EXTRACTION AND REFINING OF ALUMINIUM

MAHENDRA CHANDRA DUBE

The Aluminium Corporation of India Ltd., Jaykaynagar

Abstract

The paper deals with the important sources of bauxite in India. The quartzitic bauxite of Madras has been discussed in detail. Digestion tests of Bihar bauxite and the Bayer's process are described. The consumption of raw materials for the manufacture of alumina and aluminium are given.

Binding property of pitch and the types of electrodes are mentioned. The various theories of electrolytic reactions are described. The types of furnaces and their advantages and disadvantages are described. The refining of aluminium metal and some of its practical operating data are given. Prospects of this industry have been examined.

Introduction

ALUMINIUM metal has been known only for the last hundred and thirty years. The industrial history of aluminium starts from 1886 when Paul Heroult in France and Charles Martin Hall in U.S.A. independently discovered the method that could produce aluminium on commercial scale and today the production of aluminium is second only to steel among the industrial metals in the world.

As the metal has a great affinity for oxygen, it was impossible to separate aluminium from its oxygen by smelting with carbon or other common agents. The chemical methods discovered by Deville and others were very tedious and expensive and tremendous advance was made only in 1886 by the discovery of the electro-chemical process by Heroult and Hall, as already mentioned. They discovered the mineral cryolite which has its largest deposition in Greenland. This mineral, when in molten condition, easily dissolves alumina and the metal can be separated from its oxygen by passing a current through the molten bath containing alumina (FIG. 1).

Aluminium really began to achieve industrial importance in the period 1900-1914 and the credit goes to the German chemist Wilm who in 1907 discovered the theory of age-hardening. He had been trying to harden an aluminium alloy containing copper and magnesium by heating it to 500°C. and quenching in water. The experiment was unsuccessful as the alloy was still soft. But he found out after some days that the alloy had become harder and strength increased considerably. This chance discovery opened a new way for the development of aluminium alloys for structural materials with strength equivalent to steel.

In India the arrangement for the manufacture of aluminium metal from Indian bauxite began just prior to 1940 and the actual production of aluminium metal started
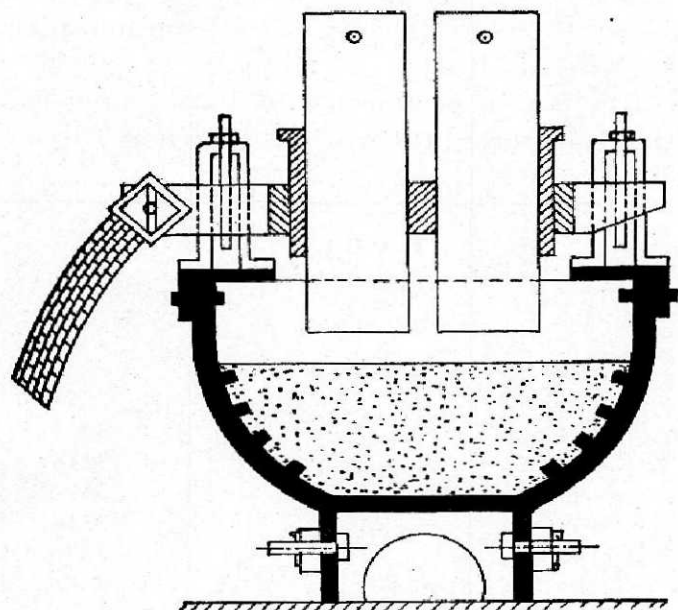

FIG. 1 — CELL BY HEROULT (1892)

TABLE 1

	1933	1939	1941	1943	1946	1947	1948	1949	1950	1951	1952
U.S.A.	39	149	280	835	375	518	565	603	718	836	—
Canada	16	75	194	450	160	269	320	369	397	445	—
Soviet Union	4	45	62	62	75	90	100	—	—	—	—
France	14	50	64	46	60	63	65	59	67	100	—
Italy	12	34	48	46	11	24	33	28	41	55	—
Norway	15	31	17	23	20	22	32	39	52	56	—
Great Britain	11	25	23	57	35	29	30	34	33	31	—
Switzerland	8	27	26	19	20	—	19	23	21	29	—
Austria } Germany }	19	199	234	250	{ — { —	8B —	13 8	16 31	20 30	14 81	—
Japan	—	23	65	133	3	2	10	23	28	37	—
Hungary	—	—	—	9	2	—	9	9	—	—	—
Sweden	—	3	2	—	4	4	4	4	4	7	—
Total world production	142	665	1220	1970	760	1070	1220	*1238	*1411	*1691	—

All figures in 1000 tons.   B: For W. Germany only.   *Figures excluding Soviet Union.

on 10 July 1944 when the first aluminium was tapped from the reduction furnaces of Messrs Aluminium Corporation of India Ltd. at Jaykaynagar. The factory was opened in 1937, but due to many unavoidable circumstances and troubles the production could not be started before July 1944. The Indian Aluminium Company, which started working in March 1942 at Travancore State, imported its alumina from Canada until 1947 when they established their alumina plant at Muri in Bihar.

The rise of production of aluminium of all the countries of the world is shown in Table 1.

TABLE 2

YEAR	PRODUCTION (in tons)
1944	1729
1945	2254
1946	3237
1947	3218
1948	3372
1949	3516
1950	3590
1951	3876
1952	3566

Table 2 indicates the average production of aluminium in India.

