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TECHNO-ECONOMIC OPPORTUNITY STUDY WITH BENCH-SCALE TESTING OF BAUXITES FOR THE ISLAMIC REPUBLIC OF IRAN

DRAFT FINAL REPORT
ATTACHMENTS

Aluterv-FKI, Budapest,October,1988

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General Description of the Bayer process for alumina production

Attachment 1

GENERAL DESCRIPTION OF THE BAYER PROCESS FOR ALUMINA PRODUCTION

Introduction

The Bayer process was named after the Austrian Karl Josef Bayer, who, while serving as a manufactring chemist in Russia, filed two patents for the production of alumina from bauxite.

The first of these in 1888 described a process for precipitation of alumina hydrate by seeding from sodium aluminate liquor. This was a departure from the Deville-Pechiney carbon dioxide precipitation process.

The second of Bayer's patents (1894) claimed a process for digesting bauxite with the sodium aluminate liquor concentrated from the previous cycle, rather than extracting the alumina by the Deville-Pechiney calcination of bauxite with sodium carbonate.

These two discoveries constitute the process used to this da for the manufacture of most of the world's alumina.

The basic chemical reactions of the process are indicated in Fig.A1.

The process may be followed in the generalized block-and-line flowheet in Fig.A2.

The first step, raw material preparation, involves mining, transportation, material handling, proportioning and grinding.

The second step, digestion involves the extraction of alumina from bauxite by a solution of sodium aluminate and sodium hydroxide initially week in sodium aluminate at elevated temperatures. The aluminium silicate with which all bauxites are contaminated to some degree, react with sodium hydroxide to form sodium aluminium silicate. It is only because this sodium aluminium silicate has a very low solubility that the Bayer process can produce the low-silica high-purity alumina needed for commercial aluminium production.

The third major step is clarification. Here the bauxite residue (the red mud) is separated from the sodium aluminate solution by sedimentation and filtration. The mud is usually washed continuously in counter-current decantation (CCD) equipment before being discarded.

In the fourth step, precipitation, the clarified sodium aluminate solution is cooled to supersaturation and seeded with alumina hydrate. After precipitation the hydrate is classified, separating coarse product fractions and fine fractions, which are retained as seed for succeeding precipitations. In most plants the spent liquor from the process, before being recycled, passes through an evaporation operation to remove the excess dilution added as wash-water in various steps in the process.

While the basic process has remained unchanged since Bayer's inventions nearly one hundred years ago, there have been a number of modifications and improvements.

These developments have been largely determined by:

a) the physical, chemical and mineralogical characteristics of the ores
b) the economics of materials (and equipment) used in the process, particularly bauxite, caustic soda, and fuel,
c) environmental imperatives and
d) product quality desired by the manufacturers of aluminium.

Required Properties of Alumina

Aluminium is produced exclusively by the electrolytic reduction of alumina dissolved in molten cryolite using carbon is some form as electrodes. This is the well-known Hall-Herault process discovered in 1886.

Figure A1

BASIC REACTIONS OF BAYER PROCESS

$Al_2O_3.H_2O(S)$	+ 2NaOH + $2H_2O$	Digested at 230°-280°C	$\rightleftarrows$	$2Na[Al(OH)_4]$	(1)
(Boehmite or Diaspore)	(Caustic Soda)			(Sodium Aluminate)	
$Al_2O_3.3H_2O(S)$	+ 2NaOH	Digested at 110°-145°C	$\rightleftarrows$	$2Na[Al(OH)_4]$	(1A)
(Gibbsite)					
$2Na[Al(OH)_4]$		Precipitation 54°-60°C	$\rightleftarrows$	$Al_2O_3.3H_2O(S)$ + 2NaOH	(2)
$Al_2O_3.3H_2O(S)$		Calcination 1000°-1200°C	$\longrightarrow$	$Al_2O_3(S)$ + $3H_2O(v)$	(3)
(Gibbsite)				(Alumina)	

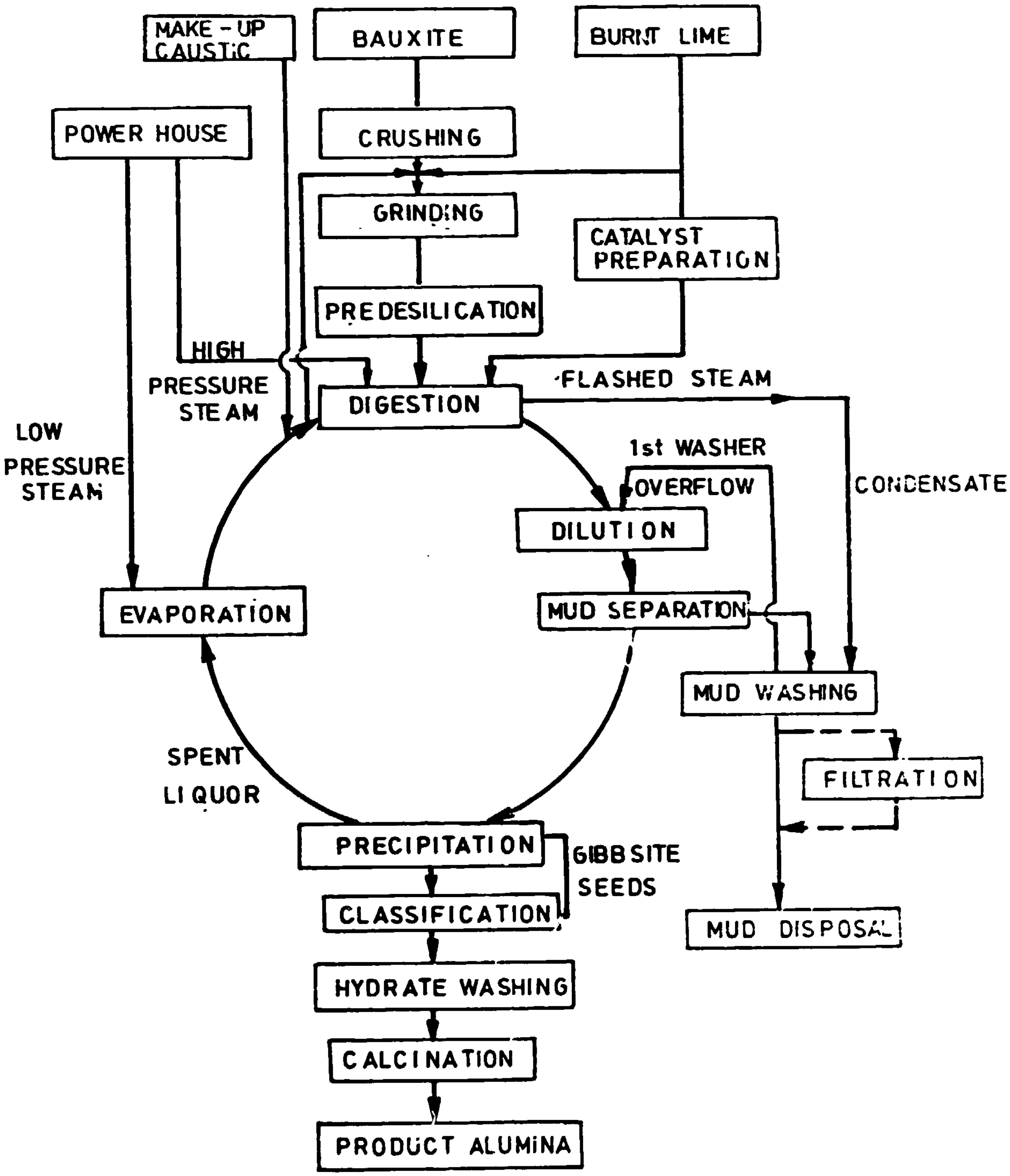


Fig. A2

BAYER PROCESS SCHEMATIC FLOWSHEET

For most of the commercial applications of aluminium, for example in the electrical industry and for the production of alloys to very close specifications, the metal must be of high purity. Because of the high energy of formation of alumina as compared with the oxides of the common metals, the latter, if present, would be reduced to metal under the electrolysis condition and therefore it is not possible to produce pure metal in one operation by reduction of an impure ore. Hence a very careful control on the quality of the main raw materials, alumina, carbon, cryolite, and aluminium fluoride, is necessary to be able to meet the normal production grade of 99.8 % plus metal.

The most critical impurities are silicon and iron and the main difficulties in manufacture of alumina arise from the necessity to keep the percentage of these elements to very small values.

Titanium and vanadium must be controlled to give conductivity grade metal, and soda and phosphorus affect the bath operation, the former by disturbing the flux composition which must always be kept close to that of cryolite which is $3NaF.AlF_3$ of the electrolysis.

A typical analysis for reduction grade alumina is given in Table A1.

Table A1.

Al_2O_3	98.5 -99.4	%
Na_2O	0.30 -0.65	%
SiO_2	0.015-0.025	%
Fe_2O_3	0.010-0.025	%
TiO_2	0.001-0.005	%
V_2O_5	0.001-0.005	%
P_2O_5	0.001-0.002	%
Ga_2O_3	0.005-0.008	%
CaO	0.05 -0.10	%
Loss on ignition	0.05 -0.50	%
MgO	0.001-0.003	%
ZnO	0.005-0.020	%
SO_2	0.001-0.020	%

The physical properties affecting the performance of the reduction plant are, degree of calcination (that is, the extent to which the alumina has been converted from the active kappa form to the non-water absorbent alpha form with associated recrystallisation), the angle of repose (which affects handling properties), and the grain size distribution.

There is a broad difference in practice between European and American producers. The traditional European plants make so-called floury, while American producers make sandy alumina. There are lots of qualities between the two traditional ones shown in Table A2.

Table A2

Comparative Table

SOME PHYSICAL SPECIFICATIONS OF TYPICAL SANDY AND FLOURY ALUMINA

Parameters	Typical Floury	Typical Sandy
Loss on Ignition (LOI)	0.3 %	0.9-1.2 %
Specific Surface Area	5-10 m^2/g	40-45 m^2/g
α Al_2O_3	60-70 %	20-30 %
Bulk Density	0.95-1.0 t/m^3	0.88 t/m^3
Angle of Repose	40-45°	28-32°
+ 100 Mesh (149 μm)	0.1 %	2-8 %
- 325 Mesh (44 μm)	50-55 %	6-10 %

Raw Materials

Aluminium is the third most abundant element in the earth's crust but only a comparatively small proportion of the aluminium minerals can be used commercially for the production of alumina. The patent literature teems with ideas for making alumina from clay or feldspathic type of mineral but in practice virtually the whole of the alumina for metal production is made from the hydrated alumina ores - the bauxites - using the classic Bayer process in one of its forms.

The Bayer process depends on the variations in solubility of hydrated alumina in sodium aluminate solutions with change of concentrations of soda and temperature; the solubility of the alumina varies widely according to the particular hydrate concerned. Alumina occurs naturally in bauxite in the form of the trihydrate gibbsite or the monohydrate (boehmite and diaspor). Alumina in the trihydrate form is much more soluble than monohydrate alumina in aluminate solutions of given soda concentration and temperature and hence the commercial extraction process varies very greatly, depending on the particular ore.

The main large deposits of bauxite are in Australia (Queensland, Northern Territory and West Australia), Jamaica, the Guianas, Venezuela and Brazil in South America, West Africa (Guinee, Ghana and Cameroon), Vietnam, India and Indonesia in Asia and Europe.

Table A3 gives typical analyses of ores from different regions. Table A4 shows some minerals occurring in bauxites.

The first point to note is the low combined silica content. Every unit of combined silica (i.e. silica present as kaolinite or halloysite) reacts in the extraction process to form an inscluble sodium-aluminium-hydrosilicate of approximate composition $3(Na_2O.Al_2O_3.2SiO_2.1\text{-}2H_2O).Na_2X$, where $X: CO_3^{2-}, 2OH^-, 2AlO_2^-, SO_4^{2-}$, etc. and consequently reduces the possible alumina yield and takes soda from the circuit. It is rare for ores of above 5-7 % SiO_2 to be economic. The percentage of quartzitic silica is important. Quartz is present in significant quantities in the South American and Australian ores but it is vertually absent in the European and Ghana ores. Its significance is that under the relatively severe conditions required to attack boehmite bauxites the quartz is attacked in a similar manner to the combined silica, increasing the soda and alumina losses.

The second point is the loss on ignition is relation to the alumina content. The broad difference between the European ores (i.e. from temperate regions), which are predominantly boehmite monohydrate, and the ores from the tropical regions, which are mainly trihydrate gibbsite. should be noted. The Jamaican and the Queensland ores have relatively lower hydration than the South American indicating a mixed tri- and monohydric ore.

The percentage of other constituents, in particular iron oxide and titania, is significant as affecting the amount of residue produced.

The other basic raw materials for the process are soda (either as caustic or soda ash), lime, and water. The quality of process water is not critical.

Table A3

ANALYSIS OF CHARACTERISTIC BAUXITE ORES

	France	Ghana	Guyana	Jamaica	Weipa	Gove	Guinea
SiO_2 combined, %	5.0	1.2	3.0	2.5	3.0	2.6	[illegible]
SiO_2 quartz, %	-	-	1.5	-	2.0	0.4	[illegible]
Al_2O_3, %	54.0	54.0	59.0	50.0	59.2	50.0	41.0
Fe_2O_3, %	25.0	16.0	3.0	19.0	7.0	19.5	[illegible]
TiO_2, %	3.0	1.8	3.0	2.5	2.5	1.2	[illegible]
L.O.I., %	11.5	27.5	29.5	25.0	26.0	24.0	15.0
Ratio $\frac{Al_2O_3}{comb.SiO_2}$	10.8	45.0	19.6	20.0	19.6	19.2	[illegible]
Moles $\frac{H_2O}{Al_2O_3}$	1.13	2.9	2.9	2.8	2.55	2.76	3.1

Table A4

SOME MINERALS OCCURRING IN BAUXITES

Gibbsite	$Al(OH)_3$ or $Al_2O_3.3H_2O$
Boehmite	$AlO.OH$ or $Al_2O_3.H_2O$
Diaspore	$AlO.OH$ or $Al_2O_3.H_2O$
Quartz	SiO_2
Kandites (kaolinite, nakrite, dickite, metahalloysite)	$Al_4Si_4O_{10}(OH)_8$ or $Al_2O_3.2SiO_2.2H_2O$
Halloysite	$Al_4Si_4O_{10}(OH)_8(H_2O)_4$
Hematite	Fe_2O_3
Goethite	$FeO.OH$
Al-Goethite	$Fe_{1-x}Al_xO.OH$
Calcite	$CaCO_3$
Anatase,Rutile	TiO_2
Crandallite	$CaAl_3(PO_4)_2(OH)_5.H_2O$
Apatite	$Ca_5(PO_4,CO_3)(F,OH.Cl)$
Chamosite	$(Fe^{2+},Fe^{3+},Mg,Al)_6(Si_3Al\,O_{10})(OH)_8$
Smectites	$(Na,Ca)(Al,Mg)Si_4O_{10}(OH)_2.nH_2O$
Illite, hydromuscovite	$(K,H_2O)Al_2[(H_2O,OH)_2AlSi_3O_{10}]$
Lithiophorite	$(Al,Li)(MnO_2)(OH)_2$
Muscovite	$KAl_2(AlSi_3O_{10})(OH,F)_2$
Siderite	$FeCO_3$
Pirite, Marcasite	FeS_2
Ilmenite	$FeTiO_3$
Zircon	$ZrSiO_4$
Hausmannite	$MnO.Mn_2O_3$
Etc.	

Most bauxite occurs near the earth's surface and therefore mining follows the usual open cast method. The physical nature of the ore varies greatly. European and West African ores are moderately hard rocks, but Jamaican ore is of earthy nature with fundamentally very small particle size: the Queensland ore is unique in being in the form of pellets. Some bauxites (for example, Ghana and Queensland ores) can with advantage be beneficiated by screening and water washing which removes the clay-like high silica fractions. Ores from the Caribbean and South America are always partially dried before shipment.

The alumina cycle

The alumina cycle consists of two parts, namely, the solution of alumina from the ore and the deposition of aluminium hydrate from the liquors. At both ends of the system, plant design depends on the solubility data of the particular hydrate concerned, in caustic soda liquors.

The solubility of gibbsite, the alumina trihydrate, is much greater than that of the alumina monohydrates, i.e. boehmite and diaspore. Figure A3 shows the solubility data for gibbsite, boehmite and diaspore, measured in synthetic solutions.

Speaking generally, the more alumina one can take into solution par unit volume of liquor the smaller the digestion unit will be. In a plant using boehmite ore there is not theoretical limit to the temperature that can be used. Higher temperature means higher pressure and hence higher costs per unit plant volume. On the other hand, the higher the temperature the lower the concentration of soda that can be used. The choice is an economic one.

From Fig. A3 it is seen that the upper temperature limit for gibbsitic bauxites is about 150 °C. This is because at temperatures above this a hydrothermal transformation of trihydrate to monohydrate occurs in alkaline liquors and therefore a solution approaching saturation with respect to trihydrate will be unstable with reference to monohydrate and boehmite will separate out. This sets an important upper temperature limit of about 150 °C on a plant treating a trihydrate ore and which utilises the high degree of solubility..

For monohydrate digestion the trend of increasing digestion temperature represents a determinative factor. Nowadays the optimum digestion temperature for boehmite lays in the range of 240 to 250 °C. Digestion at higher temperatures i.e. ranging from 260 over 280 to 300 °C, however, can not economically be performed in the autoclave system. Digestion

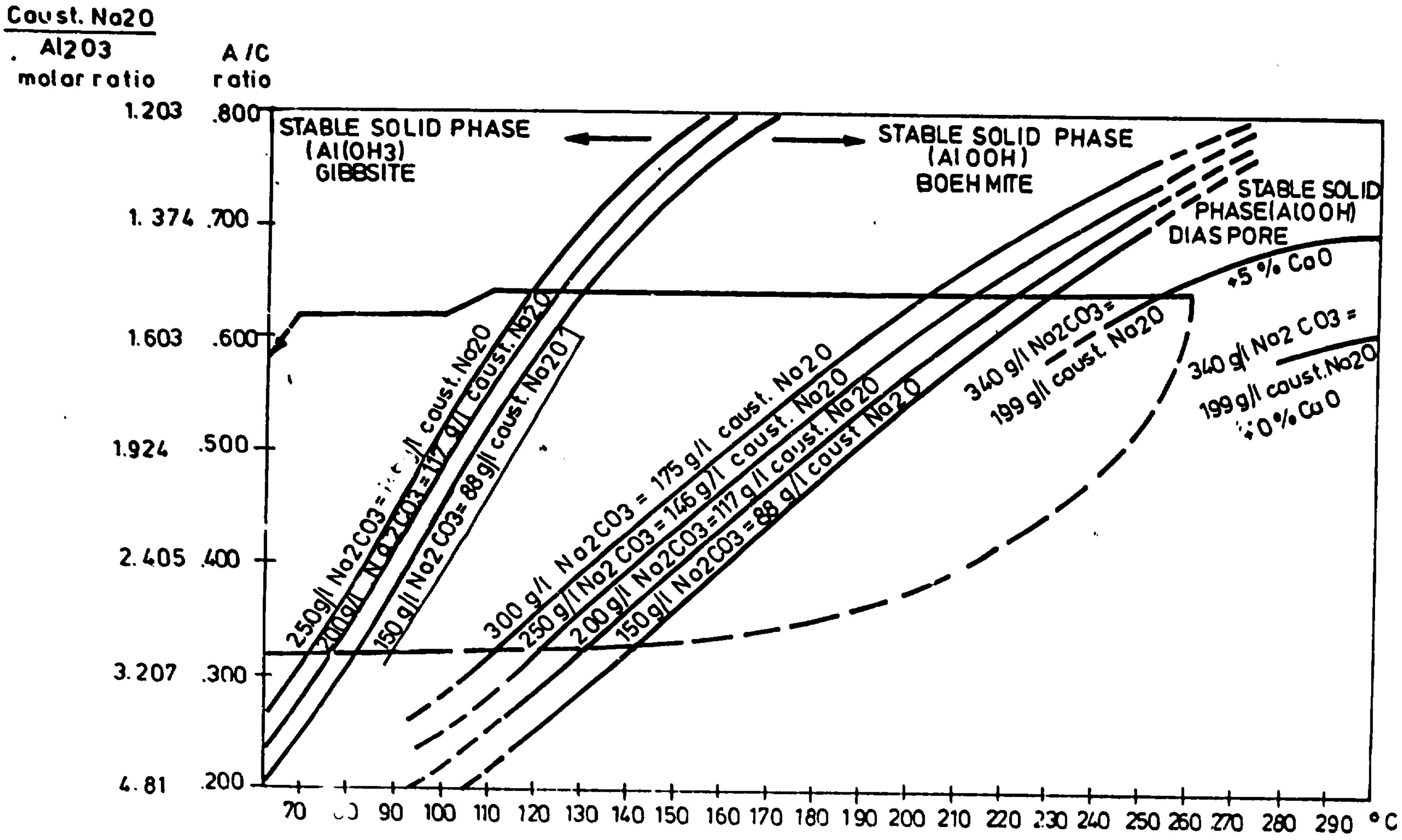


Fig. A3

EQUILIBRIUM A/C RATIOS IN SYNTHETIC LIQUORS FOR GIBBSITE, BOEHMITE AND DIASPORE IN THE FUNCTION OF THE TEMPERATURE AND CAUSTIC CONCENTRATIONS at these temperatures can advantageously be carried out merely by the use of the tube reactor. In addition to the intensification of the digestion process (short retention time, low molar ratio, i.e. high A/C ratio, alumina yield close to that of theoretical), also both the inherent investment costs for the equipment and the energy consumption diminish considerably.

Increasing the number of flashing stages for a given final digestion temperature helps to increase heat efficiency.

On digestion, the main adventages of the tube digestion system are:

1) elevation of the digestion temperature
2) decrease in energy consumption
3) reduction in investment costs
4) higher alumina yield and
5) simple maintenance.

By increasing the temperature the amount of flashed water can be high enough that evaporation can be omitted if small amounts of red mud (e.g. 0.5 t/t alumina) form of the bauxite. Also, owing to the piston-like stream of the slurry in the tube digester, the uneven holding-time (which always distrubs the digestion in autoclave series) can be minimized.

Due to the higher digestion temperature the settling properties of the red mud are improved, therefore the underflow solids concentration is higher, resulting in less dissolved caustic soda and alumina losses.

Despite of the advantages of the tube digestion system, its use is limited to the Stade plant in West Germany and the Mosonmagyarovar plant in Hungary. The answer apparently lies in the fact that:

a) the advantages of the tube digestion are in respect of the high temperature digestion and
b) the main expansions (viz. Australia, Brazil, Venezuela) have been 'low temperature plants'.

The Soda Cycle

The next cycle is the soda cycle. This relatively simple cycle is shown, in principle, in Fig.A4.

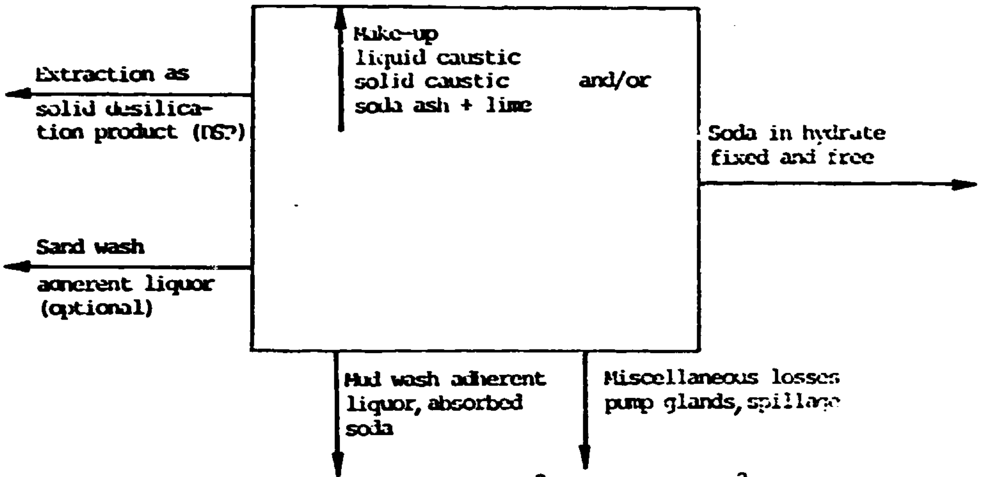
The main loss of soda from the liquor circuit is the chemical loss at the extraction plant, due to reaction with the combined silica in the ore to form the almost insoluble triple zeolitic type of compound. This, ultimately, goes out of the system with the red mud residue.

In addition to this fixed chemical soda loss, the mud, as disposed of, always contains some adherent soda liquor due to incomplete washing and also due to soda absorbed by the mud. The extent of this physical loss varies considerably according to the method of disposal of the mud.

Next there are inevitable losses of liquor by leakages, for example, from pump glands and general spillages, and finally, the loss of soda in the hydrate. This consists of two parts, the soluble soda, i.e. entrained liquor, which can be kept down to a very low value of 0.01 % on the hydrate, by good washing techniques, and a much larger fixed soda loss of the order of 0.2-0.4 % on the hydrate. This soda is thought to be locked up in the hydrate crystal lattice. The actual soda content depends on the alumina potential during decomposition and is controllable within limits.

Overall these soda losses from the circuit must be made up by addition of fresh soda and this can be added as solid caustic, liquid caustic, or from a soda-ash lime causticising unit on the site. The choice is an economic one. Separate causticising adds to the residue and cannot be carried out to more than about 90 % efficiency. Solid caustic involves the least introduction of water into the system as it can be dissolved in process liquors. On the other hand, one has to pay the alkali supplier for evaporation and the handling problems are obvious. Liquid caustic is the most convenient and it is widely used.

The actual consumption of soda expressed at 100 % caustic soda ranges from about 4-16 % on the alumina made, dependent



DSP: $3(Na_2O.Al_2O_3.2SiO_2.1\text{-}2H_2O)Na_2X$, X: CO_3^{2-}, $2OH^-$, $2AlO_2^-$, SO_4^{2-}, etc.

