so that local personnel could be trained by attachment of trainees with them. Evening classes were conducted for training supervisors. It has now been established that months of intensive in-plant training must precede the start-up of a new plant. The start-up of the new plant should preferably be in stages and blank trials, wherever feasible, may be carried out to train the personnel.

VI. Capacity of the plant and investment

34. The estimates of investment expenditure for recently built alumina plants (9) of various capacities are given below:

Annual capacity (tons)	Investment expenditure per ton of annual capacity (in $US)	
	Trihydrate bauxite	Monohydrate bauxite
100,000	170–210	190–230
165,000	140–180	160–200
330,000	110–150	140–180

The data refer to complete plants within battery limits and exclude bauxite mining and related facilities, town-site power generation, transport facilities outside plant, caustic soda or soda ash production facilities, limestone mining and treatment.

An annual capacity of 200,000 to 250,000 tons is considered an economic size for an alumina plant. The investment cost of a 200,000-ton alumina plant (10) on St. Croix Island in the Caribbean area recently built by the Harvey Aluminium Corporation has been reported to be $US 125 per annual ton.

35. In a developing country, the capital cost of installing an alumina plant will be somewhat higher than that in a developed country on account of the additional cost of transportation of imported equipment and material as well as the need for additional investment on the anciliary facilities which are usually available in developed countries. Payment for know-how as well as for start-up teams are also involved. If local circumstances do not permit the installation of a 200,000-ton capacity alumina plant, it is possible to make a beginning with a smaller capacity of the order of 50,000 to 60,000 tons, but in this case, the investment per ton-year as well as the cost of production would be somewhat higher. This handicap is overcome usually by maintaining a higher price for internal consumption by controlling or preventing imports into the country.

36. From the discussions in the paper, it is concluded that there is a vast scope for the development of alumina and aluminium industry in the developing countries having bauxite deposits and cheap power potential.

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