Refining of Bauxite for the Manufacture of Aluminium

India has abundant deposits of bauxite, roughly estimated to be 250 million tons, of all grades. The high-grade bauxite amounts to about 35 million tons distributed as under:

	Million tons
Madhya Pradesh	15·1
Orissa	8·58
Bihar	5·23
Bombay	3·23
Madras	2·00
Kashmir	1·00
Bhopal	0·25

Table 3 indicates the distribution of bauxite of 55·0 and below 55·0 per cent Al_2O_3 in different localities of these provinces.

Important analysis of the bauxite from the different quarries and localities are given in Table 4.

TABLE 3

Madhya Pradesh		HIGH GRADE ABOVE 55% Al_2O_3	LOW GRADE BELOW 55% Al_2O_3	TOTAL
Baragawan Hill		1200000	2800000	
Tikaria		2000000	5000000	
Katni		1500000	—	
Tikuria		600000	—	
Flag Staff Hill		1000000	3000000	
Sirouja		30000	3000000	
Jashpur		150000	—	
	TOTAL	6480000	13800000	20280000
Bombay				
Belgaum		75000	2000000	
Nange and Kiniya		200000	—	
Radhanagri		2000000	—	
Dhangarvadi		2000000	—	
Thana		750000	—	
	TOTAL	5025000	2000000	7025000
Bihar and Orissa				
Ranchi (scattered)		500000	110000	
Dudha Pat		250000	—	
Dudmatia Pat		500000	—	
	TOTAL	1250000	110000	1360000
Himalaya Region				
Kashmir (Jammu)		1000000	—	1000000
	TOTAL, all districts	13755000	15910000	29665000

Results of Bayer Extraction Tests of Quartzitic Type of Bauxite

Percentage of extraction of Al_2O_3 in bauxite: 94-95 per cent.

Na_2O loss in red mud per ton Al_2O_3 extracted: 82-95 lb.

Bauxite required per ton of Al_2O_3: 2·13-2·16 tons.

Although the soda loss in the production of alumina mostly depends on the percentage of SiO_2 present in the bauxite, it is interesting to note that the quartzitic type of bauxite showed Na_2O loss as low as 82-95 lb. per ton, i.e. about 4-5·0 per cent on Al_2O_3. It means that most of the silica is inert and does not react in the process. Further the SiO_2 content of most of these bauxites can be reduced by simple ore-dressing methods. The process involves only coarse crushing of the ore and screening out to —12 mesh fines:

ANALYSIS OF THE ORIGINAL SAMPLE

(*Data supplied by Mr. E. K. Dickins, Director, The Shevaroy Bauxite Production Co. Ltd.*)

L.O.I.	27·00%
Al_2O_3	52·54%
TiO_2	0·52%
Fe_2O_3	3·82%
T.SiO_2	16·11%
Reactive SiO_2	2·20%

—½ in. to 12 mesh portion		—12 mesh portion	
L.O.I.	30·30%	L.O.I.	18·80%
Al_2O_3	58·73%	Al_2O_3	37·10%
Fe_2O_3	2·59%	Fe_2O_3	6·88%
TiO_2	0·37%	TiO_2	0·89%
T.SiO_2	8·01%	T.SiO_2	36·30%
Reactive SiO_2	1·64%	Reactive SiO_2	3·50%

TABLE 4

LOCALITIES	Al_2O_3, %	SiO_2, %	TiO_2, %	Fe_2O_3, %	L.O.I., %
Bihar					
(a) Champi (Bagru Hill)	49·00	1·00	7·50	17·00	24·50
(b) Tori	55·00	0·90	10·00	7·00	27·10
(c) Pakhar	55·50	0·80	9·50	7·00	27·20
Katni	54·60	2·20	8·10	8·60	26·50
Madras Shevaroy Bauxite					
(a) Salem	52·70	1·30	1·35	15·97	29·04
(b) Quartzitic type of bauxite	49·25	T.SiO_2 23·10 R.SiO_2 2·47	0·16	2·10	25·26

Generally, the Indian bauxite takes nearabout 2-3 hr. for digestion with a 35°-40°Be sodium aluminate liquor of 1:4 molar ratio, but the Salem bauxite takes only 40 min. for digestion at atmospheric pressure and this bauxite is also different from other Indian bauxites as it contains low percentage of TiO_2. The period of digestion and the extraction of alumina depends on the structure of hydrate present in the bauxite. The crystalline hydrates differ among themselves not only in X-ray spectra and crystal habits but also in chemical properties. The two hydrates (alpha trihydrate and beta trihydrate) are readily soluble in acids and alkalies. The alpha monohydrate is relatively less soluble in acids and alkalies and requires a higher concentration of caustic, temperature and time of digestion to dissolve it. The beta monohydrate is hardly attacked under the same conditions.

Table 5 shows the study of red mud and soda losses obtained on the digestion of Bihar bauxite at different times of digestion. The bauxite value is calculated on 1:1·70 molar ratio.