Fig. A4
SODA CYCLE

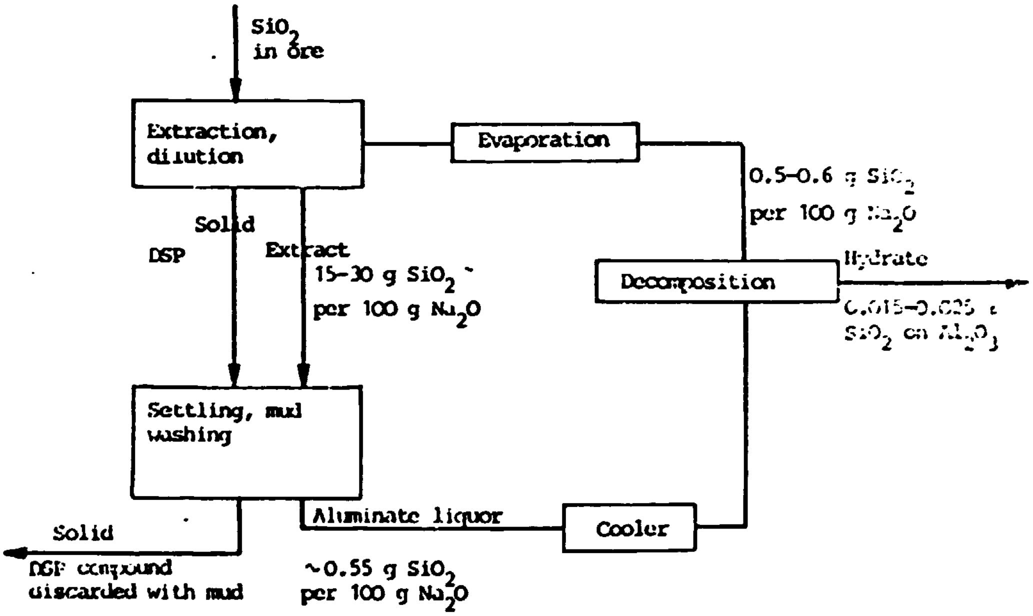


Fig. A5
SILICA CYCLE

on the silica content of the ore. Since caustic costs in the region of US$ 200 to 300 per ton is 1988, the importance of having high alumina to silica ratio in the ore is obvious.

Silica Cycle

The control of silica in the circuit is important to ensure the required purity of the alumina. Figure A5 illustrates this cycle.

Silica exists in bauxite in two main forms. Firstly as reactive silica, as minerals of the kaolinite type which are readily attacked by caustic liquors with solution of silica. This attack is very rapid under the extraction conditions.

Secondly, silica exists as quartz which is not readily attacked by caustic liquors at low temperatures but increasingly attacked at higher temperatures causing corresponding loss of alumina and soda. The quartz in Northern Australian ore is an intermediate nature, uniformly distributed, and although unattacked at 140 °C, it is slowly attacked at 190 °C when monohydrate is being extracted (10 % per hour). Where the quartz is in a relatively massive form, as, for example, in Guyana ore, it is not attacked when extracting the ore for trihydrate at 140 °C and can be removed from the system as a coarse sand. In Guinea bauxite, on the other hand, the quartz is very fine grain, uniformly distributed and is appreciably attacked even at 120 °C.

Simultaneously with solution of the silica, desilication of the solution occurs by deposition of the relatively insoluble triple compound. The most likely composition of the desilication product, i.e. sodium-aluminium-hydrosilicate formed during the digestion process is $3(Na_2O.Al_2O_3.2SiO_2.1\text{-}2H_2O).Na_2X$, where $X: CO_3^{2-}, 2OH^-, 2AlO_2^-, SO_4^{2-}$, etc. The rate of deposition is accelerated by the presence of the triple compound in the solid phase acting as a seed and by high temperature.

It is necessary to reduce the silica in the liquor passing to the decomposer to such a value that contamination of the hydrate produced during decomposition is minimised. This desilication process is only partially completed in the digestion plant unit and it is completed during settling. In practice the aim is a figure of not greater than 0.5-0.6 g SiO_2 per 100 g of caustic soda in the solution.

An interesting point is that with some very high grade low silica ores the quantity of the triple compound is so low in relation to the liquor volume that desilication rate is too slow.

The chemical reactions of the silica also affect the scale deposition on the bauxite slurry and liquor heat exchange surfaces. That is why a predesilication process has been introduced when indirect heating is applied in the digestion unit.

The Red Mud System is, of course, not cyclic, as the object is to get rid of the mud from the cycle. This part of the process has an enormous influence on the plant cost, plant location, and product quality.

The composition of the sand fraction depends on the ore. It can contain qualite an appreciable amount of quartz as from Guyana ore, or be predominatly iron oxide if from European ores. Due to its size, > 250 mesh, (63 μm) and its physical nature, it has a relatively high settling rate compared with the main bulk of mud and can, therefore, be readily separated in continuous settling equipment. It is practice to use a conventional bowl and rake classifier, although wet cyclones and hydroclones have been used in some plants. Some of the wetting liquor can be removed from the rakes by spray washing, but it is very difficult to achieve good back drainge of the wash. The sand is usually collected in a hopper and dumped by truck.

Separation of the red mud from the alumina-rich liquor is carried out by sedimentation followed by control filtration. In this process there are two main objectives. Firstly, to produce a rich aluminate liquor sufficiently free from suspended solids to prevent contamination of the hydrate deposited later. The standard required is very high. As mentioned in discussing decomposition, the deposition of alumina in the decomposers is of the order of 60 g/l solution. If the solids in suspension were say 5 ppm this would correspond to 0.008 % in the alumina made and with Fe_2O_3 content of about 55 % in the mud, a contribuution of 0.005 to the Fe_2O_3 in the product (c.f. required level of 0.012 in alumina). The second objective is to remove as much as practicable of the adhering liquor from the mud before disposal, using the minimum amount of the wash water.

The mud always possesses some degree of flocculation depending on the type of ore and extraction conditions but it is universal practice to increase this by addition of starch and/or synthetic flocculants.

The traditional design of thickener was originally used, that is, the multiple tray unit with all trays in parallel and common mud offtake, but the modern tendency is to use large single-tray units which are much easier to clean and control. A successful design used is to have the arm carrying the rakes above the liquor level, the rubber-blade rakes being attached to hanging rods and freeto trail along the bottom. Mud offtake can be either at the centre or from side outlets, and i. is common to control the outflow by a timer. The mud is usually washed in a counter current washing system.

The tendecy is to use single tray units instead of multitray, to obtain better control of efficiency. The number of stages used is an economic balance between capital cost, cost of soda, and cost of fuel for evaporation of wash water. Five or six stages are common but some plants use ten.

Water Cycle

Washing of the residues to avoid loss of soda involves addition of water to the circuit and obviously there must be a corresponding removal somewhere. Figure A6 shows in simple form the water cycle.

Water enters, in the ore as free moisture and as water of hydration of the alumina, for mud washing general floor

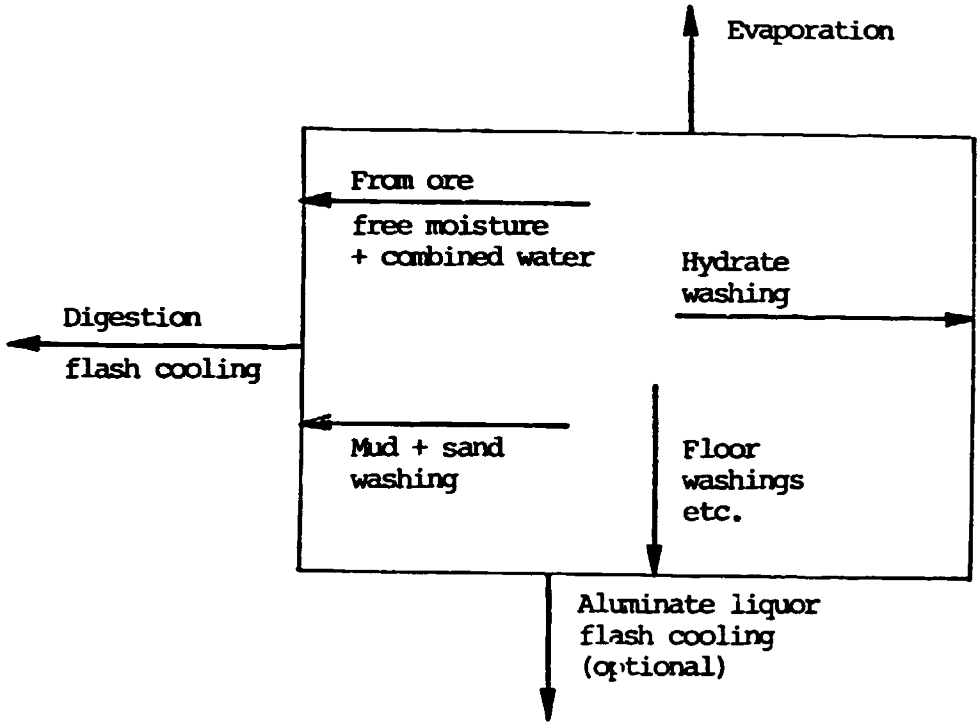


Fig. A6

WATER CYCLE

washings, and for hydrate washing. It is removed as moisture with sand and mud, and as free moisture and water of hydration in the hydrate filter cake, ultimately lost during calcination.

By far the dominating factor is the water put into the circuit for mud washing, which amounts to three to four cubic metres of water per ton dry mud, if no red mud filtration is used. To preserve the water balance some form of evaporation plant is necessary. For this purpose conventional evaporators or flash evaporators can be used. The usual practice is to evaporate liquor returning to the extraction step in conventional multistage evaporators. The evapotation rate and the type of evaporator is determined in connention with the heat economy of the process.

At the extraction end of the cycle high temperature and relatively high soda strength is required to dissolve the alumina and at the other end a low temperature and weaker liquor is required to obtain as big a deposition of hydrate as is economically practicable.

Liquor Impurities

There is one more vital cycle-this is the liquor impurities cycle. The main impurity in works liquors is sodium carbonate produced by degradation of organic matter in the ore, and from the raction of the calcite and dolomite content of bauxite with the caustic liquor. Liquors in European plants usually contain about 12 % - 15 % of the total soda in the form of carbonate. The pick up of carbon dioxide is quite considerable where open red mud slurry ponds are used and this enters the liquor circuit in the pond water used for mud washing.

Bauxite contains many elements in small quantities and several of these form soluble compounds when treated with caustic and appear as sodium salts in the liquors. The liquors contain vanadates, phosphates, arsenates, fluorides, gallium and a few other inorganic salts, and several kinds of organic compounds from the organic matter in the ore.

All these impurities tend to accumulate in the liquors and hence the use of some purifying processes may be necessary. The balance is usually maintained by treatment of part of the liquor with lime which precipitates the acid radicals as calcium salts. The particular liquor chosen and the quantity treated must be such that the carbonate and other salts causticised are suffiecient to preserve the balance, while on the other hand, simultaneous losses of alumina due to calcium aluminate formation are minimised.

A portion of this lime sludge may return to the clarification filters as filter aid and ultimately all the sludge arrives in the mud washing circuit for ultimate disposal.

In plants treating monohydrate or the extraction liquor concentration must be upwards of 150-200 g/l caustic Na_2O and when producing this in the evaporators some of the carbonate is thrown out of solution. Part of this remains as a deposit on the tubes and consequently gradually reduces the heat transfer coefficient and it is therefore necessary to wash the tubes periodically, perhaps every 96-120 hours.

Conversion of Hydrate of Alumina

The final stage in the production is the conversion of the Bayer hydrate to alumina. This is done in rotary calciners or stationary kilns fired with either fuel oil or natural gas.

The product slurry originating from the deceomposers is filtered on rotary disc or drum vacuum filters using either metal or, recently, polypropylene cloth. The cake is spray washed with condensate and the final cake contains about 8-12 % of free moisture. This, together with the combined water in the hydrate, gives a furnace feed.

The physical and chemical changes that occur in the calcination process are subjects of a number of papers. Briefly, the first effect in that of drying off the free water and the next is dehydration of the trihydrate to dehydrate alumina. This occurs over a range of temperature of about 180-600 °C.

The rate of release of the water at this stage is so rapid that self-fluidisation of the charge occurs in this section of the kiln. In fact the hydrate appears to be boiling and flows like water and one of the main arts of kiln design is to control this process. It is usual to provide a desiccating section, unlined and fitted with alloy steel lifter plates, eas baffles etc: to promote heat transfer. The remaider of the kiln is lined with relatively high alumina brick and is provided with a number of brickwork dams to retard the rate of passage of the alumina down the kiln. The dehydrated alumina in the middle portion of the kiln is principally in the form of active alumina and this persists up to a temperature of 900-1000 °C. Further calcination up to 1200-1300 °C converts this to the non-absorbent alpha form, i.e. fluory type alumina.

Alumina calcined up to about 1000 °C retains the physical nature of dry hydrate, is runny, and has a low angle of repose but during conversion to alpha and further heating, physical changes involving recrystallisation occur which lead to a more fluor-like product of higher angle repose. American reduction plants prefer the "sandy" type which may contain up to 1.5 % residual water but traditional European users demand the floury non-absorbent product.

Many alumina works produce alumina for other purposes than reduction (for example, for abrasives and refractories) and for these the kilns must be run under specially controlled conditions to ensure the correct degree of recrystallisation.

Because of the boiling phenomena and the general physical size of material, the exit gases have a very high dust content, and an elaborate dust treatment plant is absolutely essential. The gases are first passed through multiclones, then the suction fan, and finally, electrostatic precipitators.

The dust is recycled back to the kiln usually mixed with feed hydrate. The dust recirculating load can be 2-10 times the kiln output.

The hot alumina is cooled in recuperator coolers, often of the satellite type, with supplementary water cooled tubular of fluidised coolers, screened and transferred to bulk silos.

The newest constructions are the fluid bed calciners and the so-called gas suspension calciners. The benefit of these types of calciners is the lower energy consumption, but the breakage of the hydrate during calcining is higher than that of in the rotary kilns.

Measurement and Control

There is, of course, considerable use of instrumentation and automatic control techniques. These are very much affected by the tendency of many of the plant liquors to deposit scale and special designs are required to ensure continuity of operation of the sensors.

Detection of level is best carried out by reaction or a differential pressure cell, the tappings being continuously purged by non-scalling liquors, water, or air. Pressure detection is carried out similarly.

Liquor and slurry flows can be measured using electromagnetic flowmeters and there are and reasonable successes with radiation density meters for measuring slurry consistencies.

One important property of aluminate liquors is that the boiling point elevation at a given soda concentration is not affected by alumina is solution nor by solids in suspension. Hence it is possible to monitor soda concentration, for example in the evaporator plant, by means of a differential thermometer.

The key point of control is the correct proportioning of the ore and liquor fed to the extraction plant.

There is a tendency towards using computer control of the circuit but, so far the normal practice is to have a number of individual control rooms, such as for extraction, mud separation, evaporation, and calcination.

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Attachment 2

Bench-scale tests of the Characteristic Bauxite Samples

Attachment 2

1. ORIGIN, CHEMICAL AND PHASE COMPOSITION OF SAMPLES

In this report the processing of characteristic samples ICS-2 and ICS-3 are reviewed.
The lumpy bauxite samples marked ICS-2 and ICS-3 amounting to 10 kg each have been crushed in a jaw crusher first then in the hammer mill and finally ground to less than 90 µm in a ball mill. Their grain size distribution is indicated in Table A2-1 and Fig. A2-1. Grinding fineness was chosen to be 90 µm because this grain size is yet sufficient for the digestion of diasporic bauxites by the Bayer process and the soda-lime-sintering of the same, respectively, too. Instructions of the Soviet pyrogenic plants determine this parameter by specifying the 88 µm sieve residue to be maximum 10 %. Chemical composition of these samples are given in Table A2-2. the phase composition, however, in Table A2-3.

It can be established that while sample 2 can be regarded as good quality bauxite /M = 6.89/, sample 3 represents poor quality ore /M = 3.77/. Iron content of samples particularly that of sample 3 is high /17.5 % and 22.1 %, respectively/. High CO_2-content is not of advantage, however, the V_2O_5-content is worthy of attention. The Al_2O_3-content of samples is mainly present as diaspore, however, considerable amounts are bound to chamosite and clay minerals /kaolinite, illite, halloysite/, too.

Table A2-1

Grain size distribution of characteristic bauxite samples /ICS-2 and ICS-3/ after grinding in water to less than 90 /um, %

Grain size /um	ICS-2 /M = 6.89/	ICS-3 /M = 3.77/
80-90	1.0	1.1
63-80	2.1	2.2
40-63	1.3	1.1
25-40	7.0	6.5
-25	88.6	89.1

GRAIN SIZE DISTRIBUTION, %, OF BAUXITE SAMPLES ICS-2. AND ICS-3. AFTER GRINDIG IN WATER TO GRAIN SIZE LESS THAN 90 um

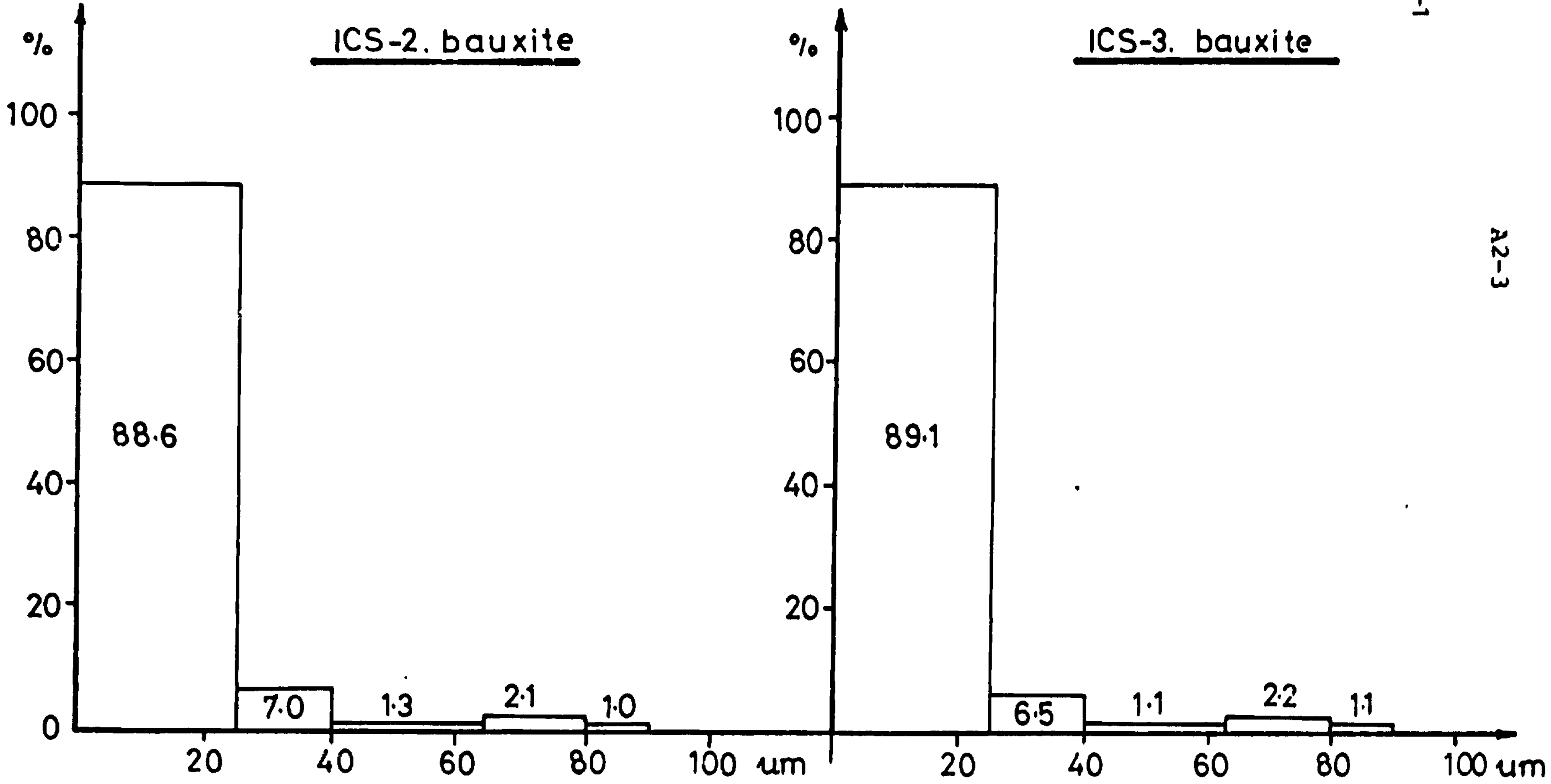


Fig.A2-1

Table A2-2

Chemical composition of characteristic bauxite samples /ICS-2 and ICS-3/

Sample	Al_2O_3 %	SiO_2 %	Fe_2O_3 %	CaO %	MgO %	Na_2O %	K_2O %	S %	TiO_2 %	CO_2 %	P_2O_5 %	V_2O_5 %	Cr_2O_3 %	LOI. %	C_{org} %	Module
ICS-2	52.4	7.6	17.5	1.5	0.4	0.12	0.20	0.04	6.3	1.60	0.20	0.12	0.006	12.5	0.14	6.89
ICS-3	44.2	11.7	22.1	1.6	0.3	0.06	0.40	0.08	5.6	2.57	0.16	0.11	0.03	12.4	0.12	3.77

Table A2-3

Phase composition of bauxite samples ICS-2 and ICS-3

Sample		ICS-2 /M=6.89/	ICS-3 /M= 3.77/
Al_2O_3 % in	gibbsite	-	1.4
	diaspore	45.1	32.2
	clay minerals*	6.9 /cham.2.7/	10.2 /cham.2.0/
	hematite	0.2	0.2
	crandallite	0.2	0.2
	total	52.4	44.2
SiO_2 % in	clay minerals*	7.6 /cham.2.7/	11.7 /cham.2.0/
Fe_2O_3 % in	clay minerals*	5.0 /chamosite/	3.7 /chamosite/
	goethite	1.0	2.0
	hematite	10.6	14.4
	siderite	0.9	2.0
	total	17.5	22.1
TiO_2 % in	anatase	4.7	4.1
	rutile	1.6	1.5
	total	6.3	5.6
CaO % in	calcite	0.8	1.5
	dolomite	0.2	-
	crandallite	0.1	0.1
	total	1.1	1.6
MgO % in	dolomite	0.1	-
	clay minerals*	0.4 /chamosite/	0.3 /chamosite/
	total	0.5	0.3
P_2O_5 % in	crandallite	0.2	0.2

* Note: in kaolinite and chamosite

2. LIABILITY TO COMMINUTION AND GRINDING OF ORES /1/

The tests were aimed to find out the feature of ores during comminution /crushing/ and grinding, moreover the change of grinding fineness while grinding in ball mill in alkaline medium.

2.1 Crushing tests

The tests were carried out with the sample ICS-3 in a jaw crusher first and then in a hammer mill. Bauxite was crushed at a performance rate of 6 kg/h with a jaw crusher featuring a gap of 8 mm. Crushed material was classified by a set of screens. The particle size distribution is given in Table A2-4 and similar figures relative to bauxites of other types and origin are also indicated for comparison.

Precrushed material was further comminuted om a hammer mill provided with a screen plate with the aperture of 1 mm. Crushing performance was 5 kg/h. Screen analysis of the crushed material is as follows:

diameter mm	mass %
+ 0.50	12.3
+ 0.20	33.5
+ 0.09	51.9
- 0.09	48.2

On basis os the comminution tests the material could be graded as a hard substance rather difficult to crush. At the same time the particle size distribution of the fractures is considered to be favourable. This is due to the brittleness of the material - apart from its hardness - thus upon a mechanical effect /particularlay the impacting effect of the hammer mill/ it gets easily comminuted.

Table A2-4

Grain size distribution, %, on comminuting different kind of bauxites

Origin and type	+ 3.15 mm	+ 2.00 mm	+ 1.00 mm	+ 0.50 mm	- 0.50 mm
Iranian bauxite ICS-3 /diasporic/	3.6	21.2	45.0	60.2	39.8
Boké bauxite /Guinea, gibbsitic/	6.9	33.8	57.8	65.5	34.5
Kincsesbánya bauxite /Hungary, boehmitic/	6.2	24.0	48.0	61.8	38.2

Note: Performance of comminution is 6 kg/h with the Iranian sample and 10 kg/h with the other ones

On carrying out plant scale operation heavy wearing of hammers and screen plate has, however, to be reckoned with.

2.2 Grindability tests

From the point of view of the characterization of materials to be ground the resistance to mechanical load and grindability, respectively, is of primary importance. The measure of grindability should indicate the result of comminution relative to the unit of energy consumption. Simplifying the problem, the result of comminution is characterized, apart from accepting the Rittinger priciple, i.e. the relation between the energy consumption and surface increment, by the increment of specific surface and the grade of dispersity, respectively.

Were

$$S = k \cdot W;$$

where: S = new surface area produced,
W = energy consumed,
k = proportionality factor

then the grindability would read: $k = \frac{S}{W}$

This provides the magnitude of new surface area produced on the expense of unit energy consumed.

Hardgrove method

Principle of method: The procedure is based on the Rittinger rule declaring that the energy consumed to grinding is proportional to the new surface area produced. With practical application a determined amount of energy is transferred to the sample adequately prepared and the result of grinding i.e. the extent of getting finer is determined by sieving.

Feature of the testing device. The grinding device consists of a lower grinding bowl. Eight nos of 25.4 mm diameter steel balls are placed uniformly in its circular race-way on the bottom. The balls are rolled by a rotating disc impsing an accurate load /28.9 ± 0.22 kg/ from above. Grinding is effected by the compressive and frictional effect. After 60 nos of revolution the device is automatically switched off.

Implementation of the test: Prior to testing the material has to be dried to constant weight then precrushed to within 0.59 and 1.19 mm particle size. Confinement is performed by suitable sieves. Particles greaterh than 1.19 mm should repeatedly be crushed as long as they fall through. Grains smaller than 0.59 mm are not involved in the test. Fifty grams of the dressed material should be placed into the grinding area uniformly spread in the circular race-way amongst the grinding balls.

After 60 revolutions of the grinding disc ground sample has to be sieved through a 74 μm aperture sieve and the oversize and undersize be determined.

Calculation of results: As already mentioned, the Hardgrove method is based on the Rittinger rule. Accordingly, the grindability index of the material tested would be:

$$H_i = \frac{S}{S_o} \cdot 100;$$

where: S = increase of specific surface area /m^2/kg/

S_o = increase of specific surface area /m^2/kg/ occurring in the course of grinding of the reference standard material

The reference standard material is the anthracite coal originating from the St.Jerome shaft /Sommerset, USA/, the increase of specific surface area amounts to 56.5 m^2/kg. The grindability of this kind of coal amounts to 100 %.

With practical tests instead of considering the increment of surface area an empiric formula has been set up according to which:

$$H_i = 13 + 6.93.W$$

where: W represents the 74 μm sieve undersize /g/ material resulting from 50 g of ground sample.

Higher H_i represents better grindability. The final result is calculated from three parallel tests by making the arithmetical mean. Deviation of individual findings must not exceed 20 %, otherwise the test has to be repeated.

Hardgrove index number of the ICS-3 Iranian sample amounts to 58. In Table A2-5 H_i-numbers of other kind of bauxites are also given for comparison. /It should be noted that the scale is not linear, i.e. an H_i twice as high does not mean twice as good grindability!/

On basis of the index number the material is hard to grind.

2.3 Grinding tests with digestion liquor

This method was developed for modelling the industrial process. The grinding tests were made with caustic liquor on the ICS-3 sample in a 5 litres capacity laboratory ball mill with a ball charge of 5 kg/mixed diameters ranging from 10 to 30 mm/ at a revolution of 65/min. Starting material was that crushed in the hammer mill which was

Table A2-5

Grindability of different kind of bauxites by the Hardgrove method

Origin and type	H_i
Iranian bauxite ICS-3 /diasporic/	58
Boké bauxite /Guinea, gibbsitic/	93
Ghana bauxite	58
Gujarat bauxit /India/	51
Kincsesbánya bauxite /Hungary, boehmitic/	136
Bakony bauxite /Hungary, boehmitic/	111

mixed with plant liquor /Na_2O_c = 193.2 g/dm^3, molar ratio = 3.05/ to produce a slurry with solids concentration of 300 g/l. Three kind of grinding fineness was intended to set during the grinding tests i.e. 160, 100 and 63 /um as upper grain limit. Grinding was performed as long as no sieve residue remained with the sieves mentioned.

Grinding times required in order to attain at the corresponding fineness are as follows:

160 /um	1.5 hours
100 /um	3.0 hours
63 /um	4.5 hours

In Table A2-6 the time requirement for grinding several types of bauxite to grain size less than 160 /um are indicated. Then various fractions of bauxite sample ICS-3 were separated on the wet screen. The grain size distribution is given in Table A2-7. Grinding with digestion liquor to grain size less than 100 /um has been repeated at various solids concentrations i.e. 200, 300, 400, 500, 600 and 800 g/dm^3. The results are given in Table A2-8.

According to the grinding tests carried out with digestion liquor, on increasing grinding fineness the time devoted to grinding increases nearly linearly. This means that in this range of fineness the disproportionate energy demand not yet occurs as it often was experienced with grinding procedures to great fineness. This can in all probability be attributed to the wet or alkaline media hindering aggregation.

2.4 Dry grinding tests

It was aimed, apart from testing the grinding character

Table A2-6

Time requirement /min/ for grinding in digestion liquor of different kind of bauxites to grain size less than 160 μm

Origin and type	Time, min.
Iranian bauxite, ICS-3 /diasporic/	90
Boké bauxite /Guinea, gibbsitic/	75
Tatabánya bauxite /Hungary, boehmitic/	45
Bakony bauxite /Hungary, boehmitic/	70
Kincsesbánya bauxite /Hungary, boehmitic/	45

Table A2-7

Grain size distribution, %, of the individual fractions after grinding with digesting liquor of bauxite sample ICS-3

Size, µm	Ground to 63 µm	Ground to 100 µm	Ground to 163 µm
125-160	-	-	4.8
100-125	-	-	3.7
80-100	-	1.8	8.0
63-80	-	0.9	11.0
40-63	1.6	3.0	15.0
25-40	5.4	8.0	23.2
25	93.0	86.3	34.3

Table A2-6

Time requirement of grinding to grain size less than 100 μm of bauxite sample ICS-3 in function of solids concentration in the course of grinding with digestion liquor

Solids content, g/dm^3	Grinding time, min.
200	185
300	180
400	180
500	185
600	170
800	175

of the material, to dress and prepare the samples required for the experiments. The tests were carried out with the bauxite samples ICS-2 and ICS-3 int the ball mill outlined with the grinding with digestion liquor. After grinding for 1 hour each the substance was sieved through a 160 μm sieve. Sample ICS-2 resulted in 50 % oversize material and sample ICS-3 in 55 % oversize material. Another mill of size Ø 400x400 mm with cylpebs charge was also used and bauxite samples were ground for 1 hour. The 63 μm sieve oversize material was 43 % for sample ICS-2 and 40 % for sample ICS-3. The samples exhibited strong adhesion and became strongly deposited on the wall of the mill and the surface of milling media. In order to decrease adhesion a surfactant /triethanol amine/ was added in an amount of 0.1 %, even then the samples could not entirely be ground to below 63 μm.

The minus 63 μm fractions: for ICS-2 sample = 35.8 %
for ICS-3 sample = 34.4 %.

Based on the experiments the dry grindability of both samples is considered to be poor, however, they feature equal characteristics.

2.5 Grinding tests with the use of water

It was aimed to scrutinize the grinding feature only, its industrial application is out of the question.

The tests were carried out similarly with the same samples in the 5 litres capacity ball mill by the use of water at a solids concentration of 400 g/dm^3. On grinding for 5 hours each a fineness of 90 μm could be achieved with both samples. This indicates a very difficult grindability.

2.6 Summary of the grinding tests

On summarizing the crushing and grinding tests it can be established that

- samples ICS-2 and ICS-3 exhibit equal properties,
- in plant scale processing of the ores high abrasion of the crushing and grinding units have to be reckoned with,
- dry grinding of materials causes problems /due to considerable aggregation/ and grinding to grain size less than 63 μm could not be performed even on the addition of a surfactant /grinding aid/,
- grinding in water can be performed to a fineness of minus 90 μm, however, at the expense of long time and high energy requirement,
- with the grinding with digestion liquor counting for industrial application the performance of ball mill decreases proportionally to the increase of grinding fineness, i.e. the specific energy demand increases,
- the most suitable grinding system is the following: grinding of bauxite in the jaw crusher, then in the hammer mill and finally grinding with digestion liquor in the ball mill at a solids concentration ranging from 600 to 800 g/cm^3,
- grinding solids concentration practically does not influence the time and energy demand of grinding in the range of 200-800 g/dm^3,
- the Hardgrove index number for the sample ICS-3 is 58 being a characteristic figure for hard to grind bauxites. Sample ICS-2 exhibits crushing and grinding properties similar to those of sample ICS-3,
- grain size distribution of samples ICS-2 and ICS-3 ground to below 90 μm is represented in Table A2-1 and Fig. A2-1; about 89 % of the samples are of grain size less

than 25 /um,
- from the point of view of both the desilication and digestion the grinding fineness/minus 90 /um/ is considered to be sufficient.

Literature

/1/ Mrákovicsné, Török K.: Grindability tests. SZIKKTI, Scientific Publications. Budapest, 1988.

3. Bench scale investigations on Iranian bauxite processing by sintering process

Some tests for orientation were carried out on a bauxite sample having an Al_2O_3/SiO_2ratio of 5.5. Later on more detailed tests were perfected by a representative sample marked "ICS3" composited and sent to Institute VAMI by Aluterv-FKI. The Al_2O_3/SiO_2 ratio of the sample "ICS3" was 4.1.

3.1. Tentative bench scale tests on bauxite sample with Al_2O_3/SiO_3 ratio of 5.5

The bauxite received first was sampled. The chemical composition of the four samples obtained was determined. The measured data and their mean values are given in Table A2-9.

The mineralogical composition of the bauxite sample was identified by X-ray diffractometry (XRD) as it follows: diaspore, kaolinite, clorite, mica, hematite, anatase, ilmenite, calcite.

Based on these data the bauxite was ranked as suitable for producing alumina by sintering process [2].

When the sodium carbonate (soda) and limestone dosage is calculated for the sinter feed composition so as to obtain a sinter consisting of water-soluble sodium-aluminates and sodium-ferrites and insoluble dicalcium-silicates [3].

Table A2-9

Chemical composition of Iranian bauxite sample

Denomination	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	K_2O	$\frac{Al_2O_3}{SiO_2}$ ratio	L.O.I.	SO_3
1-st sample	8.4	45.9	24.2	5.4	2.5	0.54	5.5		
2-nd sample	8.4	46.1	24.9	5.5	2.5	0.54	5.5		
3-rd sample	9.0	45.9	24.4	5.4	2.5	0.53	5.4		
4-th sample	8.4	45.8	24.2	5.4	2.5	0.53	5.5		
Mean value	8.4	45.9	24.4	5.4	2.5	0.53	5.5	12.9	not observed

(L.O.I.: Loss on ignition)

If raw material is bauxite, on the calculation of limestone dosage the bauxite TiO_2-content is neglected provided that it does not exceed 2.5 %, since very small amount of CaO forms perowskite ($CaTiO_3$), and formation of Ca-Na-silicates does not hinder the extraction yield of main constituents [4].

Titania content of the given bauxite sample was 5.4 %. Consequently it was necessary to clarify whether or not to consider the perowskite formation when calculating the limestone demand in the sinter feed composition. The sinter process and the leaching of the main components were compared to the regular limestone dosage.

Two mixtures were composited for these tests.

For the first mixture limestone and soda dosage were calculated by the following molar ratio formulas:

$$\frac{Na_2O}{Al_2O_3 + Fe_2O_3 + SO_3} = 1; \qquad \frac{CaO}{SiO_2} = 2$$

For the second mixture the molar ratio formulas used, respectively:

$$\frac{Na_2O}{Al_2O_3 + Fe_2O_3 + SO_3} = 1; \quad \frac{CaO}{SiO_2} = 2; \quad \frac{CaO}{TiO_2} = 1$$

The sinter feed was composited by the following method: the bauxite, the calculated amount of soda and limestone were mixed, the mixture was crushed in a laboratory porcelain mortar until min 90 % were less than 0.088 mm. The crushed mixture was briquetted by hand-press and the briquettes were sintered in a laboratory furnace.

A holding time of 45 minutes was used uniformly at the sintering temperature. Both composition of sinter feed were treated (sintered) at temperatures of 1100, 1150, 1175 and 1200 ^{o}C.
The sintered samples were leached by a standard method for measurement of the extraction yield of the main constituents at favourable leaching conditions.

The standard leaching procedure was carried out at a temperature of 90 ^{o}C with a solids to liquid ratio of 1:10 and it lasted 15 minutes. Week alkaline solution (0.5 mole NaOH) was used as solute in order to get an aluminate liquor with a Na_2O/Al_2O_3 molar ratio of about 1.5.

The extraction yields calculated from the chemical composition of the sintered and mud samples are shown in Table 2-10.

Table 2-10

Extraction yields, %

Temperature °C	1100		1150		1175		1200	
	Na_2O	Al_2O_3	Na_2O	Al_2O_3	Na_2O	Al_2O_3	Na_2O	Al_2O_3
1-st mixture	95.9	92.3	96.6	93.1	96.5	92.6	95.4	92.8
2-nd mixture	94.5	92.3	95.9	93.0	95.06	93.2	93.03	93.8

The observed high extraction yields show that the desired phase formation reactions take place almost completely still at 1100 °C.

The test results in the temperature range of 1100-1175 °C indicate that the higher the sintering temperature is the higher extraction yields are obtained, however, at 1200 °C the yields slightly decline. Decline of the extraction yields indices at 1200 °C can be interpreted by increasing part of the solids that melts during the sintering treatment.

The extraction yields of sinters resulted from the 1175 and 1200 °C treatments were compared. Although the Al_2O_3 extraction yields were less, but the sodium recovery was 1.5-2.4 % higher as the sinters, in which the limestone had been added for only to the silica content compared to the mixtures, in which the limestone dosage had been was calculated by taking both the silica and titania content of the bauxite into consideration.

The XRD patterns show that sinters obtained from the first set of mixtures are solid phase solutions of sodium-alumoferrite, perowskite, β-dicalcium-silicate and sodium-calcium-silicate phases. In sinters resulted from sintering treatment at 1100 °C negligible amount of α'-C_2S (i.e. alpha'-dicalcium-silicate) was observed. This α'-C_2S phase partly desintegrates even during the standard leaching and calcite forms as secondary phase. The iron-oxide was found only as sodium-alumo-ferrite in the solid phase solution.

It is characteristic for the sinters obtained from mixtures in which the limestone had been dosaged for both the silica and titania, that these sinters contained more amount of α'-C_2S. The α'-C_2S phase is considerably more than the β-form in the sample treated at 1100 °C.

Though sinter resulted from 1175 °C treatment contained less α'-form than β-form, the amount of α'-form is more compared to the samples originate from mixtures in which limestone were dosaged only to the silica.

The secondary calcite content in the mud samples resulted from standard leaching is proportional to the α'-dicalcium-silicate contents of the sinters. Two-base calcium-ferrite formation is an additional feature of sinters. The two-base calcium-ferrite decreases the sodium-ferrite content in the solid phase and increases the sodium-calcium-silicate at the same time, thus reducing the sodium recovery from the sinter.

As observations imply, limestone dosage for both the silica and titania results in two significant negative side-effects during sintering. The first is the formation of α'-form of dicalcium-silicate that leads to secondary sodium and alumina losses, especially during leaching, and the other is the calcium-ferrite formation that results in less sodium recovery.

Consequently further tests were done by mixtures in which limestone was dosaged for only to the silica, calculated from dicalcium silicate formation in sintering.

3.2. Bench scale tests on the representative sample

Further investigations were done by the representative Iranian bauxite sample.
Chemical composition of the sample is shown in Table A2-11
The mean composition was used for calculating the mixture composition.

Table A2-11

Chemical composition of the representative Iranian sample

Denomination	SiO_2	Al_2O_3	Fe_2O	TiO_2	CaO	K_2O	$\frac{Al_2O_3}{SiO_2}$ ratio	L.O.I.	SO_3
1-st sample	11.5	47.4	20.8	5.4	1.3	0.6			
2-nd sample	11.6	47.3	20.6	5.4	1.3	0.7			
3-rd sample	11.5	47.2	20.6	5.4	1.4	0.6			
4-th sample	11.7	47.7	20.7	5.3	1.4	0.6			
Mean value	11.6	47.4	20.7	5.4	1.35	0.6	4.1	12.5	0.14

These figures agree with chemical composition of sample marked "ICS3".
Limestone and soda dosage for further sitering tests were calculated with the following formulas:

$$\frac{Na_2O}{Al_2O_3 + Fe_2O_3 + SO_3} = 1; \quad \frac{CaO}{SiO_2} = 2$$

3.2.1. Rheological testing of bauxite slurries

It is known that water content of the sinter feed affects to a great extent the capacity of the sintering kilns and the specific heat consumption of the process step. 1 % decrease in moisture content of the sinter feed results in a 2 % specific heat consumption saving. Therefore it is desirable to keep the moisture content of the sinter feed as low as possible. The attainable lowest moisture content is determined by hydro-transport tests, so as the slurry be pumped from the mill discharge tank, from the following tanks and be pulverised through the pulveriser head of the kiln feed.

Alumina-containing mixtures to be sintered have a non-Newtonian character. These fluids unlike the Newtonian ones have no permanent viscosity. Their viscosity depends on the shear forces and increase in force causing a decrease in viscosity as the structure of the fluid destructs [5,6].

Rheology of the non-Newtonian fluids are characterised by structural viscosity, ultimate displacement stress, plastic viscosity etc.

In this investigation a quick evaluation method was used, as it is described in a more detailed form.

A ring having a diameter of 35 mm and a height of 35 mm was placed onto a horizontal flat surface. The dry composites were mixed with water for preparing mixtures with various moisture contents. The mixture was then heated to a temperature of 60 °C. The ring was filled with slurry, and after removal of the ring the spreading of the slurry was measured. Mixtures with moisture contents of a range from 36.5 to 41.3 % were tested. Results showed that mixtures with moisture contents of above 39 % flow away in every direction and form a circle with the diameter of 70-86 mm. These results are similar to those of the mixtures of the existing Soviet plants.

3.2.2. Investigations during heating of mixtures

Experiments were carried out in order to clarify the temperature range of sinter formation and determination the melting point. A dilatometer with a construction of VAMI's own was used for the tests. The temperature and height of the briquettes were automatically recorded as heating progressed by this equipment. For this purpose briquettes with a diameter of 11 mm and height of 12 mm were pressed. When sintering process was studied the rate of heating was 15-20 °C/min up to 700 °C and then 5-10 °C/min.

Test results show that variations in height change with increasing temperature (Fig.A2-2). At the beginning the height increases possibly due to the linear thermal expansion. Then the rate decreases and this phenomenon can be characterized by the slope of the curve with respect to the

Graph of dilatometration

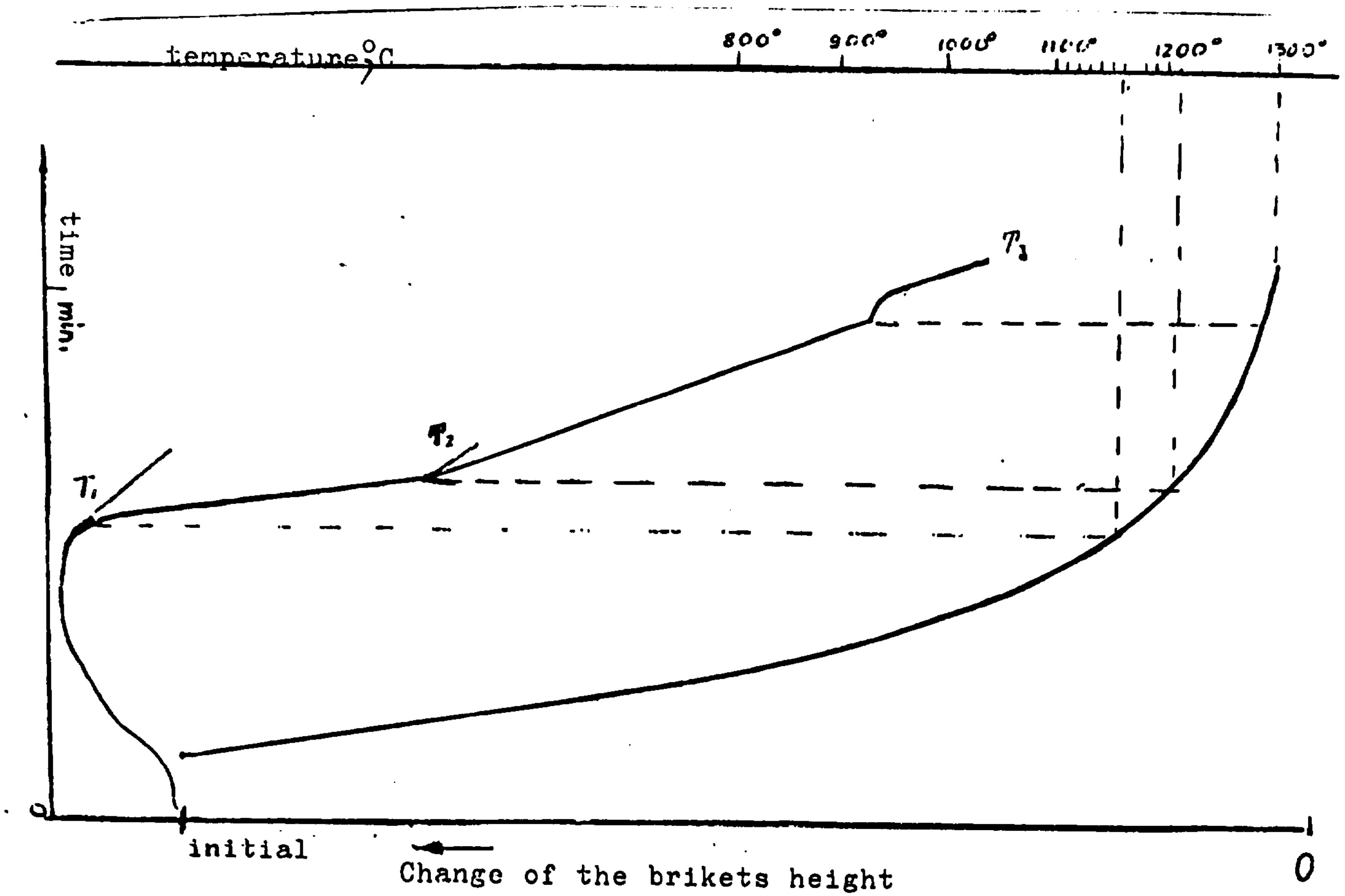


Fig.A2-2

time-axis. The negligible rate of contracting can be a consequence of the increasing surface tension and/or of release of gases from solid-phase reactions among the mixture constituents. The increasing speed of contracting is a sign of softening and melting of the material.

The initial temperature of sintering (contracting) (T') and melting point (T^3) was determined from the recorded curves.

T^2 represents a temperature where the rate of contracting slightly decreases due to the end of melting of the eutectic mixture (sodium-ferrite-dicalcium-silicate), that forms in insignificant amount during heating.

Temperature range of sintering is the difference between the melting point and the initial temperature of contracting. In this case $T^3-T^1 = 140\ ^{o}C$ was found.

3.2.3. Sinter feed testing by thermogravimetry

Sample from mixture for sinter feed was measured on a Derivatograph of the Hungarian firm, MOM, up to 1000 ^{o}C with an aim of studying the thermal effects that accompany the heating process. 1000 mg charge and 8-9 ^{o}C/min heating rate was used.

A thermogram of a mixture prepared with Iranian bauxite is shown on Fig.A2-3. The thermogram endothermic reactions are recorded at temperature of 150 ^{o}C soda loses its cristalline water (dehydration), at 520 ^{o}C diaspore loses its cristalline water, at a temperature of 815 ^{o}C soda melts and desintegrates and at 865 ^{o}C $CaCO_3$ desintegrates.

The mass losses during the heating amounts up to 30.2 %, as thermogravimetric curve (TG) shows.

These results had been taken into consideration when heat consumption of the sintering kiln was calculated.

3.2.4. Grain size distribution of the sinter feed

Completeness of sintering reactions depends on grain sizes of ground mixture. As experience gathered at plants processing low-grade bauxites shows, it is favourable for gaining maximum extraction efficiences to keep the grains higher than 88 µm less than 10 %. Laboratory screen test results are given in Table A2-12.

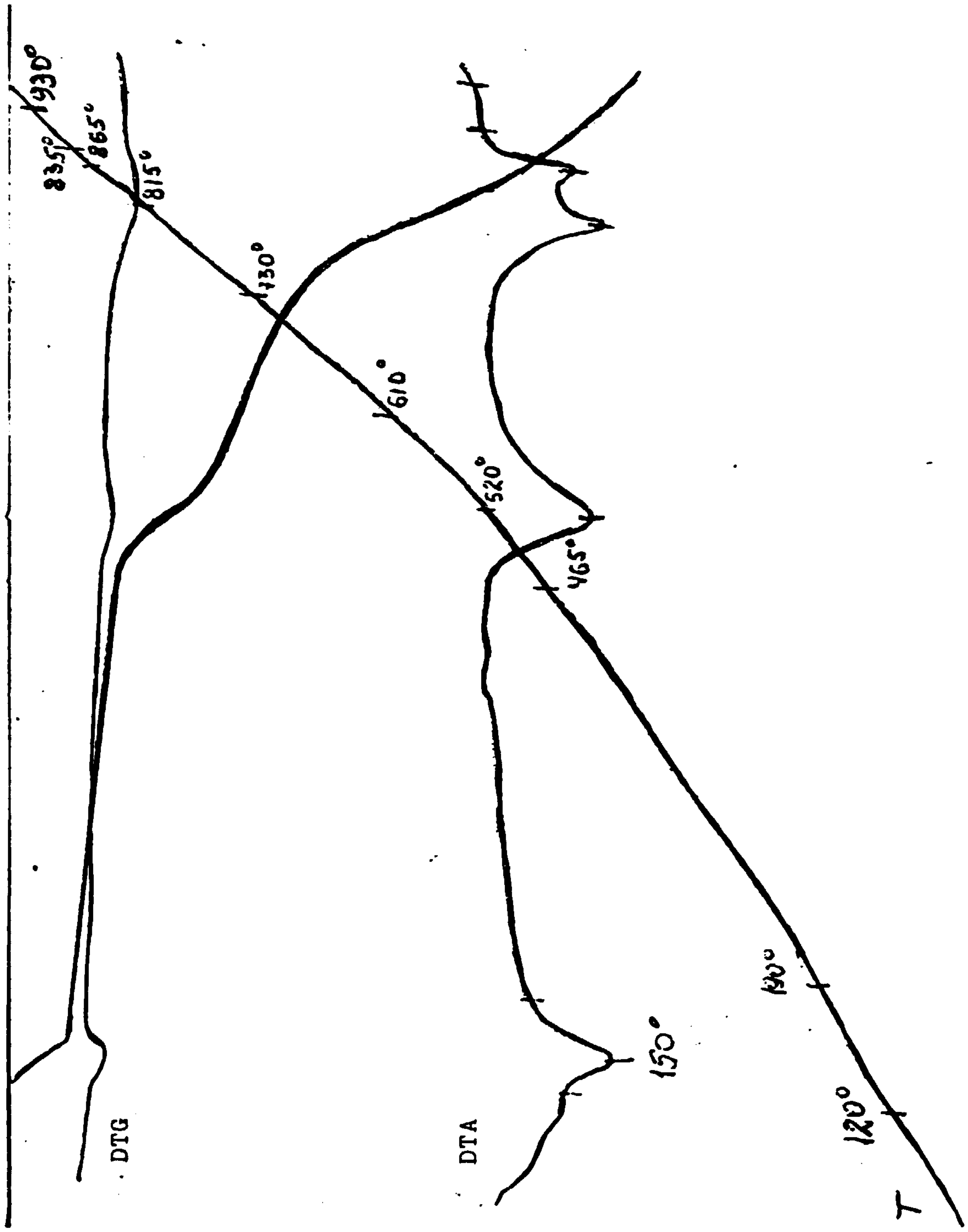
Table 2-12

Screen test results

Screen residue, %	
+160 µm	0.33 %
+ 88 µm	5.86 %
+ 53 µm	9.88 %
- 53 µm	83.83 %

A mixture like given in Table A2-12 is suitable for sintering process.