Analysis of Digestion Liquor

Total Na_2O	306·9	g./litre
Na_2CO_3 as Na_2O	43·4	,,
Al_2O_3	102·0	,,
M/R	1: 4·05	

TABLE 5

PARTICULARS	$1\frac{1}{2}$ HR.	2 HR.	$2\frac{1}{2}$ HR.
Loss on ignition, %	16·10	15·08	15·02
SiO_2, %	3·84	4·02	3·92
Fe_2O_3, %	18·18	20·20	21·41
TiO_2, %	30·62	31·12	31·64
Al_2O_3, %	24·10	22·38	20·76
Total Na_2O, %	7·10	7·20	7·20
Red mud on bauxite, %	43·28	38·96	36·75
Al_2O_3 loss on bauxite, %	10·43	8·72	7·62
Recovery of Al_2O_3 on bauxite, %	43·88	45·59	46·69
Al_2O_3 extraction, %	80·79	83·94	85·96
Soda loss on bauxite, %	3·07	2·80	2·64

There are many processes for extracting the alumina from bauxite, but Bayer's process is generally employed throughout the world.

Bayer's Process

The bauxite lumps are crushed and ground in ball mill to 60-70 per cent —200 mesh Tyler screen. The ground bauxite is digested with concentrated caustic soda solution of 40°Be in autoclave at 7-8 atmospheric pressure. The aluminium hydrate gets dissolved in caustic soda to form sodium aluminate. The sodium aluminate liquor containing impurities like iron oxide, silica and titania is diluted to 20°Be and allowed to

settle. The clear sodium aluminate liquor is decanted and subjected to the process of hydrolysis. The impurities are filtered through Kelly filter presses and the filtrate containing the clear sodium aluminate liquor is added to the process and the impurities are dumped outside. By the action of water under controlled temperature, concentration and quality and quantity of the seed and the stirring rate, the clear sodium aluminate liquor is decomposed to form aluminium hydrate and caustic soda. The precipitated aluminium hydrate is filtered through Oliver filter presses and calcined at 1300°C. in rotary kilns to drive off the combined water and moisture. Alumina thus prepared is fed in reduction furnaces for the manufacture of aluminium. Table 6 shows the average analysis of red mud and alumina produced from the bauxite of Bihar area.

TABLE 6

	RED MUD	ALUMINA
Loss on ignition, %	13-14	
SiO_2, %	3-4	0.06-0.070
Fe_2O_3, %	24-25	0.03-0.040
TiO_2, %	27-28	0.02-0.025
Na_2O, %	6.5-7.0	0.40-0.500
Al_2O_3, %	18-20	Remainder

For the manufacture of 1 ton of alumina the requirements are approximately as follows:

Bauxite	2.2-2.4 tons
Caustic soda	0.08-0.11 ton
Steam	8-10 tons
Fuel oil	0.18-0.20 ton

Electrodes

Pre-baked electrodes and Soderberg continuous type electrodes are the two main types of electrodes used in reduction furnaces. Advantages and disadvantages of these electrodes will be discussed later on. Soderberg continuous type of electrodes are used in both the plants in India. The raw materials for the manufacture of electrode are petroleum coke and pitch. The petroleum coke should be of highest purity containing only 0.2-0.3 per cent ash as the purity of the metal depends much on the purity of the paste. The binding property of a pitch is responsible for the manufacture of good paste. It has been noted that the binding property of Indian pitch is inferior as compared to the pitch of other foreign countries. The inferior binding property results in dusting of fine carbon and crumbling of anode pieces. Within the last few years many experiments were performed to improve the binding property of the pitch. It has been observed that the C_2 value of the pitch plays an important role for the binding property of the pitch. But there is a great controversy regarding the definition of C_2 value. According to Adam and Sach, C_2 value is resinous and it is usually defined as the resinous part of free carbon soluble in pyridine, but according to Italian methods C_2 value is the bituminous carbon soluble in anthracene oil and insoluble in benzene. These two methods give different readings. It has been found that if the pyridine method gives 7.0 per cent C_2 value, the Italian method gives about 22.0 per cent C_2 value of the same pitch. The higher the C_2 value, better is the binding property. C_2 value of a good pitch by the Italian method should be of the order of 24-25 per cent. Table 7 indicates the analysis of pitch from various sources.

For the manufacture of paste, the raw petroleum coke is calcined in Reidhammer furnace, crushed and ground to find out the granular composition where the litre-weight is the highest. It is mixed with 25-28 per cent of the pitch and sent to the reduction furnaces. The heat of the furnace drives away the volatile matter of the pitch and it forms a solid mass.

Reduction

*Electrolysis* — The theory of electrolysis is not yet fully developed. Many theories are

TABLE 7

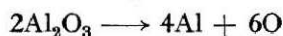|	Total Free Carbon, %	C_2 Value, %	C_1 Value, %	Coking Value, %	Ash, %	Softening Point, °C.
Italian pitch	30·0	25·0	5·0	47·50	0·20	71-72 (K and S)
Shalimar Tar Products' pitch	21·0	14·0	7·0	39·50	0·30	49
Bararee Coke Co.'s pitch	24·9	20·1	4·8	39·86	0·30	70
Bengal Chemical & Phar. Works' pitch	35·1	22·5	12·5	50·77	0·32	73

put forward and they are very interesting to study. The simplest theory which is regarded as the basis of practical work still holds good. The alumina gets dissolved in molten cryolite at 950°C. and it gets decomposed by the electric current.

$$2Al_2O_3 - 6O + 4Al$$
$$6O + 3C \rightarrow 3CO_2$$
$$6O + 6C \rightarrow 6CO$$
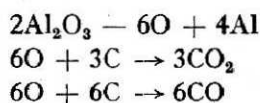
Oxygen is the primary product and the quantity of CO_2 and CO formed as the result of the combination of carbon with oxygen depends on temperature and certain other conditions. Assuming that alumina is the solvent, the following theory has gained popularity. It indicates that alumina is the solvent and sodium fluoride, one of the components of cryolite, undergoes electrolytic decomposition. The reactions are as under:
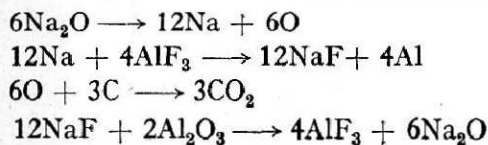
$$12NaF \longrightarrow 12Na + 12F$$
$$12Na + 4AlF_3 \longrightarrow 12NaF + 4Al$$
$$12F + 2Al_2O_3 \longrightarrow 4AlF_3 + 6O$$
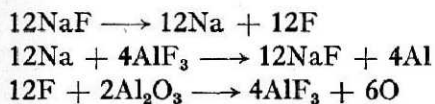
and so final results again come to

$$2Al_2O_3 \longrightarrow 4Al + 6O$$

This theory tells that cryolite is continually decomposed and formed.

Another interesting theory is developed by Gadeau. His theory indicates that Na_2O, which is always present in the molten bath, is responsible for the main reactions:

$$6Na_2O \longrightarrow 12Na + 6O$$
$$12Na + 4AlF_3 \longrightarrow 12NaF + 4Al$$
$$6O + 3C \longrightarrow 3CO_2$$
$$12NaF + 2Al_2O_3 \longrightarrow 4AlF_3 + 6Na_2O$$

About 80-90 per cent of Na reacts with AlF_3 and a small portion vaporizes and meets CO_2 at the anode to form Na_2O and CO.

Current Efficiency — The electrolysis of the molten substance differs to a great extent with that of aqueous solutions. Most of the aqueous electrolytes give nearabout 100 per cent current efficiency, but in the electrolysis of aluminium the efficiency is only 80-85 per cent. There are many reasons for the low current efficiency:

(1) *Losses by Vaporization* — This is supported by Gadeau's theory and he considers this as the most important factor for the low current efficiency.

(2) *Loss by the Formation of Metal Fog* — The formation of the metal fog much depends on the temperature of the furnace. The higher the temperature, the more the cathodic oxidation and formation of metallic fog. It has been observed that even a slight rise of temperature above the maximum causes the current efficiency to fall to a great extent. Our records indicate that the temperature of the furnace is generally between 950° and 1000°C. The temperature of 1000°C. is too high as it takes a lot of current for no good use. The rate of reoxidation also depends on the distance of anode and cathode. For a 12,000-13,000 amp. furnace the distance may be as small as 3 cm., but furnaces of self-baking electrodes of larger dimensions require a distance of 6-7 cm. Adjusting of this distance is one of the important operational problems. If the current distribution is uneven, it results in overheating or cooling

of certain portion of the bath and it also accelerates the reoxidation.

(3) Due to the dusting of anode the carbon floats on the molten bath and thus a portion of current passes through these fine particles of carbon and not through the bath. This partial short circuit of the cell occurs either between the electrodes and the metal or between the electrodes and the sides of the cell. If the dusting is excessive, it is detrimental for operation of the furnaces.

(4) The density of molten aluminium (2·3) is slightly more than the molten bath (2·2) and so aluminium is not properly separated from the bath and it has a temperature about 300°C. above its melting point.

Decomposition Voltage — It is necessary to have the knowledge of the decomposition voltage while operating a particular type of furnace. It guides in the results of heat balances and other factors. Many data have been found out by different electrochemists and they differ from 1·75 to 1·5. The theoretical decomposition voltage is nearabout 1·15 volts. The difference between the theoretical and practical decomposition voltages may be attributed to the following:

(a) Al_2O_3 is not completely saturated in cryolite;

(b) reduced electrochemical effect of the reaction of oxygen with carbon to form CO_2; and

(c) some reversible reactions between cathode and anode which are not properly studied.

The decomposition voltage of a self-baking large electrode comes to nearabout 1·55-1·6.