Fig.A2-3



Thermogram of the bauxite-charge

3.3. Investigations on sintering and leaching processes

3.3.1. Study of the effect of sintering temperature on phase-formation process

Mixtures were composited on the following molar ratios for studying phase-transformation reactions during sintering:

$$\frac{Na_2O}{Al_2O_3 + Fe_2O_3 + SO_3} = 1; \qquad \frac{CaO}{SiO_2} = 2$$

Briquettes made from the mixtures were sintered at temperatures of 1100, 1150, 1175, 1200 and 1230 °C. After this sinters were leached by the standard leaching procedure.

Extraction yields resulted from standard leaching of sinters are given in Table A2-13.

Table A2-13

Extraction yields, %

t °C	1100		1150		1175		1200		1230	
	Na_2O	Al_2O_3	Na_2O	Al_2O_3	Na_2O	Al_2O_3	Na_2O	Al_2O_3	Na_2O	Al_2O_3
yields	95.9	92.4	94.1	93.5	94.4	96.5	96.8	93.1	97.1	94.1

As the results show, high extraction yields were obtained at all sintering temperatures. The maximum yield was obtained at 1175 °C for Al_2O_3, and 1230 °C for sodium.

XRD patterns show that sinters contain solid solution of sodium-aluminate and sodium-ferrite, β-C_2S (β-dicalcium-silicate) and perowskite. The sodium and alumina losses can be interpreted as a consequence of sodium-aluminate formation. In muds obtained from standard leaching method presence of C_2S, calcite and amorphous ferri-hidroxide was observed.

Test results verify, that all main phase-formation reactions take place still at a temperature of 1100 C, and later a recristallisation can be stated.

3.3.2. Porosity tests on sinters

Leaching character depends not only on the mineralogical composition of the sinter, but on its phisical nature, namely on the porosity as well. Porosity (ε) is defined as ratio of pore volumes to total bulk volumes of sinter, expressed in percents. Sinters obtained from bauxite composites have usually small porosity number, their pores have closed character [7].

Measurement method used for determination of porosity of sinters is based on saturation of pores by carbon-tetrachloride.

Porosity of sinters in the function of sintering temperature is shown in Figure A2-4. As results show the higher the sintering temperature is the smaller the porosity of the sinter. A significant decline can be observed at a temperature of 1230 ^oC. If porosity of the sinters are small, water for leaching can not properly reach sodium-aluminate trapped into the sinter. This phenomenon causes alumina losses.

High porosity makes possible for leaching water to reach the surface of dicalcium-silicate. This is advantageous for the secondary reactions and for obtaining higher alumina and sodium losses.

On the basis of tests carried out, an optimum sintering temperature provided to be of 1175-1200 °C.

3.3.3. Technological behaviour of sinters during leaching

Preliminary tests revealed that sinters resulted from sintering at a temperature of 1175-1200 °C are quite suitable for leaching.

Leaching tests were carried out by percolating the coarse sinter. Laboratory leaching unit modelled the large-scale process by using a continuous flow of solution. Filtered liquor from zones were fed to the next zone. Five zones were used. Fig.A2-5 shows the drawing of the laboratory leaching unit.

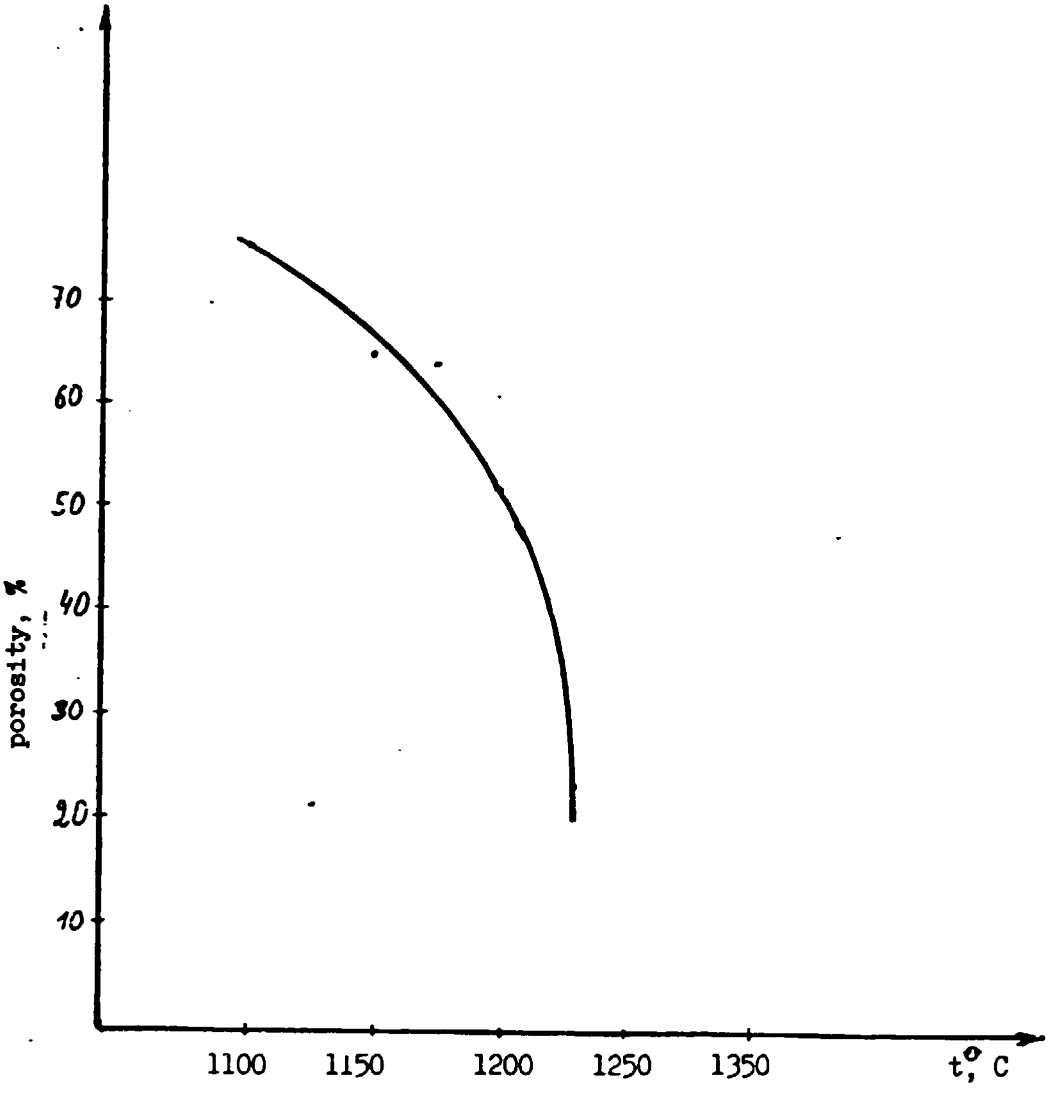
45 grams of sinter was put into a basket that had been placed into the glass. Glass had been filled with aluminate liquor solution previously. Basket was placed into the glass so that some empty volume could get underneath, similar to those of circumstances in large-scale equipment.

Leaching liquors are fed from upwards and are discharged from below the basket.

The described leaching procedure models simulates process conditions in large-scale equipment. Leaching solutions obtained from previous leaching of fine-grain sinter are sprinkled onto the sinter. Liquid to solids ratio is

Fig.A2-4

Change of porosity vs. temperature



selected so that a similar concentration of given stage should be obtained. In the first zone mud is washed by fresh water.

Leached mud is crushed in wet condition. A part of the mud is re-leached at standard conditions at a temperature of 80 °C. This leaching lasts for 10 minutes. Mud is then washed by hot water. Muds after leaching and after the standard final leaching are analysed. Leaching efficiency is calculated from difference between the sodium and alumina extraction yields in muds after normal leaching and muds after final leaching.

Grain size distribution corresponds to those of ones in large-scale plants, as follows:

-8	+7	mm	25.0 %
-7	+5	mm	30.0 %
-5	+3	mm	14.5 %
-3	+2	mm	4.0 %
-2	+1	mm	4.0 %
-1		mm	22.5 %

Na_2O and Al_2O_3 concentration of solutions that enter into a given zone are similar to concentrations in a large-scale plant.

Sinters are leached for 4 hours at a temperature of 85-90 °C. Holding time was 30 minutes in 5th and 4th, 60 minutes is 3rd, 2nd and first zone.

Test conditions and results are summarized in Tables A2-14 A2-15 and A2-16.

Results show that by using continuous leaching of sinters high sodium and alumina exraction yields can be obtained. At sinter resulted from heating at a temperature of 1200 °C, alumina extraction yield is higher by 2 %, than that of sinter treated at 1175 °C. This can be a consequence of more perfect cristallisation of β-dicalcium-silicate from $\alpha'C_2S$ form. This β-form is more inert in contact with aluminate liquor, so secondary alumina losses are bss [8].

As final leaching tests reveal (1-2 % alumina and 3-4 % sodium extraction increase), in continuous leaching some sodium-aluminate and aluminate liquor remains in the pores of the sinter. Al_2O_3 extraction yields obtained after final leaching are less than those of by standard leaching. This imply that secondary reactions take place with hydrogarnet and sodium-alumo-silicate formation.

Higher sodium extraction yield can be a consequence of desintegration of sodium-ferrite.

Continuous leaching proved to be effective proceduers in case of processing Iranian bauxites by sintering. At sinters obtained at an optimum sintering temperature of 1200 °C, expected alumina extraction yields is 91 %, sodium recovery is 95 %.

Aluminate liquor desilication, carbonisation, precipitation and calcination tests were not carried out, since process parameters are independent from the raw material. Design parameters can be determined on plant experience.

Fig.A2-5

Experimental unit for the leaching of the sinter

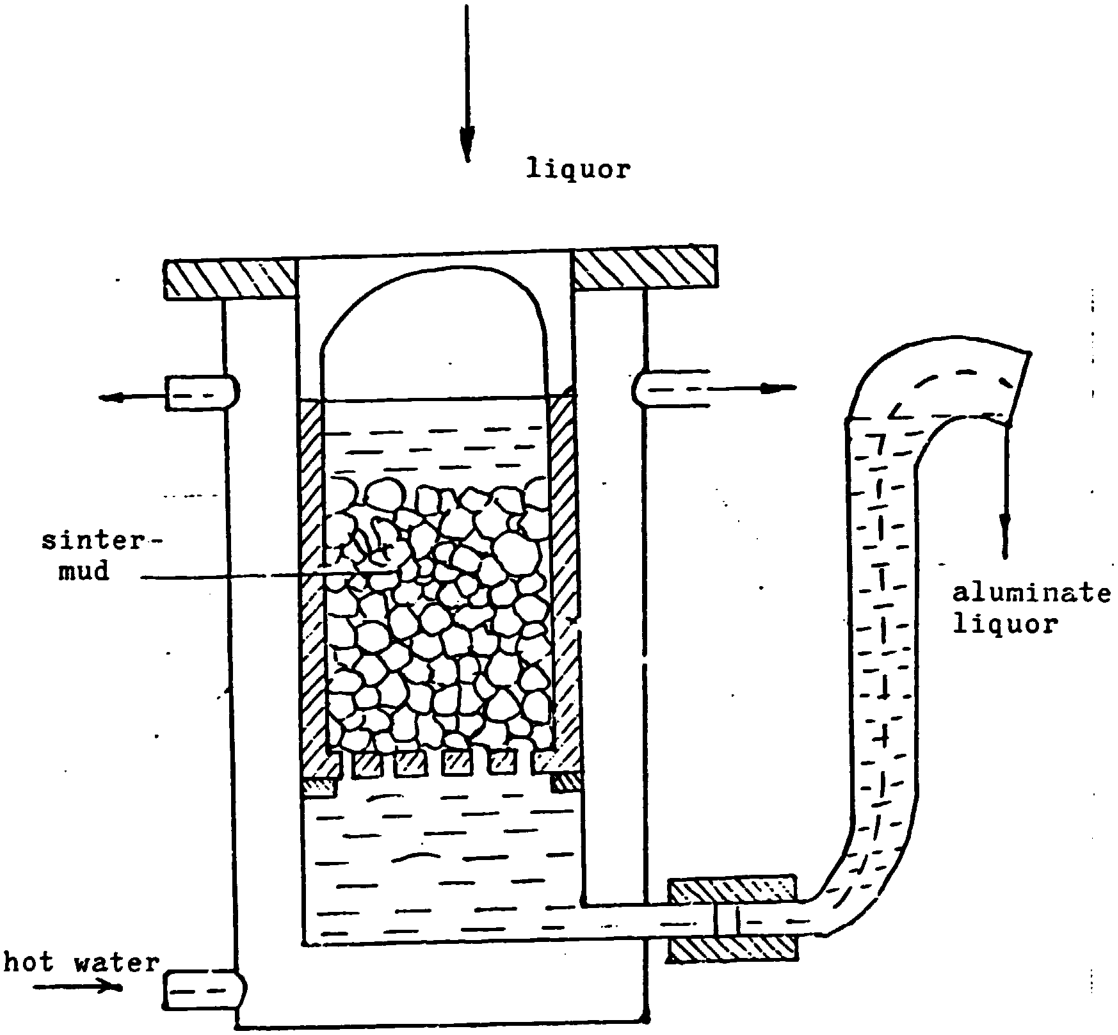


Table A2-14

Continuous leaching test results of sinter No.62
(sintering temperature 1175 °C)

Test serial number	Zone serial number	Leaching solution for zone	Liquor composition, g/dm^3 Initial			Final			return water from mud pond		Moisture content of mud,%
			Al_2O_3	Na_2O_{caust}	caustic molar ratio	Al_2O_3	Na_2O_{caust}	caustic molar ratio	Al_2O_3	Na_2O_{caust}	
1	5	63+85	82.6	82.2	1.64	154.0	138.0	1.45			
	4	70	62.0	62.0	1.65	119.6	110.1	1.51			
	3	70	32.6	40.3	2.03	82.9	77.3	1.54			
	2	70	14.3	22.9	2.60	44.6	46.5	1.71			
	1	70	water			18.2	26.0	2.36	-	6.2	-
3	5	70+85	78.0	80.6	1.70	140.3	127.1	1.49			
	4	85	60.0	60.5	1.66	108.6	100.8	1.53			
	3	80	30.0	33.3	1.83	77.0	69.8	1.49			
	2	80	13.7	15.5	1.87	43.4	40.3	1.53			
	1	70	water			17.6	18.2	1.91	5.2	6.4	59.5

Table A2-15

Continuous leaching test results of sinter No.59
(sintering temperature 1200 °C)

Test serial number	Zone serial number	Leaching solution for zone	Liquor composition, g/dm						return water	from mud pond	Moisture content of mud,%
			Initial Al_2O_3	Initial Na_2O_{caust}	caustic molar ratio	Final Al_2O_3	Final Na_2O_{caust}	caustic molar ratio	Al_2O_3	Na_2O_{caust}	
2	5	56+85	82.6	82.2	1.64	150.5	133.3	1.46			
	4	70	62.0	62.0	1.65	112.7	102.3	1.49			
	3	70	32.6	40.3	2.03	83.4	82.2	1.62			
	2	70	14.3	22.9	2.60	46.4	49.9	2.14			
	1	70	water			18.4	23.9	2.14	3.5	5.6	-
4	5	56+85	78.0	80.6	1.70	151.5	138.0	1.50			
	4	85	60.0	60.5	1.66	106.3	99.2	1.53			
	3	80	30.0	33.3	1.83	70.9	65.1	1.51			
	2	80	13.7	15.5	1.87	35.1	31.0	1.45			
	1	70	water				13.6	1.99	2.4	3.0	48.7

Table A2-16

Chemical composition of sinters, muds and extraction yields for Na_2O and Al_2O_3

Test serial number	Samples	Chemical composition, %					Yields, %		Moisture %
		SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	Al_2O_3	Na_2O	
	Sinter No.62	8.2	32.9	15.1	15.4	24.8			
	Mud after standard leaching	15.6	3.5	31.6	33.6	1.8	95.0	96.6	
1	Mud after continuous leaching	12.7	7.2	29.9	31.5	3.0	89.1	94.0	
1	Mud after final leaching	12.5	5.9	30.6	32.6	0.77	91.3	98.5	
3	Mud after continuous leaching	13.2	6.4	30.7	31.9	3.1	90.5	93.9	59.5
3	Mud after final leaching	13.3	4.8	31.9	33.3	0.78	93.2	98.5	
	Sinter No.59	8.1	32.8	15.0	15.4	25.0			
	Mud after standard leaching	15.6	3.5	32.2	33.4	1.7	95.1	96.8	
2	Mud after continuous leaching	13.9	5.9	30.7	32.3	2.4	91.3	95.3	
2	Mud after final leaching	13.4	4.7	31.6	33.5	0.78	93.3	98.5	
4	Mud after continuous leaching	13.7	6.3	30.7	32.4	2.5	90.7	95.2	48.7
4	Mud after final leaching	13.8	4.6	32.1	33.7	0.69	93.5	98.7	

4. BENCH-SCALE TESTS ON I VARIANT BAUXITE PROCESSING BY BAYER-PROCESS

4.1. Predesilication tests

Predesilication is adopted in processing high silica bauxites. It is aimed to dissolve considerable portion of reactive silica present as kaolinite in bauxite and precipitate the same to form sodium aluminium hydrosilicate prior to preheating of slurry and digesting, respectively. In this way severe scale formation on heating surfaces of slurry preheaters, digesters or tube reactors can be avoided.

Both characteristic Iranian bauxite samples prepared for the technological tests are of high silica content /module 6.89 and 3.77/ therefore in the case of processing the desilication procedure has to be performed.

In the course of bench-scale tests the desilication was carried out in a 5 litres capacity, electrically heated and mechanically agitated digester at the parameters adopted with the refineries using the European Bayer technology:

Temperature: 100° C
Solids concentration: 300 gpl
Caustic soda concentration of liquor: 161.6 gpl Na_2O_c.

Samples were withdrawn from the reactor in intervals of 30 minutes, 1, 2, 4 and 8 hours. The samples were centrifuged. The Na_2O_c-, Al_2O_3- and SiO_2-content of liquor was analysed, the solid phase washed alkaline-free, then dried and dressed for chemical analysis. The efficiency of desilication was calculated from the Na_2O/SiO_2 molar ratio measured in the solid phase. It ensues from the composition of sodium aluminium silicate that were the entire SiO_2-content bauxite converted, the Na_2O/SiO_2 molar ratio would /theoretically be 0.688/. On expressing the Na_2O/SiO_2 molar ratio achieved during predesilication in terms of precentage of the theoretical /0.688/ value one gets the proportion of total silica content of bauxite that had been converted into sodium aluminium hydrosilicate.

The results of predesilication tests carried out with bauxite ICS-2 are shown in Table A2-17and Fig.A2-6. It can be seen from the results that under the given parameters 72.7 % of the entire silica content of bauxite has been converted into sodium aluminium hydrosilicate. The non reacted proportion is present in the form of chamosite and other non soluble minerals which do not react with the digestion liquor under the conditions of predesilication. The results of predesilication tests carried out with bauxite ICS-3 are shown in Table A2-18and Fig.A2-7. Under similar desilicating parameters and within 8 hours a maximum efficiency of 52.7 % has been achieved. The results indicate that the average sample having a module of 3.77 comprises considerable proportion of silica in the form of minerals /chamosite, chlorites, etc./ which do not get dissolved under the conditions of desilication. Part of silicates /first of all the chamosite/ remains unchanged even after the high-temperature digestion.

The predesilication is motivated in the course of processing the ores characterized by the average samples cited.

Table A2-17

Predesilication test

Bauxite: ICS-2

Temperature: 100° C

Solids concentration: 300 gpl

Sampling: 30', 1 h, 2 h, 4 h, 8 h

Liquor analysis

Sampling time	Na_2O_c gpl	Al_2O_3 gpl	Molar ratio	SiO_2 gpl
initial liquor	161.6	83.0	3.20	0.48
30'	160,4	91.0	2.90	1.17
1 h	157.6	88.5	2.92	0.95
2 h	157.2	89.0	2.90	0.72
4 h	151.1	83.9	2.96	0.43
8 h	150.2	83.6	2.95	0.39

Chemical composition of the solid phase

	Al_2O_3 %	SiO_2 %	Fe_2O_3 %	TiO_2 %	LOI. %	CaO %	MgO %	Na_2O %	$\frac{Na_2O}{SiO_2}$ Mr.	Efficiency %
30'	50.6	8.4	17.4	6.4	12.4	1.9	0.6	2.3	0.28	40.7
1 h	50.1	8.1	17.1	6.2	12.4	1.6	0.6	2.6	0.33	48.0
2 h	50.2	8.2	16.9	6.1	12.5	1.5	0.6	3.1	0.39	56.7
4 h	50.2	8.2	16.8	6.1	11.8	1.4	0.5	3.7	0.46	66.8
8 h	49.6	8.4	16.7	6.1	11.8	1.5	0.5	4.1	0.50	72.7

Fig.A2-6

PREDESILICATION TEST

Bauxite : ICS–2
Temperature : 100°C
Solids concentration : 300 gpl
Initial Na_2O_C conc. : 161·6 gpl

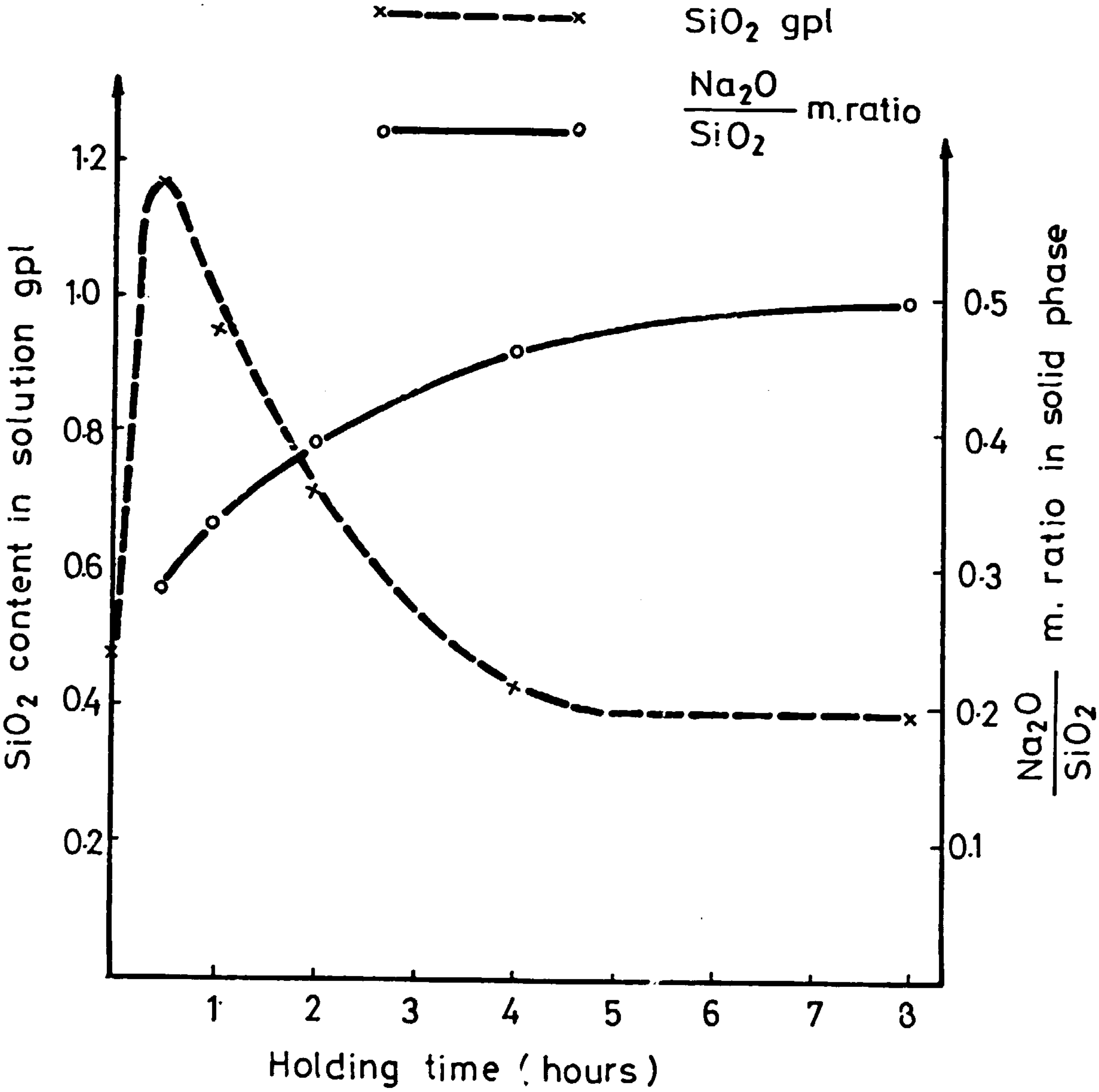


Table A2-18

Predesilication test

Bauxite: ICS-3

Temperature: 100° C

Solids concentration: 300 gpl

Sampling: 30', 1 h, 2 h, 4 h, 8 h

Liquor analysis

Sampling time	Na_2O_c gpl	Al_2O_3 gpl	Molar ratio	SiO_2 gpl
initial liquor	161.6	83.0	3.20	0.48
30'	144.4	79.6	2.99	0.74
1 h	149.4	81.4	3.01	0.61
2 h	142.1	77.9	3.00	0.41
4 h	142.4	78.9	3.00	0.41
8 h	143.9	78.9	3.00	0.35