Type of Electrodes — Throughout the world the multiple-pre-baked electrodes and the self-baking Soderberg type of electrodes are used in the reduction furnaces. It is very difficult to say which type is more advantageous, but Soderberg type of electrodes are gaining prominence. It is very difficult to enclose a furnace using multiple-pre-baked electrodes and to make arrangements for the recovery of fluorine, and the periodic withdrawal of the electrodes and the introduction of new electrodes results in discontinuity of cell operation. Otherwise the multiple-pre-baked electrodes are simple and give satisfactory operating results (FIG. 2). The self-baking electrode can be enclosed in a box-like frame and the fluorine and other tar matters, etc., can be removed easily and can be separated in an adjoining fluorine-recovery plant. Soderberg continuous type of elec-
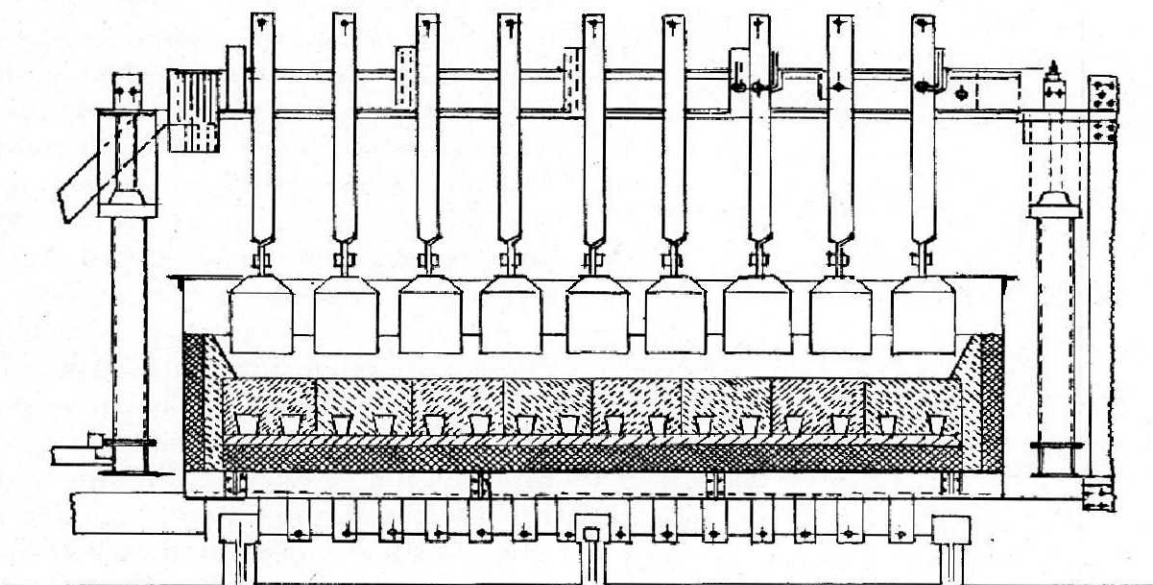

FIG. 2 — CROSS-SECTION AND DETAILS OF INSTALLATION OF A 30,000 AMP. MULTIPLE-PRE-BAKED CELL

trode forms one compact mass and has lower current density than multiple-pre-baked electrodes.

Effect of Impurities Present in Raw Materials

The main raw material is alumina. The purity of this should be thoroughly checked. Generally the Bayer's process alumina is quite suitable and the impurities like iron, silicon, etc., have not much effect on electrolysis, but even a little amount of vanadium and phosphorus present in alumina may lead to a trouble in operation as it increases the resistance of the cell. Current efficiency is lowered and the furnace runs hot. The Indian bauxite contains both these impurities and when the bauxite is digested with caustic soda these impurities find their way together with the alumina in the solution. The alumina produced gets contaminated with these impurities, and so it is always advisable to remove these impurities while refining the bauxite for the manufacture of alumina. Titanium, to the extent of 0·04-0·05 per cent, is not harmful in electrolysis, but if the metal is used for the manufacture of electric cables, even 0·01 per cent of Ti lowers the conductivity of the product. Proper care is necessary for the prevention of TiO_2 to be precipitated along with aluminium hydrate.

The influence of Ti and vanadium on conductivity is shown in Table 8.

TABLE 8

SILICON	IRON	TITANIUM	VANADIUM	SPECIFIC RESISTIVITY, MICROHM AT 20°C.
0·15	0·35	0·010	0·012	2·85
0·14	0·26	0·020	0·010	2·87
0·14	0·24	0·040	0·013	2·94
0·19	0·19	0·005	0·014	2·81
0·22	0·22	0·005	0·028	2·90
0·21	0·18	0·005	0·049	3·07

The mesh size of alumina to be used in the reduction furnaces is a matter of controversy. Some operators prefer coarser alumina and some finer. Coarser alumina generally comes under 40-50 per cent —200 mesh and below this it is generally termed as finer alumina. Our experience shows that finer alumina has a tendency to sink at the bottom of the furnace and thus make the cathode dirty.

Operation

The molten cryolite dissolves theoretically 20·0 per cent alumina, but in practice it is not more than 8-10 per cent. The average voltage of the cell is at 5·0-5·5 volts. When the concentration of alumina in the bath falls to 1·5-2·0 per cent, the voltage jumps to 40-50 volts. This phenomenon is called 'anode effect' and it indicates that fresh addition of alumina is required in the furnace. An electric lamp is connected in parallel to the cell which lights up during the anode effect and attracts the attention of the operator. This should not be allowed for more than 2-3 min. as during anode effect the temperature of the furnace increases considerably and lot of cryolite and paste are lost for nothing. It seems that during the anode effect the voltage increases due to the formation of a very thin layer of anodic gas which surrounds the anode when the alumina concentration falls to a certain value. The molten bath does not wet the anode and the electric current passes from the anode to the bath through small electric arcs and thus overheats the bath. The recent practice is to prolong the period between two anode effects. Generally an anode effect occurs between 3 and 4 hr. The practice which does not allow the anode effect to appear is called 'scheduled stirring'. The quantity of alumina is calculated in a way that after regular interval the calculated alumina is added to the bath and thus avoid the anode effect. This is a very delicate process and a very correct calculation is required. If the quantity of alumina is more than the calculated

quantity, the alumina gets deposited over the carbon cathode and makes the cell hot. The advantages of this practice are that unnecessary loss of cryolite, electrode and current is saved. The approximate consumption of raw materials and power for the manufacture of 1 ton of aluminium are shown as under:

Alumina	1·95-2·0 tons
Cryolite	0·09-0·1 ton
Aluminium fluoride	0·015-0·02 ton
Paste	0·6-0·62 ton
Calcium fluoride	0·01-0·015 ton
Power	23,000-24,000 kWh.