Chemical composition of the solid phase

	Al_2O_3 %	SiO_2 %	Fe_2O_3 %	TiO_2 %	LOI. %	CaO %	MgO %	Na_2O %	$\frac{Na_2O}{SiO_2}$ Mr.	Efficiency %
30'	47.3	11.2	20.0	5.3	11.6	1.4	0.5	2.2	0.20	29.4
1 h	47.3	11.0	20.0	5.3	11.7	1.4	0.5	2.4	0.23	32.7
2 h	47.4	11.2	19.9	5.2	11.5	1.4	[illegible]	3.1	0.29	41.6
4 h	47.3	11.2	19.7	5.2	11.3	1.3	0.5	3.7	0.34	49.6
8 h	47.0	11.1	19.5	5.1	11.4	1.5	0.6	3.9	0.36	52.7

Fig.A2-7

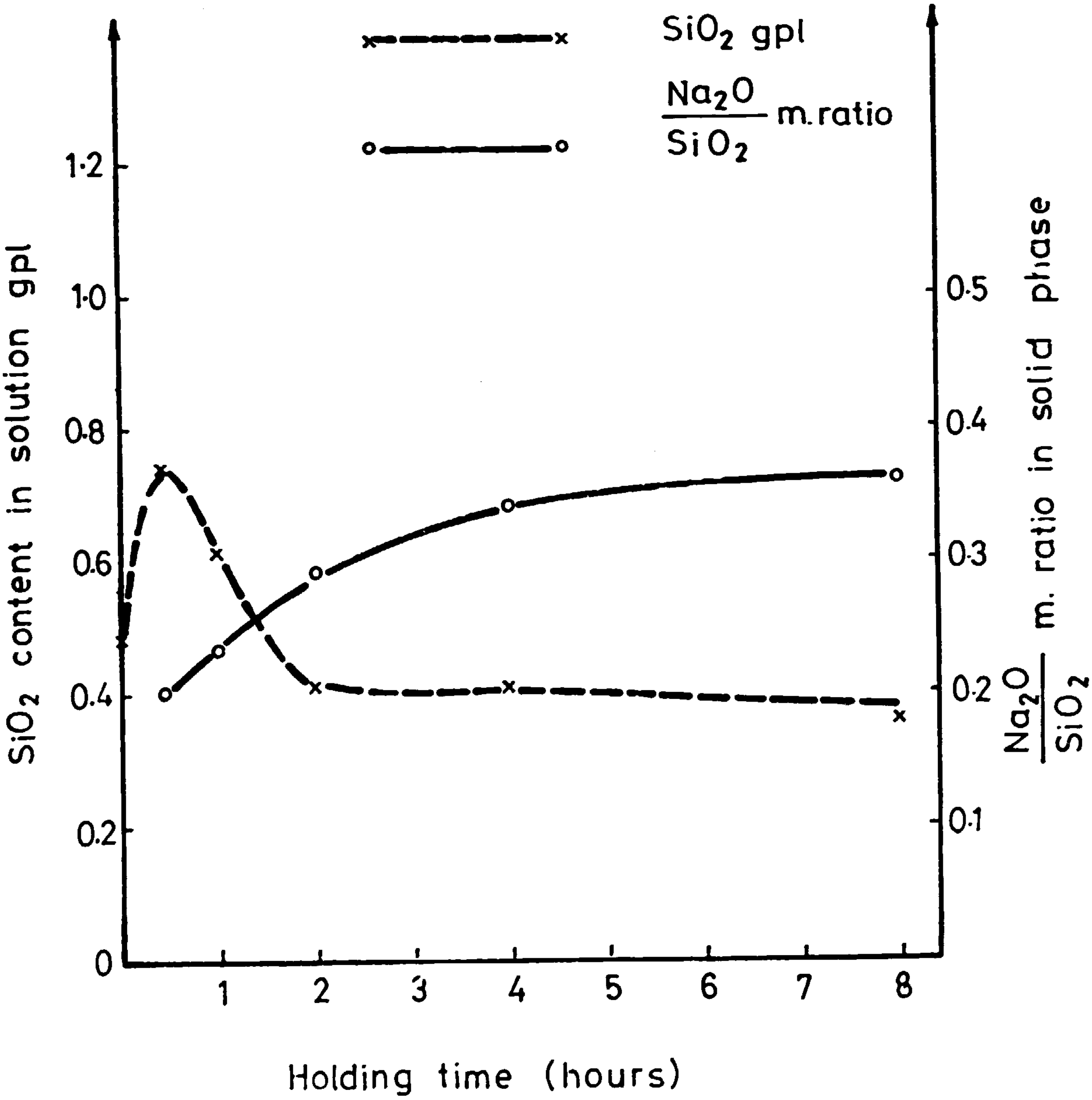
PREDESILICATION TEST

Bauxite : ICS-3

Temperature : 100°C

Solids concentration : 300 gpl

Initial Na_2O_C conc. : 161·6 gpl



4.2.DIGESTION TESTS

4.2.1.Testing methodology

Digestion tests were carried out with the average bauxite samples marked ICS-2 and ICS-3 of modules 6.89 and 3.77, respectively. The composition was given in Chapter 1. Corresponding to the grinding fineness adopted for diasporic bauxites, both bauxite samples were ground to below 90 /um and were admeasured in the air-dry state to the digestion tests. For the investigation of the effect of grinding fineness also samples having been ground to below 125 /um and 160 /um were used with some experiments.

Corresponding to the usual practice with the investigation to qualify bauxites, plant liquor resulting from the process liquor circuit of the Almásfüzitő Alumina Plant /Refinery/ which also comprised the common impurities was used as digestion liquor. Main components and impurities of the digestion liquor are as follows /impurities comprised with liquors of lower or higher concentrations than that given do change proportionally/.

Na_2O_t	188.8 gpl
Na_2O_c	161.6 gpl
Al_2O_3	83.0 gpl
Molar ratio	3.2
Na_2CO_3	42.7 gpl
C_{org}	4.4 gpl
V_2O_5	0.6 gpl
SO_3	0.9 gpl
F	1.6 gpl

The bench-scale digestion tests were carried out in a 5 litres capacity electrically heated mechanically agitated digester at temperatures of 260 and 280° C. Lime addition was performed in the form of lime milk with a concentration of 200 gpl solids content, the lime having been slaked with water. Heat-up prior to reaching digestion temperature took 1 hour to 1 hour and 10 minutes. No laboratory modelling device for the tube digestion can be made due to the small diameter of the tube, however, we are in possession of several comparative data concerning digestion carried out in laboratory digester and plant scale tube digesting facility, thus modelling of the tube digestion was performed similarly in the laboratory digester and intensive agitation was applied. The tests carried out at 260° C serve to the modelling of solution with digesters and tube reactors, while the tests performed at 280° C serve exclusively to the modelling of the solution with the tube reactor.

After digestion the slurry having been recooled down to 70-80° C was separated with a centrifuge at a revolution of 2000/min. The sodium aluminate solution was analyzed, however, the red mud treated with hot water containing 2 gpl of Na_2O to reslurry it three times, then repeatedly centrifuged and dried. The cake was made it analyzed. The Al_2O_3-recovery was calculated from the analyses of starting bauxite and red mud resulted after digestion according to the formula below:

$$Al_2O_3\text{-recovery } /\%/ = \left[1 - \frac{Al_2O_{3rm} \cdot Fe_2O_{3bx}}{Al_2O_{3bx} \cdot Fe_2O_{3rm}}\right] \times 100.$$

Chemical analysis of red mud samples was made by the atomic absorption method, the mineralogic composition, however, was determined by the X-ray diffraction, and derivatographic method and by the infra red spectroscopy.

4.2.2.Digestion tests carried out on the ICS-2 bauxite sample having a module of 6.89

4.2.2.1.Determination of optimum amount of lime addition

The digestion of diasporic bauxites can be performed at high temperatures and by the addition of lime. The CaO added to digestion, apart from promoting the dissolution of the diasporic mineral, considerably reduces the bound Na_2O-losses. In the presence of lime part of the reactive silica gets bound during digestion as a hydrogarnet mineral /further on CAS/ of composition $3CaO.Al_2O_3.kSiO_2/6-2k/H_2O$ instead of sodium aluminium hydrosilicate diminishing the losses of reagent hereby. In the course of digestion the CaO-addition was optimized by considering both the Al_2O_3 and Na_2O losses bound in red mud. The experiments aiming to determine the optimum amount of lime to be added were carried out at the following parameters: 1.55 molar ratio for the admeasurement, 160 gpl digestion liquor concentration, 260° C and 280° C and zero to 10 % of lime addition calculated on dry bauxite.

Chemical analyses of the sodium aluminate liquor and red mud corresponding to the tests carried out at 260° C as well as the digestion recovery data are summarized in Table A2-19. The mineral composition of red muds are given in Table A2-20 Figure A2-8 indicates the formation of Al_2C_3-recovery and the undigested amount of diaspore in function of the amount of lime. In Figure A2-9 the formation of Na_2O- and Al_2O_3-losses bound in red mud /i.e. the Na_2O/SiO_2 and Al_2O_3/SiO_2 ratios/ are indicated. It reveals from the test results and figures that at 260° C and without any additive considerable part of diaspore content of bauxite remains undigested, however, undigested diaspore

Table 2-19

Effect of lime addition for digestion

Modelling of autoclave and tube digestion

Bauxite: ICS-2

Digestion temperature: 260° C

Holding time: 1 hour

Calculated molar ratio: 1.55

Lime addition: 0-10 % /for dried bauxite/

Digesting liquor: Na_2O_c: 161.6 gpl; Al_2O_3: 83.0 gpl; M.r.: 3.2
Na_2O_t: 188.8 gpl; SiO_2: 0.48 gpl

	Quantity of lime added %				
	0	3	5	7	10
Sample	ICS-2 Ch	ICS-2 M1	ICS-2 M2	ICS-2 M3	ICS-2 M4
Liquor analysis after digestion					
Na_2O_c gpl	145.8	148.0	147.7	140.8	147.9
Al_2O_3 gpl	130.4	156.7	154.7	142.0	146.5
Na_2O_t gpl	172.9	178.8	180.3	169.6	176.1
SiO_2 gpl	0.4	0.48	0.48	0.45	0.45
M.r.	1.84	1.55	1.57	1.61	1.65
Chem.compositon of red mud Al_2O_3 %	32.8	19.3	15.9	15.3	15.2
SiO_2 %	11.8	14.2	14.3	14.0	13.8
Fe_2O_3 %	26.2	30.4	31.3	29.6	27.1
TiO_2 %	8.8	9.9	9.8	9.7	8.9
L.O.I %	9.0	8.2	8.2	8.7	9.0
CaO %	1.8	7.2	10.1	13.2	16.4
MgO %	0.7	0.9	1.0	1.0	0.8
Na_2O %	8.1	8.1	7.8	7.0	6.8
Na_2O/SiO_2	0.68	0.57	0.56	0.50	0.49
Al_2O_3/SiO_2	2.78	1.36	1.11	1.09	1.10
Al_2O_3 yield %	58.2	78.8	83.0	82.7	81.3

Table A2-20

Mineralogical composition of red muds

/Effect of lime addition/

Modelling of autoclave and tube digestion
Bauxite: ICS-2
Digestion temperature: 260° C
Holding time: 1 hour

Sample		Quantity of lime added %				
		0	3	5	7	10
		ICS-2 Ch	ICS-2 M1	ICS-2 M2	ICS-2 M3	ICS-2 M4
Al_2O_3 % in:	diaspore	21.7	4.6	1.0	0.6	0
	sodalite	2.0	2.5	2.7	2.8	2.8
	cancrinite	4.7	5.7	5.8	5.8	5.3
	CAS	0.4	2.9	3.5	3.3	5.5
	undigested silicates /chamosite/	4.0	3.6	2.9	2.8	1.6
	total	32.8	19.3	15.9	15.3	15.2
SiO_2 % in:	sodalite	2.3	2.9	3.2	3.3	3.2
	cancrinite	5.5	6.7	6.8	6.8	6.3
	CAS	-	1.0	1.4	1.1	2.3
	undigested silicates /chamosite/	4.0	3.6	2.9	2.8	2.0
	total	11.8	14.2	14.3	14.0	13.8
Fe_2O_3 % in:	goethite	1.7	1.4	1.2	1.0	0.7
	hematite	17.0	22.3	24.7	22.4	22.5
	undigested silicates /cham./	7.5	6.7	5.4	5.2	3.9
	total	26.2	30.4	31.3	29.6	27.1
TiO_2 % in:	perowskite	0.9	2.9	4.7	9.7	8.9
	Na-titanates + rutile	7.9	7.0	5.1	0	0
	total	8.8	9.9	9.8	9.7	8.9
CaO % in:	perowskite	0.6	2.0	3.3	6.8	6.3
	CAS	0.7	4.7	5.8	5.4	9.2
	calcite	0.5	0.5	1.0	1.0	0.9
	total	1.8	7.2	10.1	13.2	16.-

Fig.A2-8

Al_2O_3 YIELD AND UNDIGESTED DIASPORE VS. QUANTITY OF LIME ADDED TO DIGESTION

Bauxite	: ICS-2
Digestion temperature	: 260°C
Holding tima	: 1 hour
Digestion liquor conc.(Na_2O_C)	: 161.6 gpl

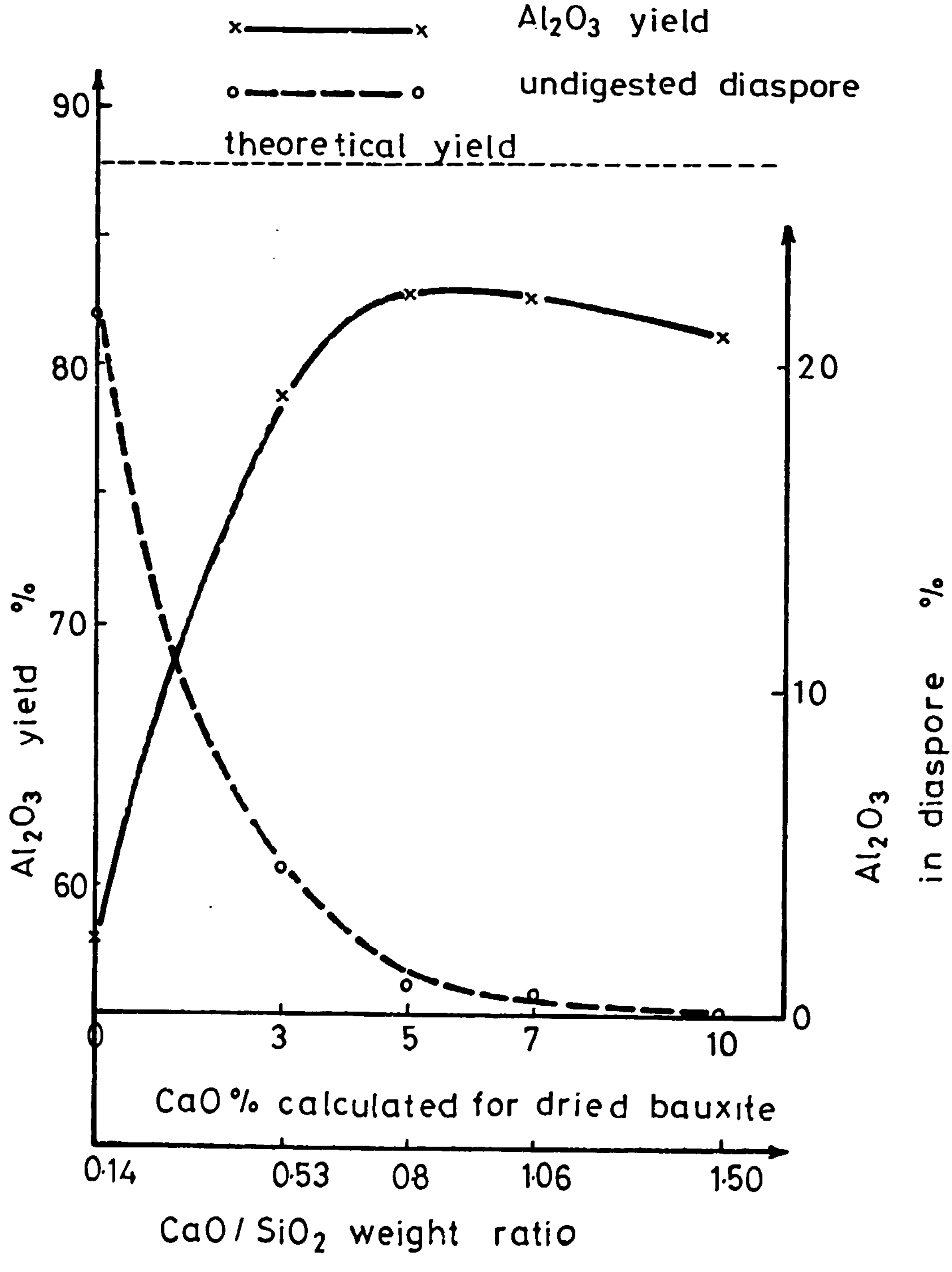
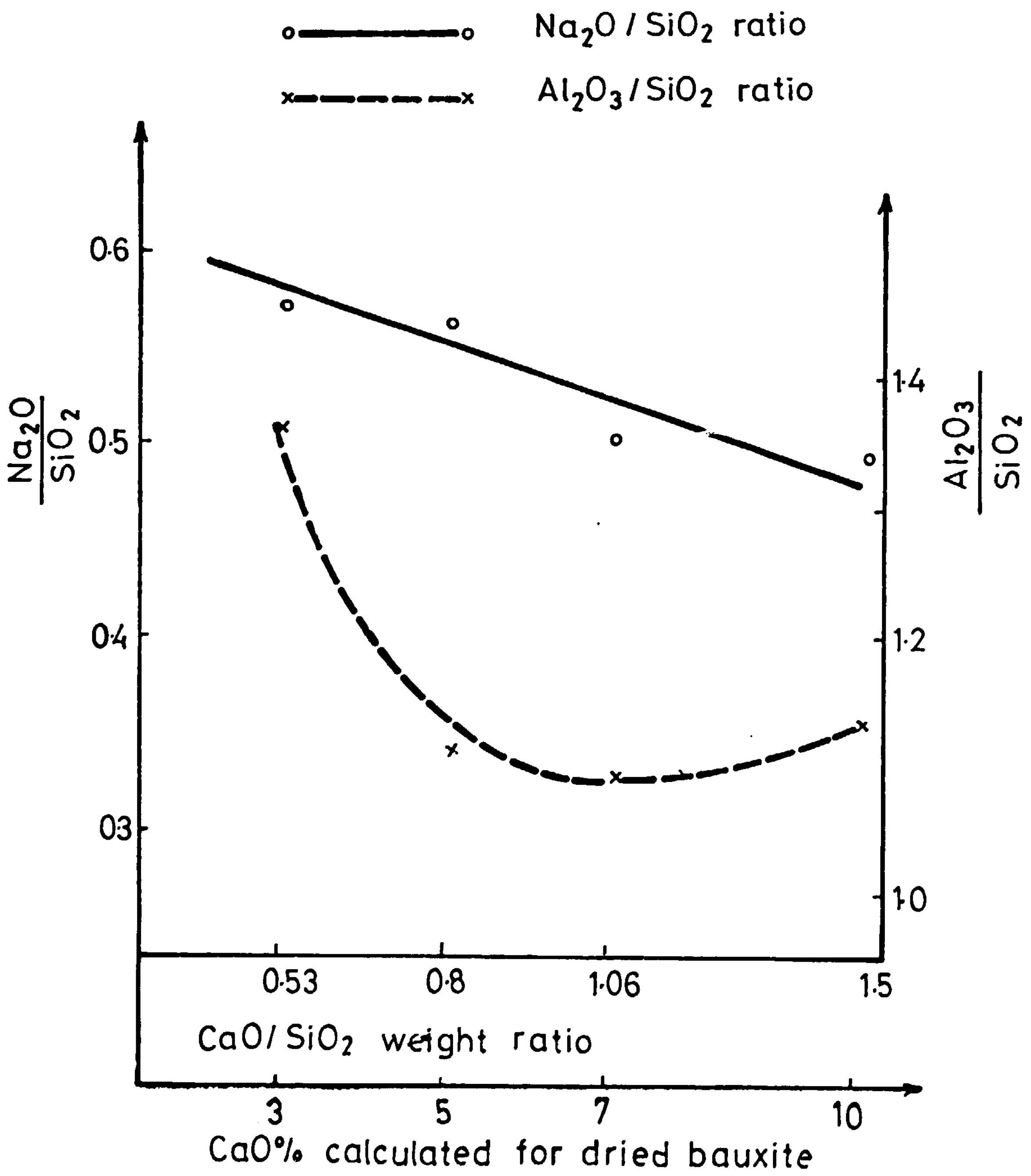


Fig.A2-9

CHANGING OF Na_2O/SiO_2 AND Al_2O_3/SiO_2 W. RATIO IN RED MUD VS. QUANTITY OF LIME ADDED TO DIGESTION

Bauxite : ICS-2
Digestion temperature : 260°C
Holding time : 1 hour
Digestion liquor conc.(Na_2O_c) : 161·6gpl



remains even with the addition of 3 or 5 % of CaO. In the tests carried out with 7 and 10 % of lime additive calculated on the dry weight of bauxite practically all the diaspore got digested and the Na_2O-losses were also favourable. The Na_2O/SiO_2 weight ratio in red mud was 0.50 and 0.49, respectively, compared to 0.69 as the theoretical value. On further increasing the amount of lime additive, owing to the Al_2O_3-losses bound in calcium aluminium silicate, the Al_2O_3-recovery decreased, however, relative to the Na_2O-losses no considerable decrease was observed.

Based on the results and taking both the Al_2O_3-recovery and the bound Na_2O- losses into account 7 % of lime addition is considered to be optimum.

Test results carried out at 280° C and with various amounts of lime are given in Tables A2-21, A2-22 and in Figures A2-10, A2-11. It can be seen from the data and figures that the diaspore gets practically fully digested at 280° C in the presence of as low as 3-5 % of CaO. The reduction of Na_2O-losses, however, gives reason for the addition of more /7 %/ lime. Considering that in the presence of that high amount of lime the digestion of diaspore gets completed even at the lower /260° C/ temperature, from the point of view of chemical technology 260° C is adequate for the digestion temperature, however, owing to energetic aspects the investigation of the probable application of the tube reactor with its final temperature of 280° C could also come up.

It should be noted that the high TiO_2-content of bauxite binds considerable amounts of lime in form of $CaTiO_3$. The 260° C tests were repeated in a way that lime milk was added under pressure to the bauxite slurry when the

Table A2-21

Effect of lime addition for digestion

Modell of tube digestion

Bauxite: ICS-2

Digestion temperature: 280° C

Holding time: 1 hour

Calculated molar ratio: 1.55

Lime addition: 3-10 % /for dried bauxite/

Digesting liquor: Na_2O_c: 161.6 gpl; Al_2O_3 83.0 gpl; M.r.: 3.2
Na_2O_t: 188.8 gpl; SiO_2 0.48 gpl

		Quantity of lime added %			
		3	5	7	10
Sample		ICS-2 M5	ICS-2 M6	ICS-2 M7	ICS-2 M8
Liquor analysis after					
digestion	Na_2O_c gpl	149.2	146.7	142.5	152.9
	Al_2O_3 gpl	158.3	155.7	151.3	150.0
	Na_2O_t gpl	175.5	172.6	167.8	179.9
	SiO_2 gpl	0.45	0.45	0.4	0.35
	M.r.	1.55	1.55	1.57	1.67
Chem. composition of red mud					
	Al_2O_3 %	15.7	15.7	15.1	15.4
	SiO_2 %	14.9	14.4	14.0	13.7
	Fe_2O_3 %	31.9	30.0	29.5	27.9
	TiO_2 %	10.5	9.6	9.4	9.1
	LOI %	7.6	8.2	8.5	8.8
	CaO %	7.8	10.5	12.4	16.8
	MgO %	1.0	0.9	0.9	0.9
	Na_2O %	8.5	8.1	7.2	6.6
	Na_2O/SiO_2	0.57	0.56	0.51	0.48
	Al_2O_3/SiO_2	1.05	1.09	1.08	1.12
	Al_2O_3 yield %	83.6	82.5	82.9	81.6

Table A2-22

Mineralogical composition of red muds

/Effect of lime addition/
Modelling of tube digestion

Bauxite: ICS-2

Digestion temperature: 280° C

Holding time: 1 hour

	Quantity of lime added %			
	3	5	7	10
Sample	ICS-2 M5	ICS-2 M6	ICS-2 M7	ICS-2 M8
Al_2O_3 % in: diaspore	0.7	0.5	0.5	0
sodalite	3.0	2.6	3.1	2.6
cancrinite	6.6	5.8	5.7	5.5
CAS	2.8	4.0	3.1	5.8
undigested silicates /chamosite/	2.6	2.8	2.7	1.5
total	15.7	15.7	15.1	15.4
SiO_2 % in: sodalite	3.5	3.2	3.6	3.0
cancrinite	7.8	6.8	6.6	6.5
CAS	1.0	1.6	1.1	2.5
undigested silicates /chamosite/	2.6	2.8	2.7	1.7
total	14.9	14.4	14.0	13.7
Fe_2O_3 % in: goethite	1.4	1.1	1.1	1.0
hematite	25.7	23.7	23.4	23.7
undigested silicates /chamosite/	4.8	5.2	5.0	3.2
total	31.9	30.0	29.5	27.9
TiO_2 % in: perowskite	3.1	3.2	9.1	9.1
Na-titanates+rutile	7.4	6.4	0	0
total	10.5	9.6	9.1	9.1
CaO % in: perowskite	2.2	2.2	6.4	6.4
CAS	1.6	7.5	5.2	9.4
calcite	1.0	0.8	0.8	1.0
total	7.8	10.5	12.4	16.8

Fig.A2-10

Al_2O_3 YIELD AND UNDIGESTED DIASPORE VS. QUANTITY OF LIME ADDED TO DIGESTION

Bauxite : ICS-2

Digestion temperature : 280 °C

Holding time : 1 hour

Digestion liquor conc.(Na_2O_C) : 161.6 gpl

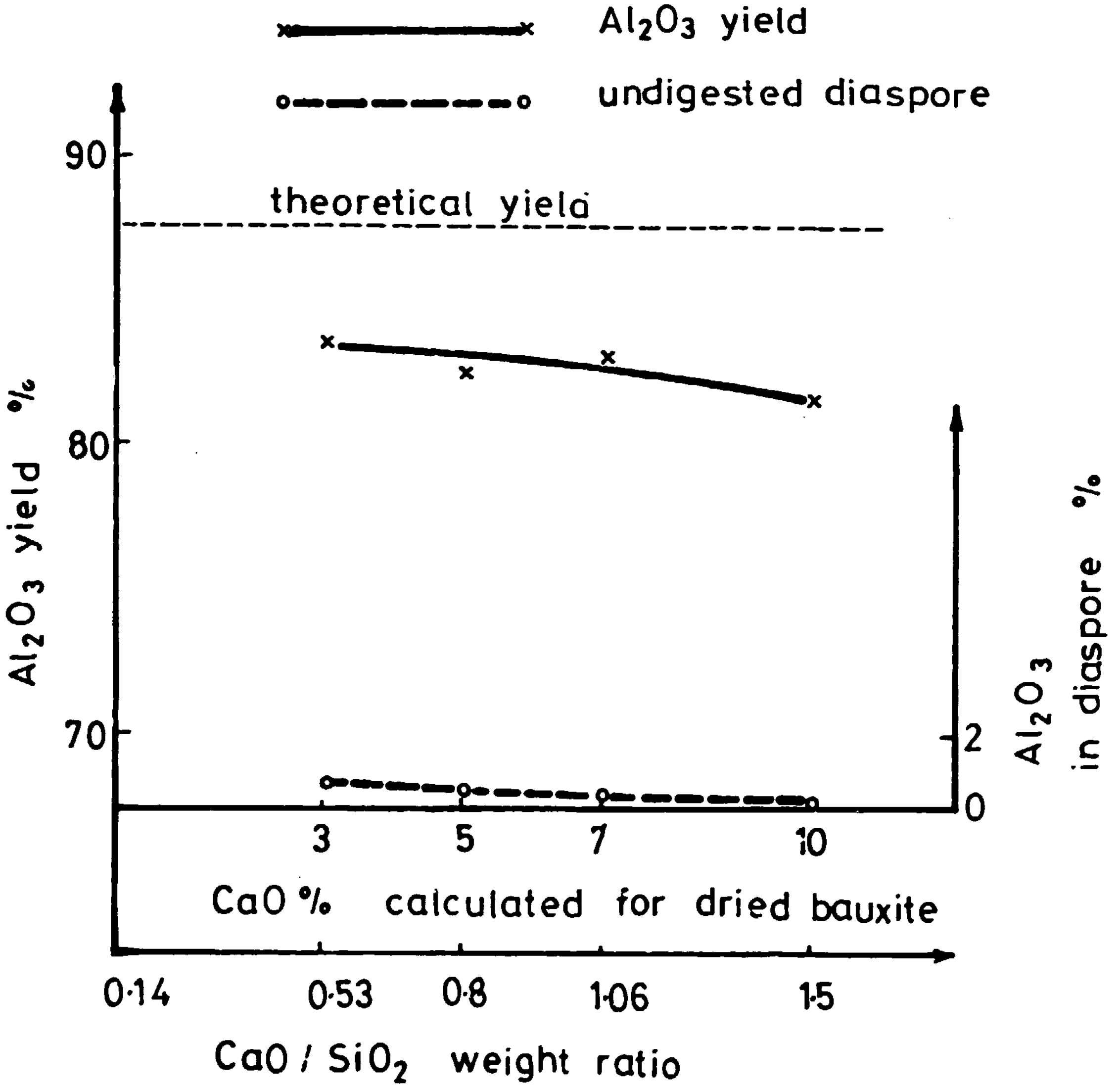
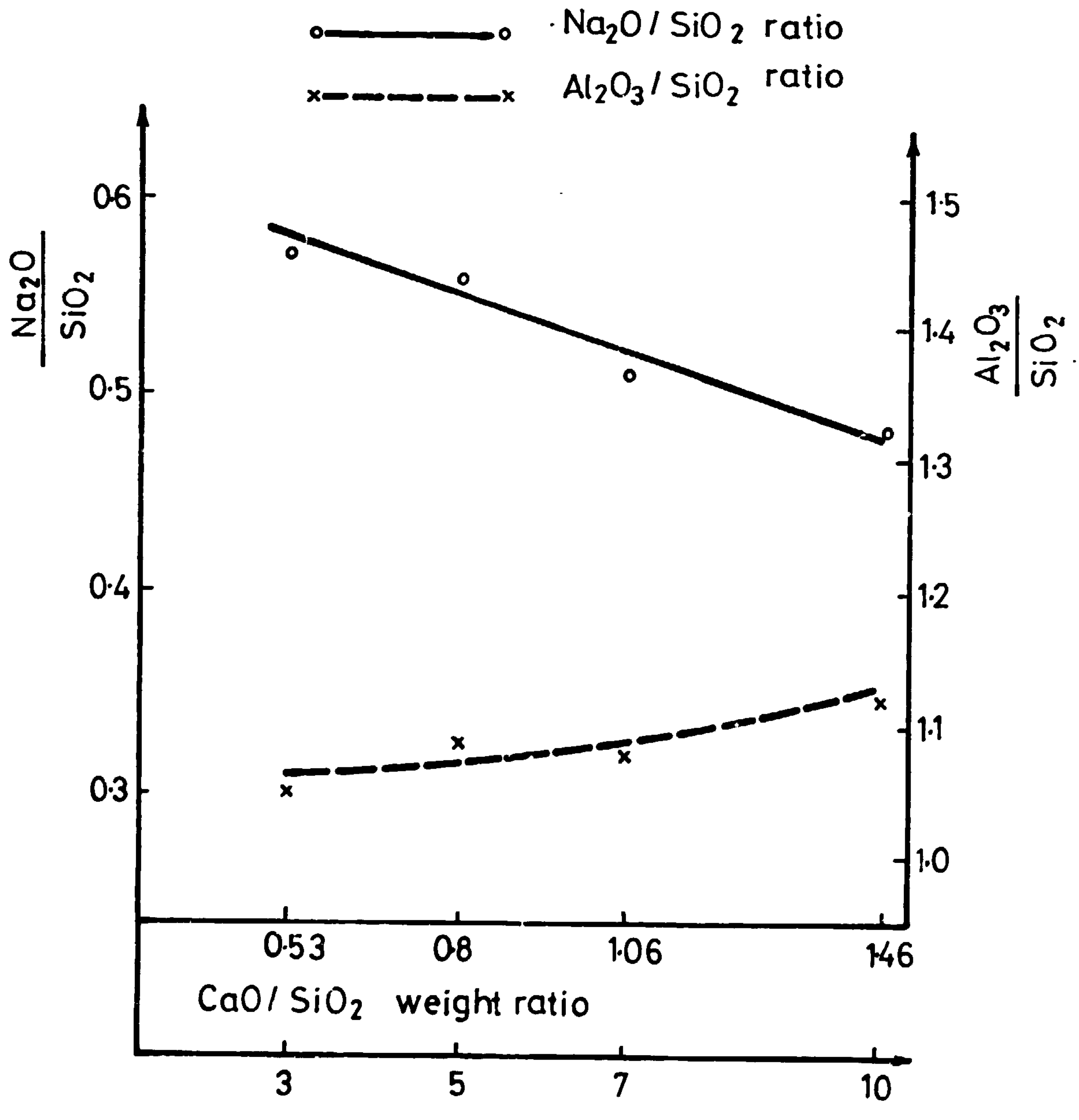


Fig.A2-11

CHANGING OF Na_2O/SiO_2 AND Al_2O_3/SiO_2 W. RATIO IN RED MUD VS. QUANTITY OF LIME ADDED TO DIGESTION

Bauxite	: ICS-2
Digestion temperature	: 280°C
Holding time	: 1 hour
Digestion liquor conc.(Na_2O_C)	: 161.6 gpl



CaO % calculated for dried bauxite

digestion temperature was reached. According to the results no evaluable deviation was found for digestion recovery and bound Na_2O-losses compared to the method of adding lime prior to heat-up.

4.2.2.2. Digestion tests with digestion liquors of various concentrations

The effect of concentration of digestion liquor was investigated at 260° C with the addition of 7 % of CaO calculated on dry bauxite. Comparative digestion tests were made with digestion liquors having various i.e. 141.2; 161.6 and 182.4 gpl Na_2O concentrations. Chemical analyses of the aluminate liquors and red muds moreover the digestion recovery data are given in Table A2-23, the mineral composition of red muds, however, in Table A2-24. According to the results, the digestion recovery is practically the same at the given parameters and in the range of concentration investigated. In the course of making the design the optimum concentration may be modified within the given limits taking the energetic and technologic aspects into consideration.

4.2.2.3. Digestion tests on bauxite samples ground to various grain sizes

A comparison of digestibility of wet ground bauxite samples of grain size less than 90 /um and 160 /um was made under equal digestion parameters and the same amount of lime addition. The test results are given in Tables A2-25 and A2-26.

On the intensive agitation in the laboratory digester both bauxite samples were practically digested with a similar digestion efficiency. It should be noted that even in the sample ground to below 160 /um more than 90 %

Table A2-23

Digestion tests at different digesting liquor concentration

Modelling of autoclave and tube digestion

Bauxite: ICS-2

Digestion temperature: 260° C

Holding time: 1 hour

Calculated molar ratio: 1.55

Lime addition: 7 % /for dried bauxite/

Sample -	ICS-2 K1	ICS-2 K2	ICS-2 K3
Digesting liquor			
Na_2O_c gpl	141.2	161.6	182.4
Al_2O_3 gpl	72.6	83.0	93.8
M.r.	3.2	3.2	3.2
Liqour analysis after digestion Na_2O_c gpl	130.2	140.8	157.9
Al_2O_3 gpl	130.7	142.0	162.3
M.r.	1.64	1.61	1.61
Chem. composition of red mud			
Al_2O_3 %	15.7	15.3	15.4
SiO_2 %	14.0	14.0	13.9
Fe_2O_3 %	29.3	29.6	29.6
TiO_2 %	10.0	9.7	9.7
L.O.I. %	9.1	8.7	8.4
CaO %	11.1	13.2	13.5
MgO %	0.9	1.0	0.9
Na_2O %	8.1	7.0	7.3
Na_2O/SiO_2	0.57	0.50	0.53
Al_2O_3/SiO_2	1.12	1.09	1.11
CaO/SiO_2	0.79	0.94	0.98
Al_2O_3 yield %	82.1	82.7	82.6

Table A2-24

Mineralogical composition of red muds

/Tests at different liquor concentration/
Modelling of autoclave and tube digestion

Bauxite: ICS-2

Digestion temperature: 260° C

Holding time: 1 hour

		Digesting liquor Na_2O_c conc.gpl		
		141.2	161.6	182.4
Sample		ICS-2 K1	ICS-2 K2	ICS-2 K3
Al_2O_3 % in:	diaspore	0.6	0.6	0
	sodalite	2.3	2.8	2.3
	cancrinite	5.5	5.8	5.1
	CAS	4.7	3.3	5.4
	undigested silicates /chamosite/	2.8	2.8	2.6
	total	15.9	15.3	15.4
SiO_2 % in:	sodalite	2.8	3.3	2.7
	cancrinite	6.6	6.8	6.1
	CAS	1.8	1.1	2.5
	undigested silicates /chamosite/	2.8	2.8	2.6
	total	14.0	14.0	13.9
Fe_2O_3 % in:	goethite	1.3	1.0	1.2
	hematite	22.8	22.4	23.6
	undigested silicates /chamosite/	5.2	5.2	4.8
	total	29.3	29.6	29.6
TiO_2 % in:	perowskite	2.9	9.7	4.7
	Na-titanates+rutile	7.1	0	5.0
	total	10.0	9.7	9.7
CaO % in:	perowskite	2.0	6.8	3.3
	CAS	7.9	5.4	9.0
	calcite	1.2	1.0	1.2
	total	11.1	13.2	13.5

Table A2-25

Effect of grain size of bauxite

Modelling of autoclave and tube digestion

Bauxite: ICS-2 <90 µm; ICS-2 < 160 µm

Digestion temperature: 260° C

Holding time: 1 hour

Calculated molar ratio: 1.55

Lime addition: 10 % /for dried bauxite/

Digesting liquor: Na_2O_c 161.6 gpl; Al_2O_3 83.0 gpl; M.r.: 3.2
Na_2O_t 188.8 gpl; SiO_2 0.49 gpl

Sample		Grain size of bauxite samples	
		< 90 µm	<160 µm
Liqour analysis after digestion			
	Na_2O_c gpl	147.9	140.0
	Al_2O_3 gpl	146.5	142.2
	Na_2O_t gpl	176.1	167.1
	SiO_2 gpl	0.45	0.42
	M.r.	1.65	1.62
Chem. compositon of red mud	Al_2O_3 %	15.2	14.9
	SiO_2 %	13.8	13.4
	Fe_2O_3 %	27.1	27.0
	TiO_2 %	8.9	10.3
	L.O.I. %	9.4	8.6
	CaO %	16.4	16.0
	MgO %	0.8	1.1
	Na_2O %	6.8	6.4
	Na_2O/SiO_2	0.49	0.48
	Al_2O_3/SiO_2	1.10	1.11
	Al_2O_3 yield %	81.3	81.6
	CaO/SiO_2	1.19	1.19

Table A2-26

Mineralogical composition of red muds

/Effect of grain size of bauxite/
Modelling of tube digestion

Digestion temperature: 260° C
Holding time: 1 hour

Sample	Grain size of bauxite	
	ICS-2 < 90 µm	ICS-2 < 160 µm
Al_2O_3 % in: diaspore	0	0
sodalite	2.8	3.0
cancrinite	5.3	4.5
CAS	5.5	4.6
undigested silicates /cham./	1.6	2.8
total	15.2	14.9
SiO_2 % in: sodalite	3.2	3.6
cancrinite	6.3	5.4
CAS	2.3	1.6
undigested silicates /cham./	2.0	2.8
total	13.8	13.4
Fe_2O_3 % in: goethite	0.7	0.8
hematite	22.5	21.0
undigested silicates /cham./	3.9	5.2
total	27.1	27.0
TiO_2 % in: perowskite	8.9	10.3
Na-titanates+rutile	0	0
total	8.9	10.3
CaO % in: perowskite	6.3	7.2
CAS	9.2	7.6
calcite	0.9	1.2
total	16.4	16.0

of the material was in the range below 100 /um.
Based on the practice of plants processing diasporic bauxites, grinding of the ore to below 90 /um is proposed for the case of industrial processing. In favour of perfect digestion grinding to this grain size is a firm solution, coarser grain size would cause erosion problems according to industrial practice.

4.2.2.4 Digestion tests carried out for the determination of optmimum digestion molar ratio /bauxite to liquor ratio/

For the determination of the optimum after-digestion molar ratio a curve characteristic of the digestion was plotted. A set of experiments comprising six digestion tests was performed with a digestion liquor having a caustic concentration of 161.2 gpl Na_2O_c, at 260° C with the addition of optimum /7 %/ amount of CaO and various admeasurements of bauxite values. Calculated molar ratio of admeasurement was selected within the range of 1.3-1.7. The analyses of the aluminate liquor and red mud pertaining to the test series are given in Table A2-27 and the mineral composition of the three red muds in Table A2-28. The characteristic curve plotted from the experimental data is given in Figure A2-12. On basis of the investigation of the efficiency data of digestion and the undigested values of diaspore the optimum molar ratio assuring complete digestion is considered to be 1.55.

Table A2-27

Characteristic digestion curve for determination optimum molar ratio

Modelling of tube digestion
Bauxite: ICS-2
Digestion temperature: 260° C
Holding time: 1 hour
Calculated molar ratio: 1,3-1,7
Lime addition: 7 % for dried bauxite

Liquor analysis after digestion

Sample	Na_2O_c gpl	Al_2O_3 gpl	Molar ratio	Na_2O_t gpl	SiO_2 gpl	Calculated molar ratio
Digesting liquor	161.6	83.0	3.20	188.8	0.48	-
ICS-2 Mv-1	138.2	160.1	1.42	166.4	0.4	1.30
ICS-2 Mv-2	139.4	162.7	1.41	166.7	0.4	1.40
ICS-2 Mv-3	141.6	164.0	1.42	166.5	0.4	1.45
ICS-2 Mv-4	140.1	153.6	1.50	168.3	0.4	1.50
ICS-2 Mv-5	140.8	148.5	1.56	167.5	0.4	1.55
ICS-2 Mv-6	143.0	137.8	1.71	169.5	0.4	1.70

Chemical composition of red mud

Sample	Al_2O_3 %	SiO_2 %	Fe_2O_3 %	TiO_2 %	L.O.I. %	CaO %	MgO %	Na_2O %	$\frac{Al_2O_3}{SiO_2}$	Al_2O_3 yield %
ICS-2 Mv-1	24.0	12.2	25.3	8.6	10.2	10.2	0.8	6.6	1.97	68.3
ICS-2 Mv-2	19.7	13.2	27.1	9.2	9.8	11.3	0.9	6.9	1.49	75.7
ICS-2 Mv-3	17.9	13.5	27.6	9.3	9.7	11.3	0.9	7.4	1.30	78.3
ICS-2 Mv-4	15.8	13.9	28.5	9.5	9.5	11.5	0.9	7.5	1.14	81.5
ICS-2 Mv-5	14.8	14.1	28.6	9.5	9.4	11.7	1.0	7.5	1.05	82.7
ICS-2 Mv-6	14.9	14.0	28.8	9.5	9.4	12.3	1.0	7.5	1.06	82.7

Table A2-23

Mineralogical composition of red muds

/Effect of calculated molar ratio/
Modelling of tube digestion

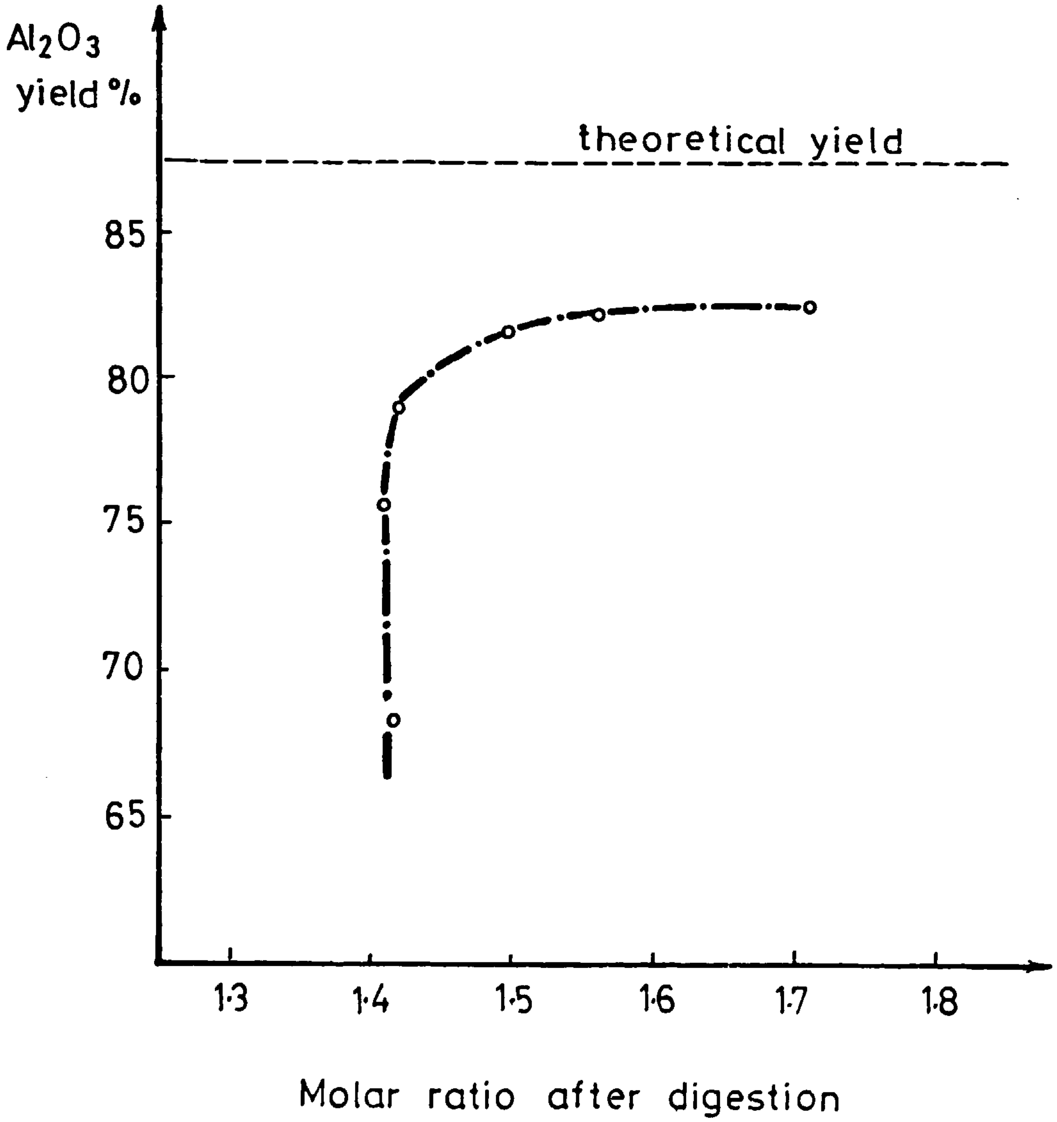
Bauxite: ICS-2
Digestion temperature: 260° C
Holding time: 1 hour
Lime addition: 7 % for dried bauxite

	M.r. after digestion		
	1.50	1.56	1.71
Sample	ICS-2 Mv-4	ICS-2 Mv-5	ICS-2 Mv-6
Al_2O_3 % in: diaspore	1.6	0.3	0
sodalite	2.0	2.3	2.2
cancrinite	6.8	5.5	5.7
CAS	3.2	4.2	4.7
undigested silicates /cham./	2.2	2.5	2.3
total	15.8	14.8	14.9
SiO_2 % in: sodalite	2.3	2.9	2.7
cancrinite	8.0	6.8	6.9
CAS	1.4	1.9	2.1
undigested silicates /cham./	2.2	2.5	2.3
total	13.9	14.1	14.0
Fe_2O_3 % in: goethite	1.2	1.1	1.0
hematite	19.3	22.8	23.5
undigested silicates /cham./	8.0	4.7	4.3
total	28.5	28.6	28.8
TiO_2 % in: perowskite	5.3	4.8	4.4
Na-titanates+ rutile	4.2	4.7	5.1
total	9.5	9.5	9.5
CaO % in: perowskite	3.7	3.4	3.1
CAS	6.4	7.0	7.9
calcite	1.4	1.3	1.7
total	11.5	11.7	12.9

Fig.A2-12

CHARACTERISTIC DIGESTION CURVE

Bauxite	: ICS-2
Digestion temperature	: 260°C
Holding time	: 1 hour
Lime addition	: 7 %
Digestion liquor conc.	(Na_2O_c) : 161·6 gpl



4.2.2.5. Digestion tests for the determination of optimum retention time

For the determination of optimum digestion retention time the tests were carried out with a digestion liquor having a concentration of 161.6 gpl of Na_2O_c at 260° C and with 7 % of CaO addition. After achieving the final digestion temperatures, samples were withdrawn under pressure after 10, 20, 30 and 40 minutes and 1 hour, respectively. The aluminate liquor and red mud samples were analyzed as usual and the results are given in Table A2-29. It can be seen from the results that bauxite got digested completely after 30 minutes and the Al_2O_3-recovery reached the maximum value i.e. 82.3 %.

The results have the meaning for the industrial practice that in the case of adopting tube digestion a retention time of half an hour would be sufficient because in this case the slurry flows like a piston. In the case of digestion in autoclaves a retention time of about 1 hour would be required for the perfect digestion as a consequence of the forward hurry of the slurry.

4.2.3. Digestion tests on the characteristic bauxite sample ICS-3 having a module of 3.77

Bench-scale digestion tests were carried out with the low /3.77/ module characteristic bauxite sample by the similar system as it had been done with the 6.89 module bauxite. The results of testing series are summarized below.

4.2.3.1. Determination of the optimum amount of lime additive

Digestion tests were carried out with 3, 5, 7 and 10 % of

Table A2-29

Influence of the holding time

Modelling of autoclave and tube digestion

Bauxite: ICS-2

Digestion temperature: 260° C

Holding time: 10', 20', 30', 40', 1 hour

Calculated molar ratio: 1.55

Lime addition: 7 % for dried bauxite

Liquor analysis after digestion

Holding time	Na_2O_c gpl	Al_2O_3 gpl	Molar ratio
Digesting liquor	161.6	83.0	3.20
10'	143.0	145.2	1.62
20'	142.0	147.8	1.58
30'	141.4	149.1	1.56
40'	143.2	152.0	1.54
1 h	142.7	151.4	1.55

Chemical composition of red mud

Holding time	Al_2O_3 %	SiO_2 %	Fe_2O_3 %	TiO_2 %	L.O.I %	CaO %	MgO %	Na_2O %	$\frac{Al_2O_3}{SiO_2}$	Al_2O_3 yield %
10'	19.9	13.3	27.2	9.2	9.7	11.8	0.9	6.9	1.49	75.6
20'	16.7	14.0	27.9	9.4	9.9	12.1	0.9	6.8	1.26	80.0
30'	15.1	14.2	28.9	9.5	9.9	12.4	0.9	7.3	1.05	82.3
40'	15.3	14.2	28.9	9.5	9.9	12.6	0.9	7.1	1.04	82.3
1 h	15.0	14.1	28.7	9.5	9.6	12.3	0.9	7.2	1.06	82.2

CaO addition calculated on the weight of dry bauxite, with a digestion liquor concentration of 161.6 gpl, ad temperatures of 260 and 280° C. Aluminate liquor and red mud analysis pertaining to the digestion tests carried out at 260° C, morover the bound Na_2O- and Al_2O_3-losses and Al_2O_3-recovery data are given in Table A2-30, while the phase analysis of red muds in Table A2-31 Al_2O_3-recovery data of the amount of undigested diaspore is indicated in Fig. A2-13. The ratios of Na_2O/SiO_2 and Al_2O_3/SiO_2 characteristic of bound losses in function of the amount of CaO added are indicated in Fig. A2-14. Maximum Al_2O_3-recovery achieved was 69.6 %. The Na_2O/SiO_2ratio can be reduced to within 0.52-0.53. The digestion of diaspore gets completed by the addition of 7 % of CaO. The addition of 7 % of lime is considered to be optimum from the point of view of both the bound Al_2O_3- and Na_2O-losses.