At the Aluminium Corporation of India Ltd., 24,000 amp. furnaces are operated. The power is supplied to the furnaces from the Company's own thermal station.

Improvements are being done in the design and working of the furnaces. In modern plants the tendency is to go for 40,000-50,000 amp. furnaces. The furnaces are of enclosed type so as to facilitate the recovery of gases and tar products (FIG. 3). But the enclosed type of furnaces, however, involve comparatively large and expensive installations and the operation of the furnaces behind the closed doors becomes more difficult to inspect and control. Messrs Dett Norske Aktieselskab for Elektrokemisk Industry, Norway, have patented a new furnace in which they have provided an arrangement containing the advantages of enclosed and open type furnaces. The invention relates to continuous self-baking electrode type. It is based on the fact that the whole of the furnace gas develops in direct contact with the electrode, and bubbles up through the melt close to the surface of electrode dipping into. The lower end of the electrode is surrounded at the bath surface by a small gas chamber. The arrangement can be safely used in Soderberg electrodes with vertical studs inserted in the chamber from the above and the current is supplied through them. The gas chamber outlets are connected into a pipe which carries the gas to the washing plant.

Refining of Aluminium Metal

If precautions are taken to use alumina, paste and cryolite of high purity, it is possible to manufacture aluminium metal of 99·6-99·7 per cent purity. The main impurities are iron and silicon and other impurities like copper, titanium, vanadium, manganese, magnesium and sodium also find their way in traces in aluminium metal. For many purposes covering a large field due to its better tensile strength than super-purity aluminium (99·99 per cent) and tolerable resistance to corrosion, the commercially pure metal is quite satisfactory. But at the same time metal of super-purity has its own advantages and has extremely valuable properties like high resistance to corrosion
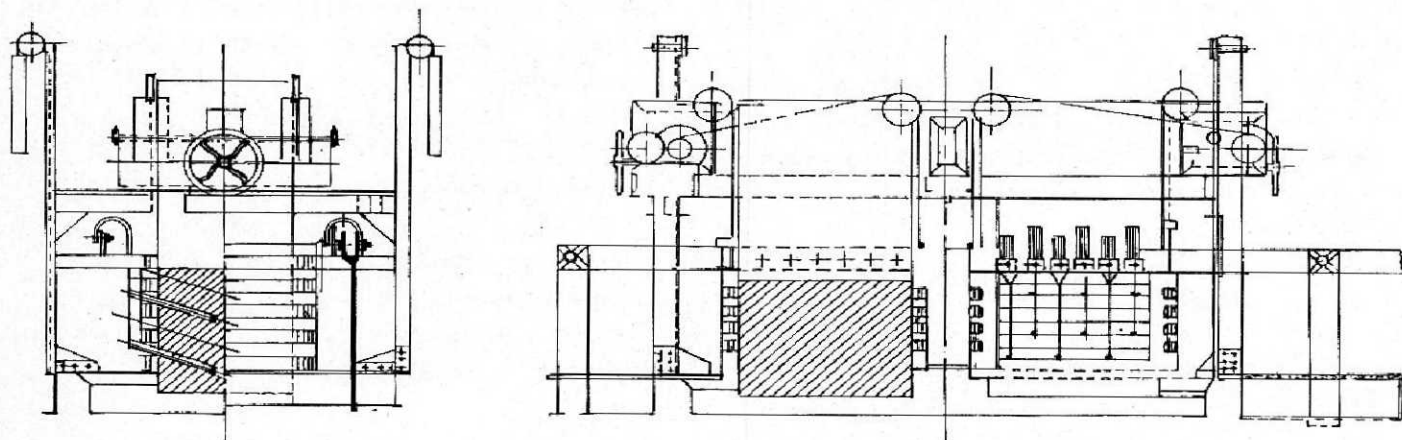

FIG. 3 — ENCLOSED 25,000 AMP. FURNACE

and high conductivity. Certain branches of electrical engineering require purity of this order as even the minute traces of certain impurities may bring down the electrical conductivity. The super-purity aluminium will play an important part in developing certain alloys of specially controlled purity. At present there is no huge production of super-purity aluminium in the world. In India the aluminium industry is in its infant state and there seems to be no work done on the refining of aluminium, but in other countries some processes are developed for the production of super-purity aluminium. The Hoope's process of electrolytic refining was the first to get aluminium of 99·9 per cent purity. The process utilized a cell having three layers of materials, the bottom (anode) layer, aluminium-copper alloy, the middle layer cryolite and aluminium fluoride and the top (cathode) layer, molten pure aluminium. The refining furnaces are quite different from the reduction pots. The polarity is opposite. The carbon electrodes are the cathode and the carbon furnace bottom the anode. With carbon electrodes in contact with the pure aluminium, the passage of direct circuit through the cell removes the aluminium from the aluminium-copper alloy at the bottom of the furnace in the fluoride bath and deposits pure aluminium in a layer above the bath (FIG. 4). At Erftwerk, Grevenbroich, Germany, a refining plant working 43 furnaces with 120 tons refined metal production per month works on the three-layer process. The plant takes aluminium alloy scraps for refining. The bottom layer is the anode. It consists of an aluminium alloy with 25-35 per cent copper, the middle layer electrolyte is of the following composition:

AlF_3 　26·0 per cent
Na_3AlF_6 　30·0 　,,
BaF_2 　18·0 　,,
CaF_2 　16·0 　,,

The melting point of the salt mixture is 680°C. The top layer is the cathode of the refined aluminium.
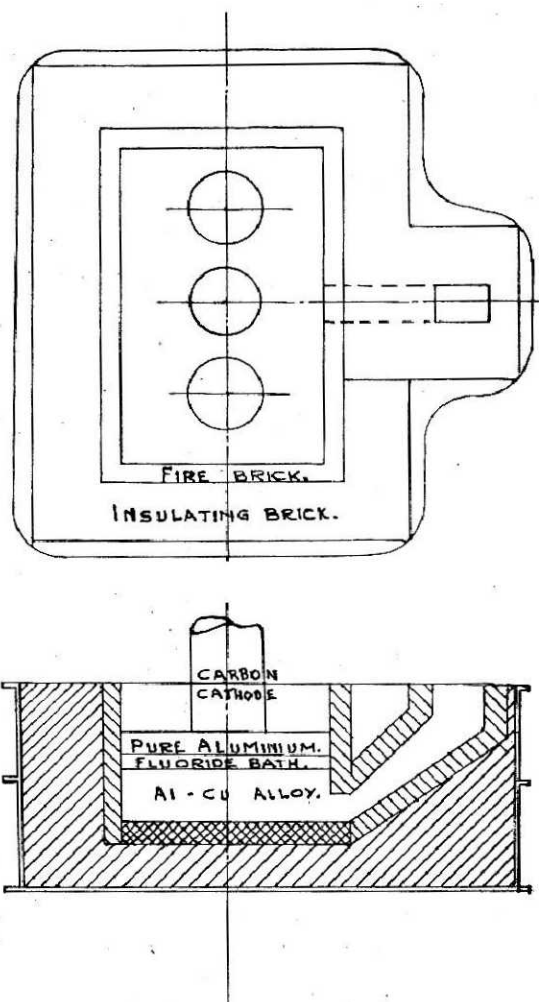

FIG. 4 — ALUMINIUM PURIFYING FURNACE

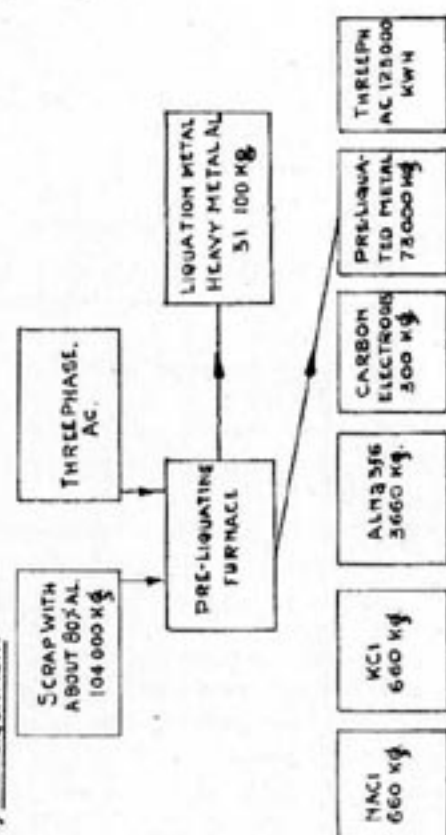|	
Depth of the anode metal	30-40 cm.
Depth of the electrolyte	8-10 cm.
Depth of the cathode metal	20-25 cm.
Temperature of cathode metal	70°-75°C.

Consumption and Operating Figures

Power consumption per 100 kg.	1900-2000 kWh.
Electrolyte consumption	6-8 kg.
Graphite electrode	6-8 kg.
Current efficiency	90-92 per cent
Average voltage per furnace	5·2 volts
Average current	13,800 amp.
Current density	0·35 amp./sq. cm.

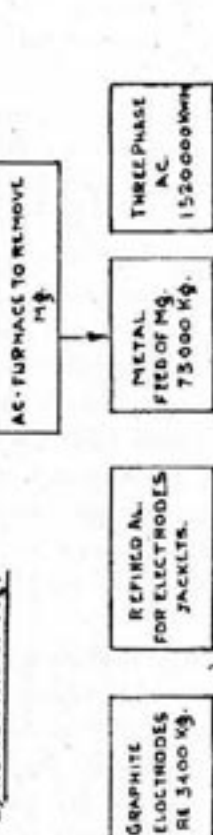5) PRODUCTION OF THE ELECTROLYTE FOR REFINING CELLS

RAMSHOFEN PLANT

FLOW SHEET OF AL-REFINING WITH PRE-LIQUATION FURNACE

Feed.-REMELTED METAL OR THE LIKE LOW IN Mg; NO ADDITIONS OF VERGIN AL NEEDED; IF SCRAP FROM AIRPLANES IS USED. ELEKTRON METAL IS TO BE REMOVED.

1) PRE-LIQUATION.