On repeating the digestion tests at 280° C the Al_2O_3-recovery ranging 69.8-72.3 % was achieved. The only difference compared to the results obtained with 260° C lies in the condition that the diaspore has become digested even at a lime addition of as low as 3 % of CaO. The addition of 7 % of lime, however, is motivated by the intention to reduce bound Na_2O-losses also even at 280° C.

The test results are summarized in Tables A2-32 and A2-33 and indicated in Figs.A2-15 and A2-16.

4.2.3.2. Digestion tests carried out in digestion liquors of various concentrations

Similarly as with sample ICS-2 the digestibility of bauxite was investigated at 260° C by the use of digestion liquor /of Na_2O_c concentrations: 138; 161.6 and 180 gpl/ and

Table A2-30

Effect of lime addition for digestion

Modelling of autoclave and tube digestion

Bauxite: ICS-3

Digestion temperature: 260° C

Holding time: 1 hour

Calculated molar ratio: 1.55

Lime addition: 3-10 % /for dried bauxite/

Digesting liquor: Na_2O_c: 161.6 gpl; Al_2O_3 83.0 gpl; M.r.: 3.2
Na_2O_t: 188.8 gpl; SiO_2 0.48 gpl

		Quantity of lime added %			
		3	5	7	10
Sample		ICS-3 M1	ICS-3 M2	ICS-3 M3	ICS-3 M4
Liquor analysis after digestion	Na_2O_c gpl	146.3	131.5	130.6	134.5
	Al_2O_3 gpl	145.9	142.3	141.5	142.0
	Na_2O_t gpl	174.5	158.0	155.0	160.1
	SiO_2 gpl	0.45	0.40	0.40	0.40
	M.r.	1.65	1.52	1.52	1.56
Chem.composition of red mud					
	Al_2O_3 %	22.2	18.0	17.1	16.2
	SiO_2 %	15.0	16.2	15.6	14.2
	Fe_2O_3 %	26.7	29.1	28.1	25.5
	TiO_2 %	7.3	7.4	7.1	6.5
	L.O.I. %	9.5	9.1	9.5	11.3
	CaO %	6.2	9.2	11.5	17.0
	MgO %	0.8	0.8	0.8	0.8
	Na_2O %	8.8	9.6	8.3	7.4
	Na_2O/SiO_2	0.59	0.59	0.53	0.52
	Al_2O_3/SiO_2	1.48	1.11	1.10	1.14
	Al_2O_3 yield %	58.4	69.1	69.6	68.2

Table A2-31

Mineralogical composition of red muds

/Effect of lime addition/
Bauxite: ICS-3
Digestion temperature: 260° C
Holding time: 1 hour
Modelling of autoclave and tube digestion

	Quantity of lime added %			
	3	5	7	10
Sample	ICS-3 M1	ICS-3 M2	ICS-3 M3	ICS-3 M4
Al_2O_3 % in: diaspore	7.4	1.2	0.4	0
sodalite	3.1	4.5	3.4	3.2
cancrinite	5.9	7.6	7.1	5.9
CAS	2.2	3.3	4.9	5.5
undigested silicates /cham./	3.6	1.4	1.3	1.6
total	22.2	18.0	17.1	16.2
SiO_2 % in: sodalite	3.7	5.0	3.9	3.8
cancrinite	6.9	8.7	8.5	6.9
CAS	0.8	1.1	1.9	1.9
undigested silicates /cham./	3.6	1.4	1.3	1.6
total	15.0	16.2	15.6	14.2
Fe_2O_3 % in: goethite	2.0	1.8	1.6	1.5
hematite	18.1	24.7	24.1	21.0
undigested silicates /cham./	6.6	2.6	2.4	3.0
total	26.7	29.1	28.1	25.5
TiO_2 % in: perowskite	2.0	3.3	2.9	6.5
Na-titanates+rutile	4.7	4.1	4.2	0
total	6.7	7.4	7.1	6.5
CaO % in: perowskite	1.4	2.3	2.0	4.6
CAS	3.6	5.4	8.0	9.1
calcite	1.2	1.5	1.5	3.3
total	6.2	9.2	11.5	17.0

Fig.A2-13

Al_2O_3 YIELD AND UNDIGESTED DIASPORE VS. QUANTITY OF LIME ADDED TO DIGESTION

Bauxite	: ICS-3
Digestion temperature	: 260°C
Holding time	: 1 hour
Digestion liquor conc. (Na_2O_C)	: 161·6 gpl

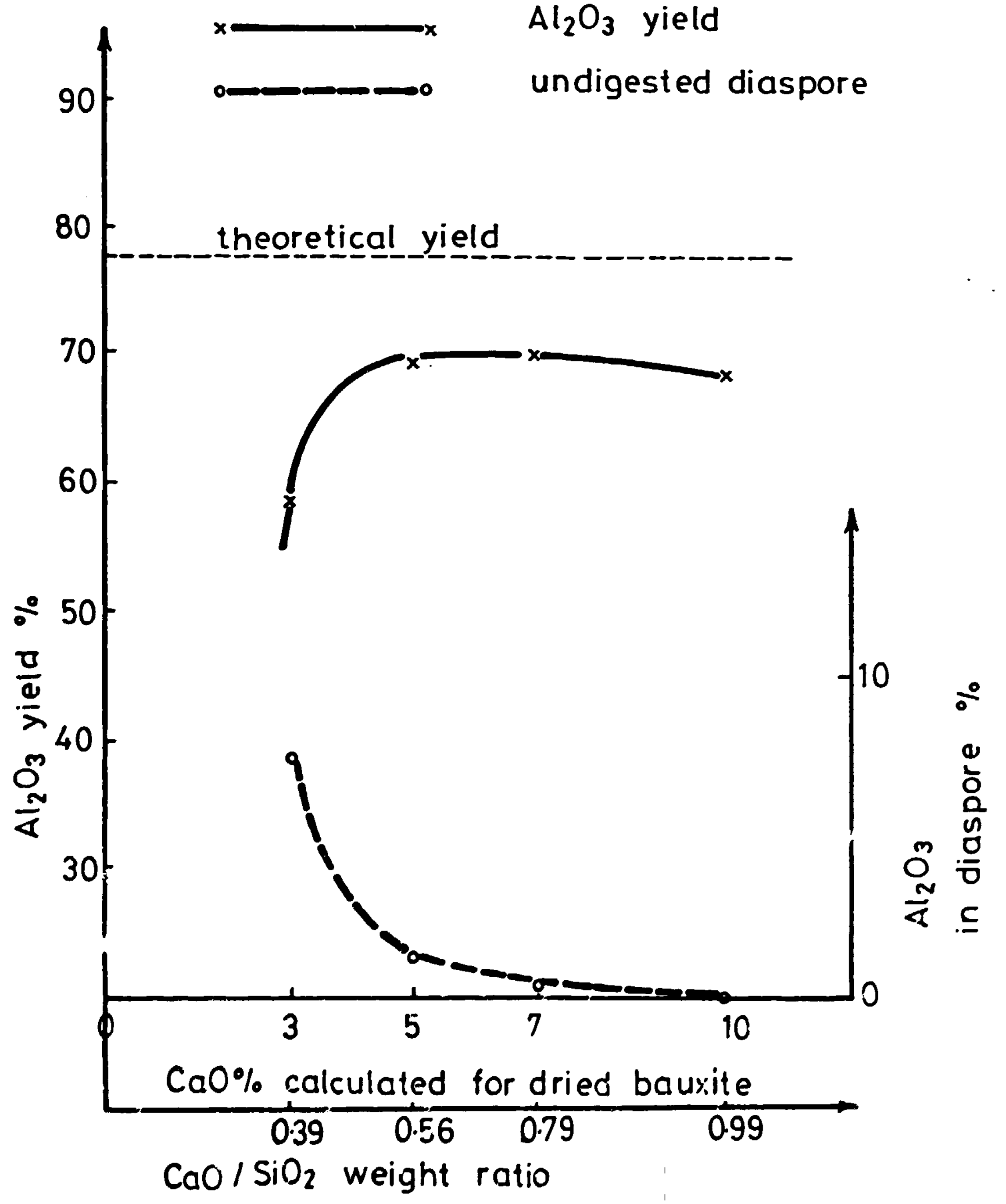


Fig.2-14

CHANGING OF Na_2O/SiO_2 AND Al_2O_3/SiO_2 W. RATIO IN RED MUD VS QUANTITY OF LIME ADDED TO DIGESTION

Bauxite : ICS-3
Digestion temperature : 260°C
Holding time : 1 hour
Digestion liquor conc.(Na_2O_C : 161·6 gpl

o———o Na_2O/SiO_2 ratio
x– – – –x Al_2O_3/SiO_2 ratio

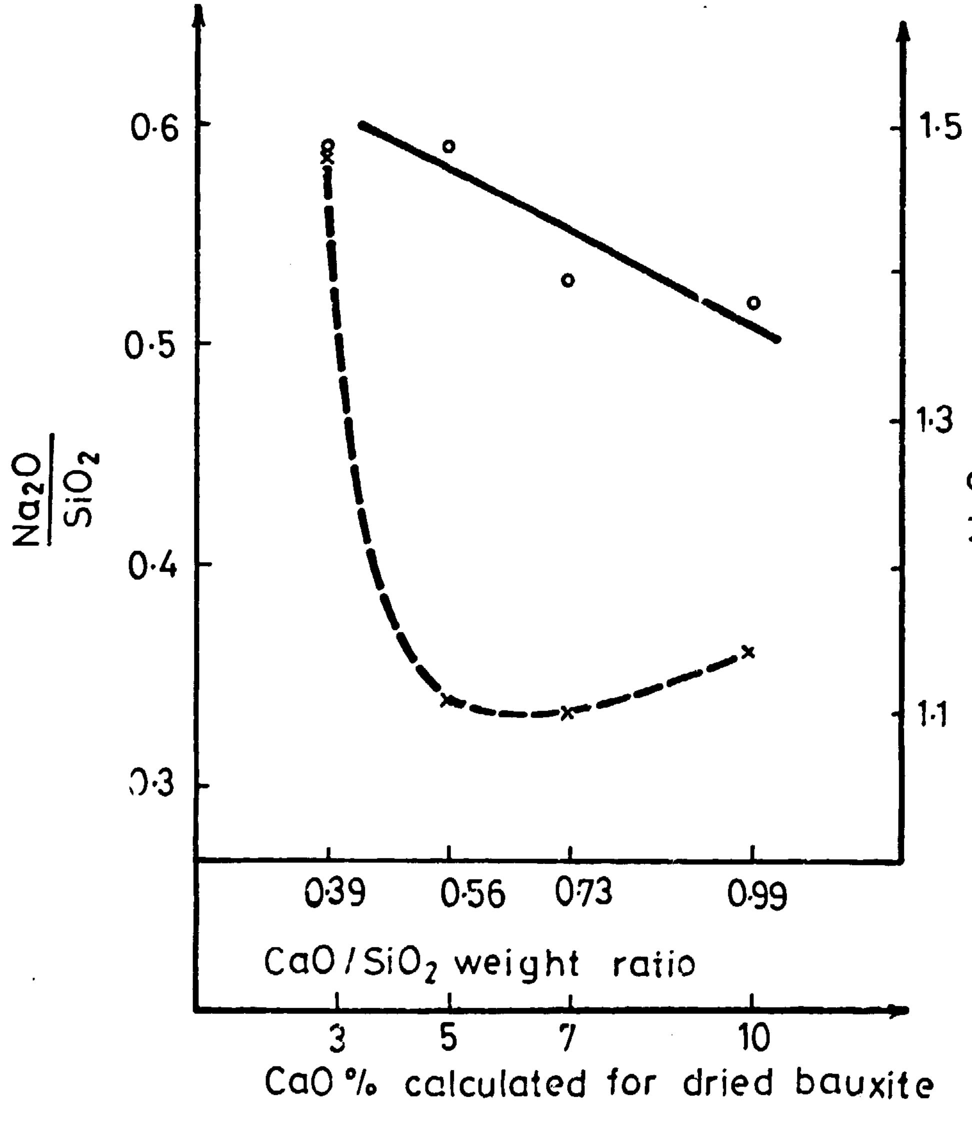


Table A2-32

Effect of lime addition for digestion

Modelling of tube digestion

Bauxite: ICS-3

Digestion temperature: 280° C

Holding time: 1 hour

Calculated molar ratio: 1.55

Lime addition: 3-10 % /for dried bauxite/

Digesting liquor: Na_2O_c: 161.6 gpl; Al_2O_3:83.1 gpl; M.r.: 3.2
Na_2O_t: 188.8 gpl; SiO_2:0.48 gpl

		Quantity of lime added %			
		3	5	7	10
Sample		ICS-3 M5	ICS-3 M6	ICS-3 M7	ICS-3 M8
Liquor analysis after digestion	Na_2O_c gpl	132.0	133.1	131.3	133.5
	Al_2O_3 gpl	143.7	145.3	142.8	142.6
	Na_2O_t gpl	160.1	156.2	156.4	157.0
	SiO_2 gpl	0.40	0.45	0.45	0.45
	M.r.	1.51	1.51	1.51	1.54
Chem. composition of red mud	Al_2O_3 %	16.9	17.2	17.1	16.3
	SiO_2 %	16.9	16.8	16.2	14.5
	Fe_2O_3 %	30.5	29.5	28.3	27.4
	TiO_2 %	7.7	7.4	7.2	6.6
	L.O.I. %	7.8	8.5	9.3	10.4
	CaO %	6.9	8.9	11.2	15.1
	MgO %	0.9	0.8	0.8	0.8
	Na_2O %	10.2	9.6	8.8	7.7
	Na_2O/SiO_2	0.58	0.57	0.54	0.53
	Al_2O_3/SiO_2	1.0	1.02	1.06	1.12
	Al_2O_3 yield %	72.3	70.8	69.8	70.2

Table A2-33

Mineralogical composition of red muds

/Effect of lime addition/

Modelling of tube digestion

Bauxite: ICS-3

Digestion temperature: 280° C

Holding time: 1 hour

		Quantity of lime added %			
		3	5	7	10
Sample		ICS-3 M5	ICS-3 M6	ICS-3 M7	ICS-3 M8
Al_2O_3 % in:	diaspore	0.7	0.3	0.3	0
	sodalite	4.4	4.3	3.7	3.4
	cancrinite	8.7	8.0	7.7	6.5
	CAS	1.8	3.3	4.1	5.4
	undigested silicates /cham./	1.3	1.3	1.3	1.0
	total	16.9	17.2	17.1	16.3
SiO_2 % in:	sodalite	5.1	5.0	4.4	4.0
	cancrinite	9.9	9.4	9.0	7.6
	CAS	0.6	1.1	1.5	1.9
	undigested silicates /cham./	1.3	1.3	1.3	1.0
	total	16.9	16.8	16.2	14.5
Fe_2O_3 % in:	goethite	1.5	1.4	2.0	0.8
	hematite	26.6	25.7	23.9	24.7
	undigested silicates /cham./	2.4	2.4	2.4	1.9
	total	30.5	29.5	28.3	27.4
TiO_2 % in:	perowskite	4.0	2.8	3.9	6.6
	Na-titanates+ rutile	3.7	4.6	3.3	0
	total	7.7	7.4	7.2	6.6
CaO % in:	perowskite	2.8	2.0	2.7	4.6
	CAS	3.0	5.4	6.7	8.9
	calcite	1.1	1.5	1.8	1.6
	total	6.9	8.9	11.2	15.1

Fig.A2-15

Al_2O_3 YIELD AND UNDIGESTED DIASPORE VS. QUANTITY OF LIME ADDED TO DIGESTION

Bauxite : ICS-3

Digestion temperature : 280°C

Holding time : 1 hour

Digestion liquor conc.(Na_2O_C) : 161·6gpl

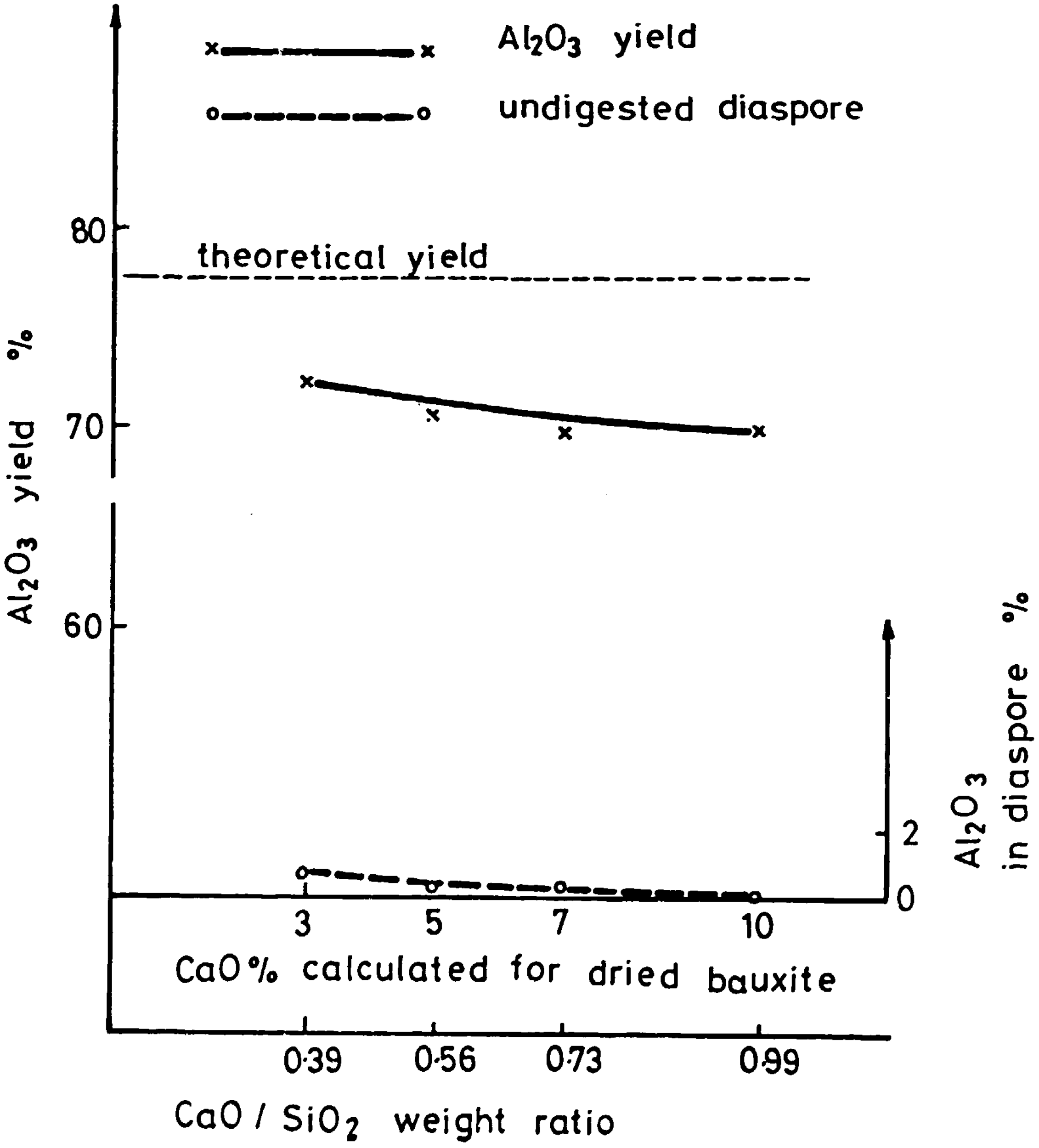
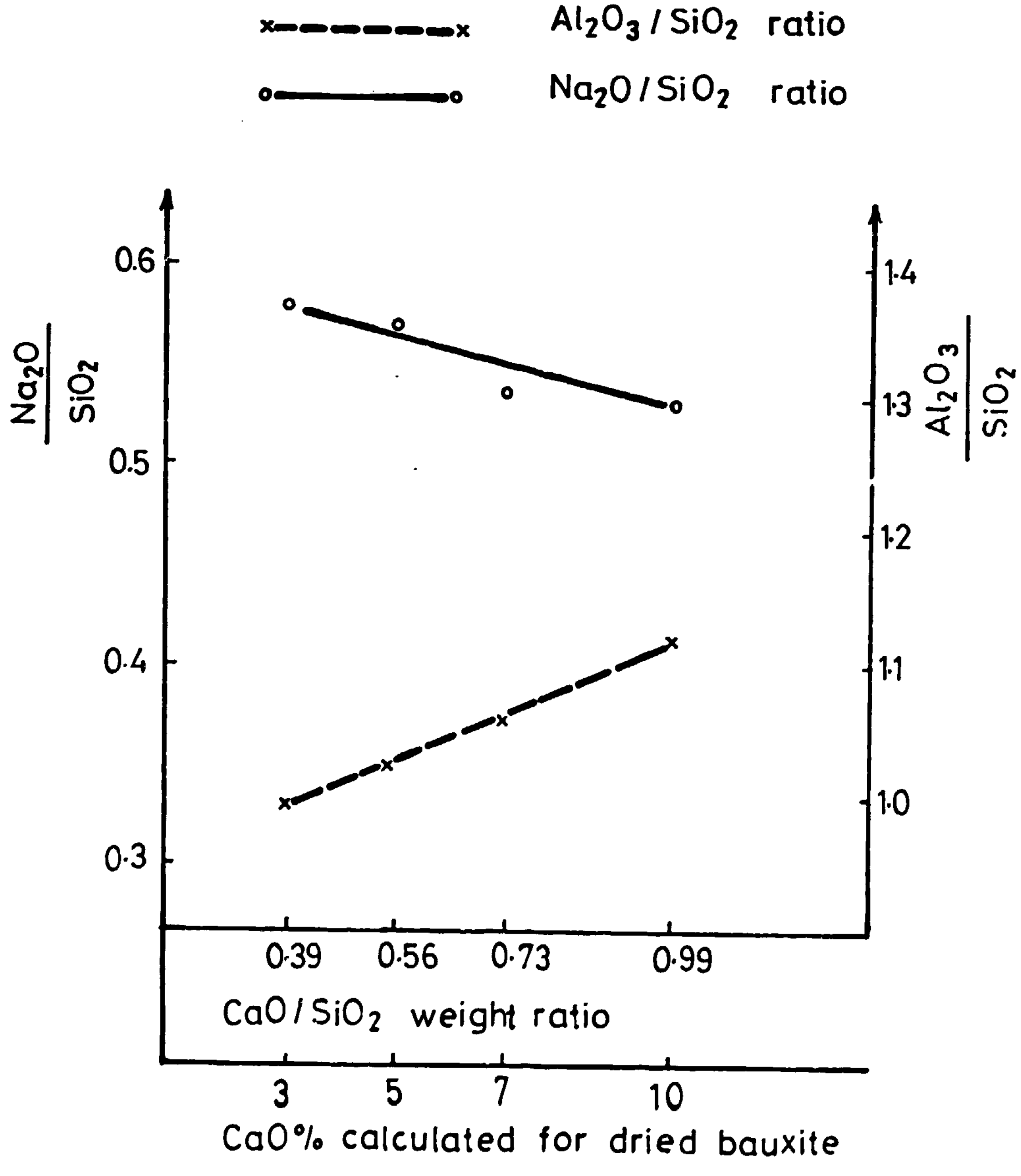


Fig.A2-16

CHANGING OF Na_2O/SiO_2 AND Al_2O_3/SiO_2 W.RATIO IN RED MUD VS QUANTITY OF LIME ADDED TO DIGESTION

Bauxite	: ICS-3
Digestion temperature	: 280°C
Holding time	: 1 hour
Digestion liquor conc.(Na_2O_C)	: 161·6 gpl



7 % of lime additive. The results are given in Tables A2-34 and A2-35.

Minimum amount /1.9% of Al_2O_3/ of undigested diaspore remained in the case of 138 gpl digestion liquor. However, at 161.6 and 180 gpl concentrations practically no undigested diaspore was left.

4.2.3.3. Digestion tests carried out on samples ground to various grain size

Parameters and results of comparative digestion tests carried out on samples ground to below 90 /um and 160 /um are given in Tables A2-36 and A2-37.

With the sample ground to below 160 /um the Al_2O_3-recovery is less by about 4 %, however, with the sample ground to finer size than 90 /um the digestion of diaspore is practically completed.

4.2.3.4. Digestion tests aiming to determine the optimum molar ratio /bauxite to liquor ratio/

In order to determine the optimum digestion molar ratio digestion series comprising six tests at 260° C and by the optimum addition of 7 % CaO were carried out. The parameters and results are given in Tables A2-33 and A2-39 The characteristic digestion curve plotted on basis of the experimental data are shown in Fig. A2-17. Based on the results the optimum molar ratio assuring perfect digestion is considered to be 1.55.