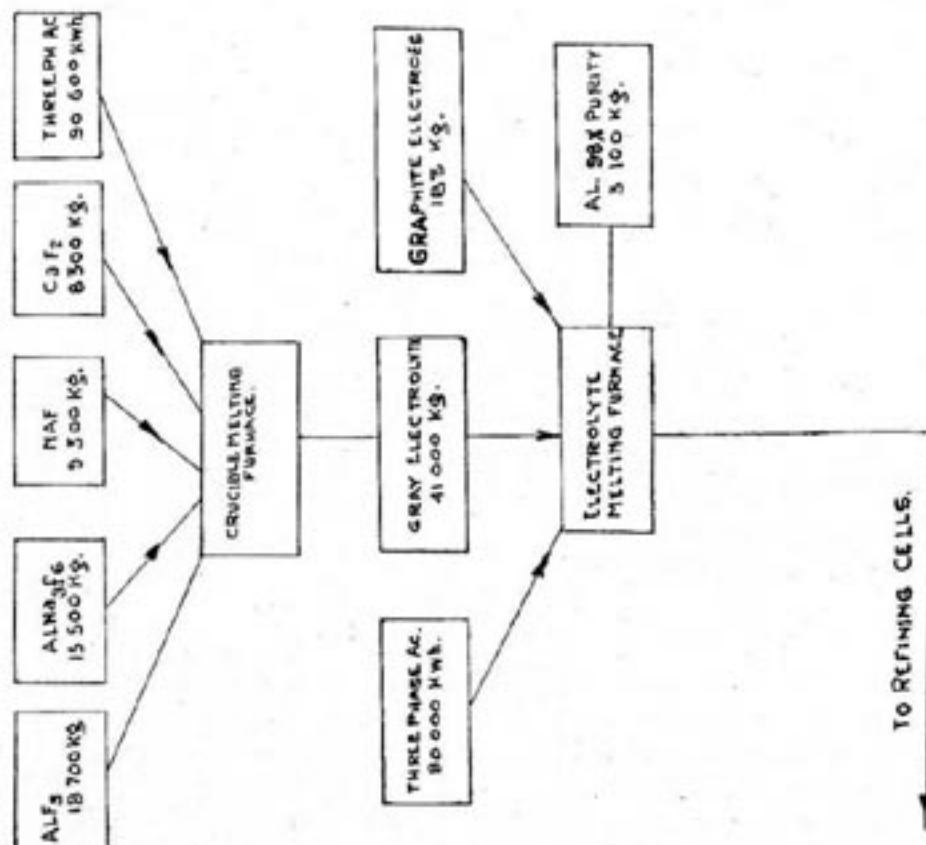2) REMOVING OF Mg.

4) REFINEMENT.

FIG. 5

But if iron and magnesium content is very high, the scrap metal is subjected to the processes of preheating first in a resistance furnace to eliminate the heavy metals and then in an arc-type furnace using NaCl, KCl and cryolite and carbon electrodes to eliminate magnesium and then subjected to final refining.

Fig. 5 shows the flow sheet of a full scrap-refinement plant at Ranshofen Plant, Germany.

Prospects of the Industry in India

The average annual production of aluminium in India is 3500 tons, but the consumption is of the order of 14,000-15,000 tons. It is hoped that the consumption will further increase to 20,000 tons by 1955-56 as estimated by the Planning Commission. As already shown in Table 3, India has abundant deposits and one of the best bauxites of the world. But the position of caustic soda is not satisfactory as India manufactures only 12,000 tons as against the consumption of 60,000 tons. Aluminium and caustic soda industries both consume huge electric power. The Government is putting up many power projects in different parts of the country, but it is doubtful that these projects will be able to supply the power as cheap as other principal aluminium-producing countries. Further, production of artificial cryolite is uneconomical, as the raw material fluorspar, available in India, is of very impure quality and it has been seen in our laboratory that the cost per ton of artificial cryolite comes much more than that of the imported natural cryolite. Further, the aluminium industries to be developed may face a shortage of petroleum coke.

Considering all these points, it is to be seen whether the industry will be able to compete the foreign open market and stand on its own legs. Despite all these drawbacks the development of the industry cannot be ignored as aluminium and its alloys are going to play a very important role in the future industrialization and defence of the country. It is expected that the Government would take keen interest and extend facilities and help for the progress of the aluminium industry.

References

1. EUGLE, H. & GREGORY, HOMER E., *Aluminium*.
2. *An Introduction to Aluminium and its Alloys* (The Aluminium Development Association, London).
3. *Production of Aluminium*, Field Information Agency, Technical U.S. Group, Control Council for Germany.
4. "Electrical Conductors", *Light Metals* (Nov. 1949).
5. "Insoluble Matter of Coal-tar", *J.S.C.I.*, **67** (Nov. 1948).
6. "World Production of Aluminium", *Metal Industry* (Nov. 1950).
7. LUZZATTO, B. A. BRUNO, *Reflections on the Electrolytic Cells Used in the Production of Aluminium*.

Discussion

MR. P. P. BHATNAGAR (National Metallurgical Laboratory, Jamshedpur)

It is noticed that 18-20 per cent Al_2O_3 is lost in the red mud. Is it because of the diasporic nature of the bauxite ?

For the utilization of red mud, would it not be desirable to roast the red mud with soda and dissolve the alumina ?

MR. M. C. DUBE (Aluminium Corporation of India Ltd., Jaykaynagar)

We are not recovering Al_2O_3 from the red mud at present as we have not found it economical.

We are, however, separating sodium vanadate and sodium phosphate which amount to 0·1 ton per 100 tons bauxite digested. It analyses:

V_2O_5	10-12%
P_2O_5	14-15%
Na_2CO_3	15-20%
$NaAlO_2$	1-2%
Combined water	Rest