Table A2-34

Digestion tests at different digesting liquor concentration

Modelling of autoclave and tube digestion

Bauxite: ICS-3

Digestion temperature: 260° C

Holding time: 1 hour

Lime addition: 7 % for dried bauxite

Calculated molar ratio: 1.55

Sample	ICS-3 K1	ICS-3 K2	ICS-3 K3
Digesting liquor			
Na_2O_c gpl	138.0	161.6	180.0
Al_2O_3 gpl	70.4	83.0	92.5
M.r.	3.2	3.2	3.2
Liquor analysis after digestion			
Na_2O_c gpl	116.9	130.6	153.0
Al_2O_3 gpl	122.2	141.5	166.8
M.r.	1.57	1.52	1.51
Chem.composition of red mud			
Al_2O_3 %	18.9	17.1	17.3
SiO_2 %	15.7	15.6	15.9
Fe_2O_3 %	26.9	28.1	28.3
TiO_2 %	7.0	7.1	7.2
L.O.I. %	10.4	9.5	9.9
CaO %	11.1	11.5	11.7
MgO %	0.7	0.8	0.8
Na_2O %	8.7	8.3	8.4
Na_2O/SiO_2	0.55	0.53	0.53
Al_2O_3/SiO_2	1.20	1.10	1.09
CaO/SiO_2	0.71	0.74	0.735
Al_2O_3 yield %	64.9	69.6	69.4

Table A2-35

Mineralogical composition of red muds

/Effect of dig. liquor concentration/
Modelling of autoclave and tube digestion

Bauxite: ICS-3
Digestion temperature: 260° C
Holding time: 1 hour

		Digesting liquor concentration		
	- Na_2O_c gpl	138.0	161.6	180.0
Sample		ICS-3 K1	ICS-3 K2	ICS-3 K3
Al_2O_3 % in	diaspore	1.9	0.4	0
	sodalite	4.0	3.4	3.6
	cancrinite	6.7	7.1	7.3
	CAS	4.7	4.9	5.1
	undigested silicates /chan./	1.6	1.3	1.3
	total	18.9	17.1	17.3
SiO_2 % in	sodalite	4.7	3.9	4.2
	cancrinite	7.8	8.5	8.6
	CAS	1.6	1.9	1.8
	undigested silicates /chan./	1.6	1.3	1.3
	total	15.7	15.6	15.9
Fe_2O_3 % in	goethite	2.0	1.6	1.1
	hematite	21.9	24.1	24.8
	undigested silicates /chan./	3.0	2.4	2.4
	total	26.9	28.1	28.3
TiO_2 % in	perowskite	2.7	2.9	3.3
	Na-titanates+ rutile	4.3	4.2	3.9
	total	7.0	7.1	7.2
CaO % in	perowskite	1.9	2.0	2.3
	CAS	7.7	8.0	8.4
	calcite	1.5	1.5	1.0
	total	11.1	11.5	11.7

Table A2-36

Effect of grain size of bauxite

Modelling of autoclave and tube digestion

Bauxite: ICS-3 < 90 μm; ICS-3 < 160 μm

Digestion temperature: 260° C

Holding time: 1 hour

Calculated molar ratio: 1.55

Lime addition: 7 % /for dried bauxite/

Digesting liquor: Na_2O_c 161.6 gpl; Al_2O_3 83.0 gpl; M.r.: 3.2
Na_2O_t 188.8 gpl; SiO_2 0.48 gpl

Sample		Grain size of bauxite	
		< 90 μm	< 160 μm
Liquor analysis after digestion			
	Na_2O_c gpl	130.6	131.5
	Al_2O_3 gpl	141.5	140.9
	Na_2O_t gpl	155.0	156.8
	SiO_2 gpl	0.40	0.40
	M.r.	1.52	1.54
Chem.composition of red mud	Al_2O_3 %	17.1	19.1
	SiO_2 %	15.6	16.4
	Fe_2O_3 %	28.1	28.0
	TiO_2 %	7.1	7.0
	L.O.I. %	9.5	7.7
	CaO %	11.5	12.0
	MgO %	0.8	0.9
	Na_2O %	8.3	8.3
	Na_2O/SiO_2	0.53	0.51
	Al_2O_3/SiO_2	1.10	1.16
	Al_2O_3 yield %	69.6	65.9

Table A2-37

Mineralogical composition of red muds

/Effect of grain size of bauxite/

Modelling of autoclave and tube digestion

Bauxite: ICS-3

Digestion temperature: 260° C

Holding time: 1 hour

Sample	Grain size of bauxite	
	< 90 /um	< 160 /um
Al_2O_3 % in: diaspore	0.4	1.6
sodalite	3.4	4.2
cancrinite	7.1	7.9
CAS	4.9	4.0
undigested silicates /cham./	1.3	1.4
total	17.1	19.1
SiO_2 % in : sodalite	3.9	4.7
cancrinite	8.5	8.9
CAS	1.9	1.4
undigested silicates /cham./	1.3	1.4
total	15.6	16.4
Fe_2O % in: goethite	1.6	1.4
hematite	24.1	24.0
undigested silicates /cham./	2.4	2.6
total	28.1	28.0
TiO_2 % in: perowskite	2.9	4.9
Na-titanates+rutile	4.2	2.1
total	7.1	7.0
CaO % in: perowskite	2.0	3.4
CAS	8.0	6.6
calcite	1.5	2.0
total	11.5	12.0

Table A2-38

Characteristic digestion curve for determination optimum molar ratio

Modelling of autoclave and tube digestion

Bauxite: ICS-3

Digestion temperature: 260° C

Holding time: 1 hour

Calculated molar ratio: 1,3-1,7

Lime addition: 7 % for dried bauxite

Liquor analysis after digestion

Sample	Na_2O_c gpl	Al_2O_3 gpl	Molar ratio	Na_2O_t gpl	SiO_2 gpl	Calculated molar ratio
Digesting liquor	161.3	82.3	3.2	188.8	0.48	-
ICS-3 Mv-1	139.5	160.5	1.43	164.2	0.25	1.30
ICS-3 Mv-2	140.1	162.3	1.42	164.0	0.25	1.40
ICS-3 Mv-3	142.2	161.4	1.45	164.3	0.30	1.45
ICS-3 Mv-4	143.8	158.7	1.49	164.3	0.30	1.50
ICS-3 Mv-5	146.0	143.6	1.56	165.0	0.30	1.55
ICS-3 Mv-6	149.4	144.8	1.70	166.3	0.30	1.70

Chemical composition of red mud

Sample	Al_2O_3 %	SiO_2 %	Fe_2O_3 %	TiO_2 %	L.O.I. %	CaO %	MgO %	Na_2O %	$\frac{Al_2O_3}{SiO_2}$	Al_2O_3 yield %
ICS-3 Mv-1	23.2	14.1	25.8	6.5	9.9	10.7	0.7	7.4	1.64	55.0
ICS-3 Mv-2	19.7	14.9	26.3	6.8	9.8	11.5	0.8	7.9	1.32	62.5
ICS-3 Mv-3	18.9	15.3	27.0	7.0	9.6	11.5	0.8	8.2	1.23	65.0
ICS-3 Mv-4	18.2	15.6	28.9	7.0	9.2	11.7	0.8	8.4	1.17	68.5
ICS-3 Mv-5	17.7	15.6	28.7	7.1	9.0	11.5	0.8	8.4	1.13	69.2
ICS-3 Mv-6	17.5	15.9	28.5	7.1	9.1	11.6	0.9	8.4	1.10	69.3

Table A2-39

Mineralogical composition of red muds

/Effect of molar ratio/

Modelling of autoclave and tube digestion

Bauxite: ICS-3

Digestion temperature: 260° C

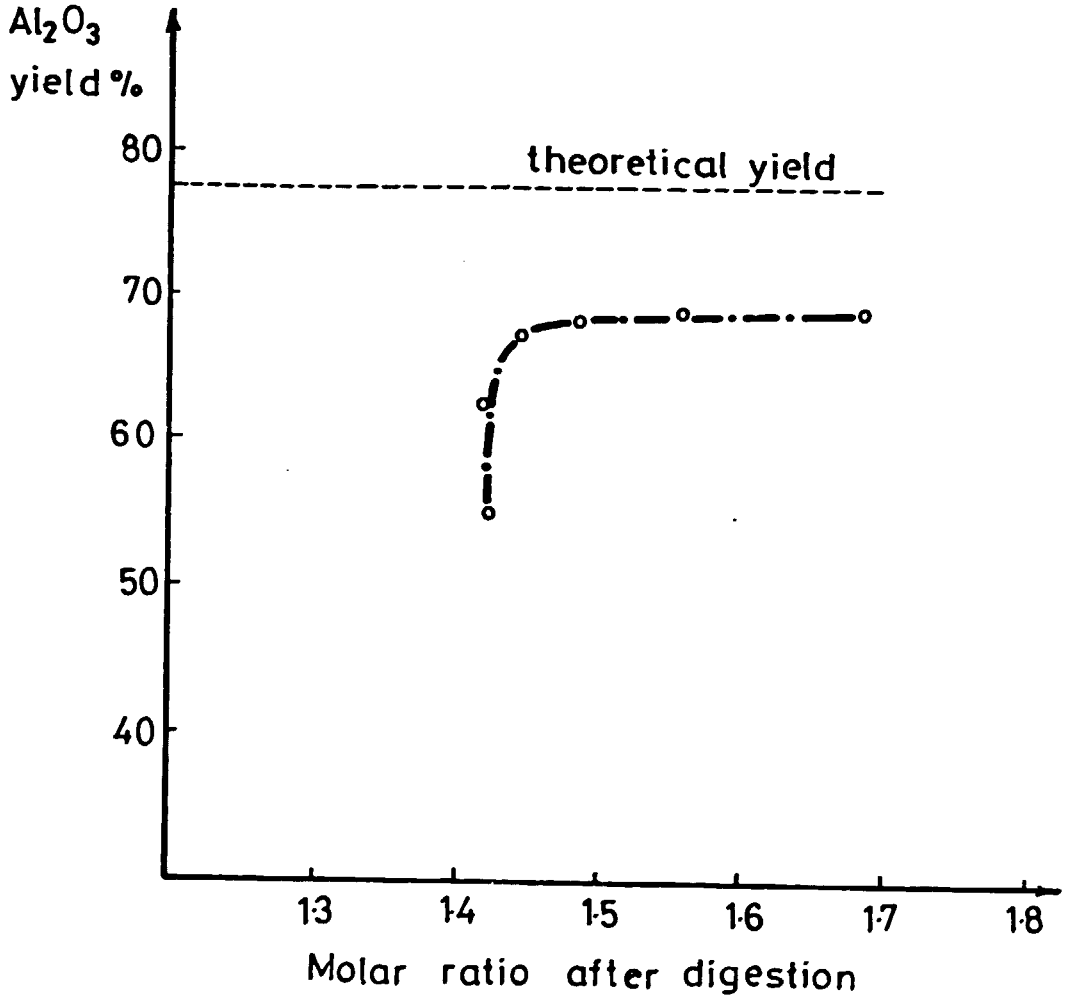
Holding time: 1 hour

		M.r. after digestion		
		1.49	1.56	1.70
Sample		ICS-3 Mv-4	ICS-3 Mv-5	ICS-3 Mv-6
Al_2O_3 % in:	diaspore	0.8	0.3	0.4
	sodalite	3.2	3.4	3.4
	cancrinite	7.8	7.9	7.4
	CAS	4.8	4.8	4.1
	undigested silicates /cham./	1.6	1.3	2.2
	total	18.2	17.7	17.5
SiO_2 % in :	sodalite	3.6	3.9	3.7
	cancrinite	9.0	9.0	8.4
	CAS	1.4	1.4	1.6
	undigested silicates/cham./	1.6	1.3	2.2
	total	15.6	15.6	15.9
Fe_2O_3 % in:	goethite	1.5	1.1	1.4
	hematite	24.4	25.2	23.0
	undigested silicates /cham./	3.0	2.4	4.1
	total	28.9	28.7	28.5
TiO_2 % in:	perowskite	4.0	3.9	5.1
	Na-titanates+rutile	3.0	3.2	2.0
	total	7.0	7.1	7.1
CaO % in:	perowskite	2.8	2.7	3.5
	CAS	7.9	7.8	6.6
	calcite	1.0	1.0	1.5
	total	11.7	11.5	11.6

Fig.A2-17

CHARACTERISTIC DIGESTION CURVE

Bauxite : ICS-3
Digestion temperature : 260°C
Holding time : 1 hour
Lime addition : 7 %
Digestion liquor conc.(Na_2O_C) : 161·6 gpl



4.2.3.5 Determination of optimum retention time

The results of tests carried out for the determination of optimum retention time are summarized in Table A2-40. Similarly as with sample ICS-2, the temperature of 260° C and a retention time of 30 minutes was sufficient for the perfect digestion of diaspore.

Table A2-40

Effect of the holding time

Modelling of autoclave and tube digestion

Bauxite: ICS-3

Digestion temperature: 260° C

Holding time: 10 minutes - 1 hour

Calculated molar ratio: 1.55

Lime addition: 7 % /for dried bauxite/

Digesting liquor: Na_2O_c 161.6 gpl; Al_2O_3 83.0 gpl; M.r.: 3.2
Na_2O_t 188.8 gpl; SiO_2 0.48 gpl

		Holding time			
		lo min.	20 min.	30 min.	1 hour
Liquor analysis after digestion	Na_2O_c gpl	130.0	131.4	132.5	133.1
	Al_2O_3 gpl	138.9	141.2	144.5	144.0
	Na_2O_t gpl	154.1	155.7	156.0	155.6
	SiO_2 gpl	0.40	0.40	0.40	0.40
	M.r.	1.54	1.51	1.51	1.52
Chem. composition of red mud	Al_2O_3 %	18.4	18.1	17.7	17.6
	SiO_2 %	16.1	16.1	16.3	16.1
	Fe_2O_3 %	28.0	28.2	28.6	29.5
	TiO_2 %	7.1	7.3	7.3	7.3
	L.O.I. %	9.0	8.6	8.4	7.6
	CaO %	12.4	12.0	12.4	12.3
	MgO %	0.8	0.8	0.8	0.8
	Na_2O %	8.4	8.6	8.4	8.2
	Na_2O/SiO_2	0.52	0.53	0.52	0.51
	Al_2O_3/SiO_2	1.14	1.12	1.09	1.09
	Al_2O_3 yield %	67.1	67.9	69.1	70.1

Attachment 3

Technological flow-sheets, material balances and water balances

A3-1

Technological flow-sheet and material flow for 1 ton of alumina produced

Low quality bauxite sintering process

Table A3-1

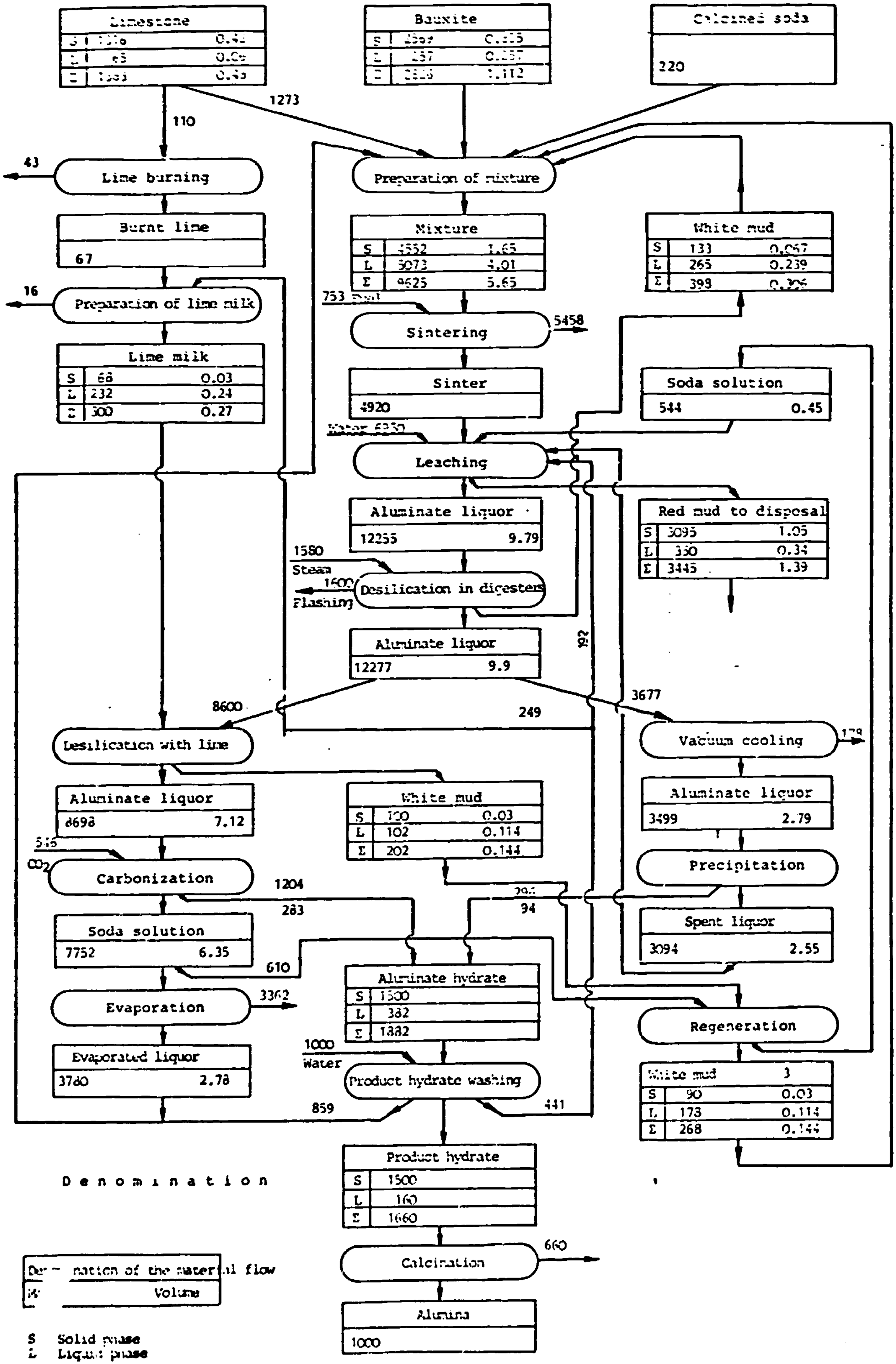
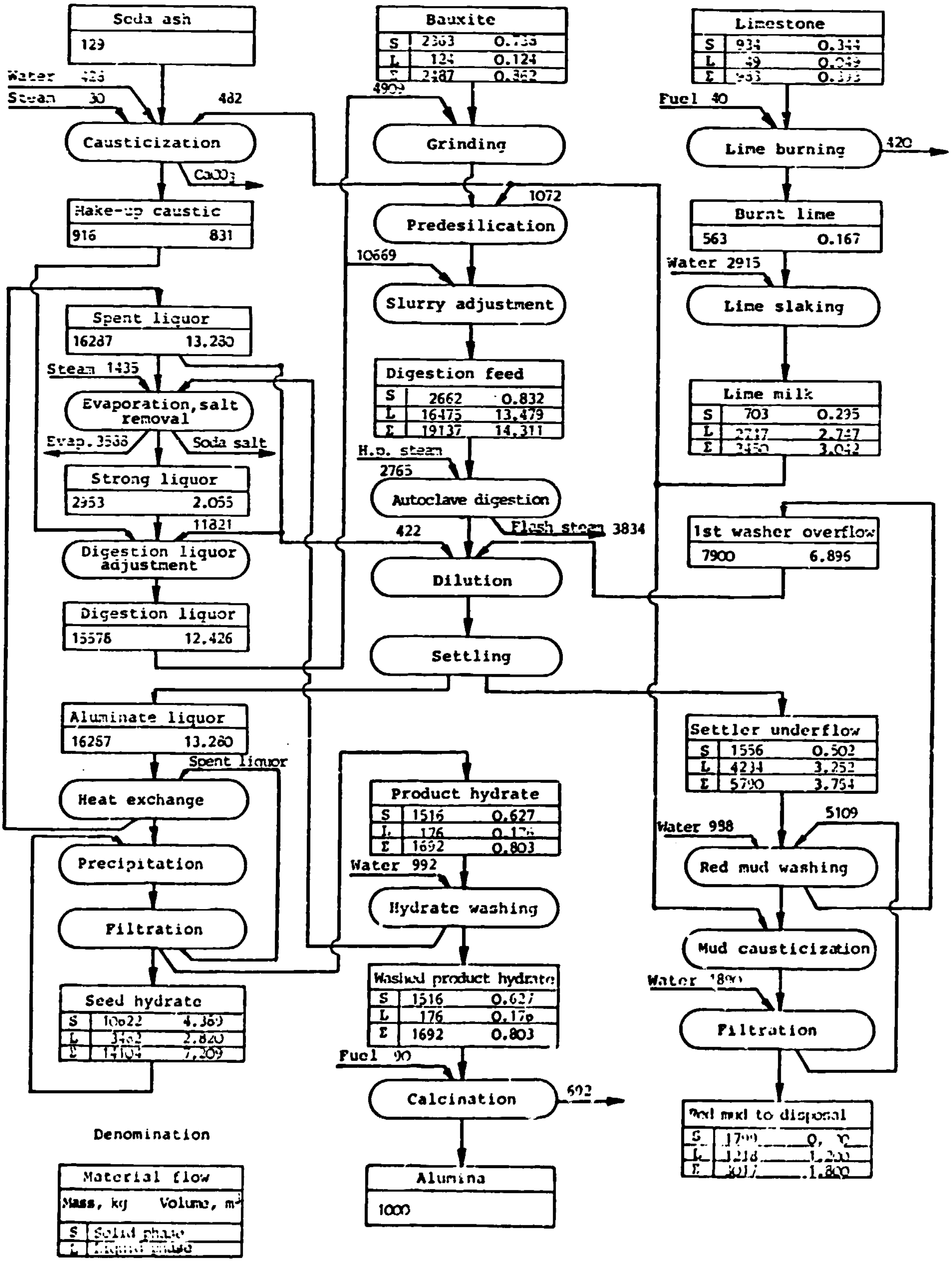


Table A3-2

Technological flow-sheet and material flow for 1 ton of alumina
High quality bauxite, Bayer process, autoclave digestion



A3-3

Technological flow-sheet and material flow for 1 ton of alumina
High quality bauxite, Bayer process, tube digestion

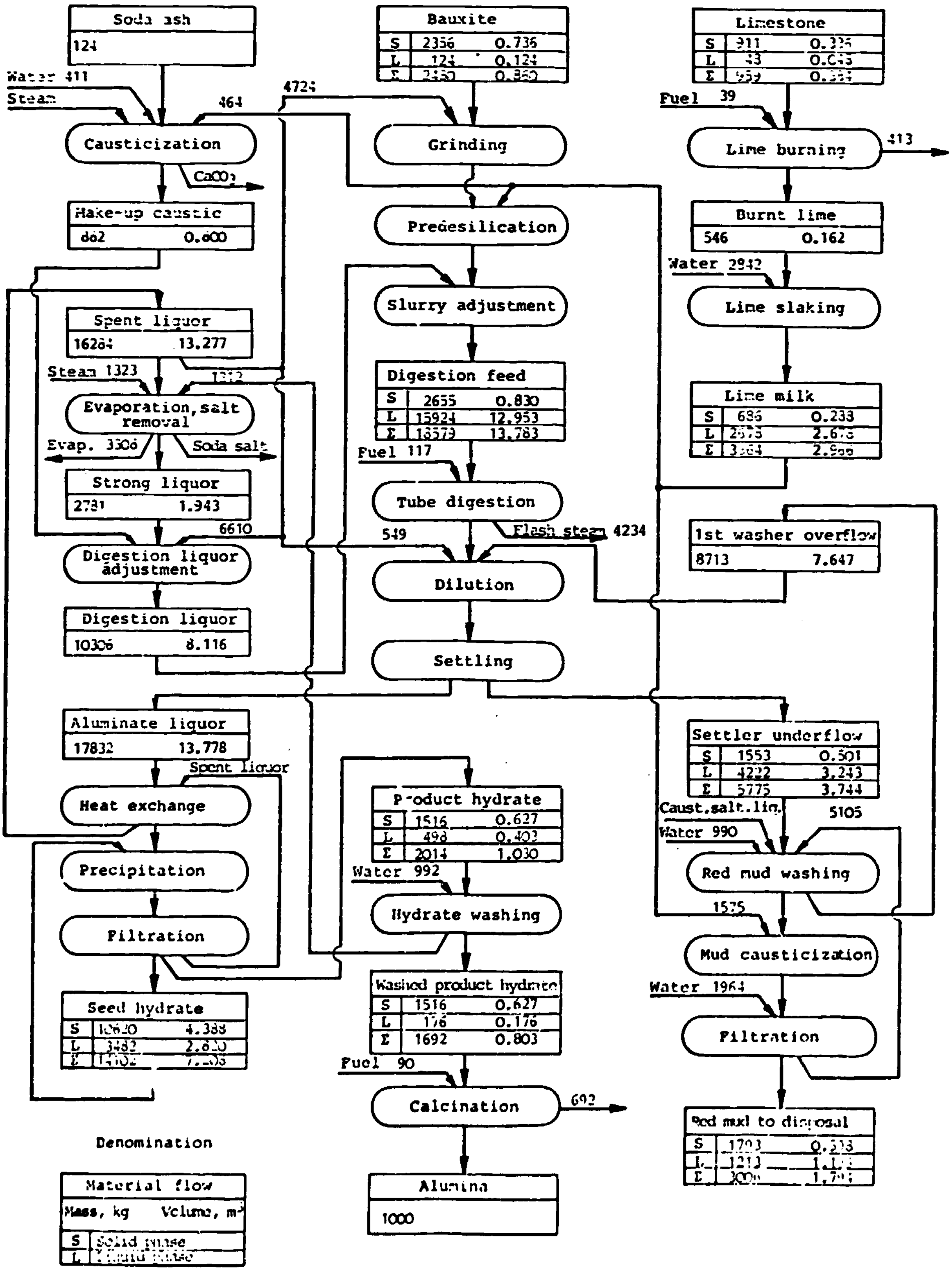


Table A3-4

Technological water balance
Low quality bauxite sintering variant
kg water/t alumina

		solid phase	liquid phase
IN:	Sinter feed :		
	with bauxite	318	257
	with limestone	–	60
	Aluminate liquor autoclave desilication: contact heating	–	1580
	Mud washing	–	6950
	Lime burning	–	5
	Hydrate washing	–	1000
	Total	318	9852
	Grand total	10170	
OUT:	Sintering	–	4237
	Aluminate liquor autoclave desilication: flash steam	–	1160
	Evaporation	–	3256
	Vacuum cooling	–	178
	Lime burning, flue gas losses	–	9
	Mud disposal	310	350
	Calcination	540	130
	Total	850	9320
	Grand total	10170	

Table A3-5

Technological water balance
High quality bauxite, autoclave digestion
kg water/t alumina

		solid phase	liquid phase
IN:	Bauxite: bound	258	-
	adhesive moist.	-	124
	Alkaline condensate		
	to lime slaking	-	2915
	to hydrate washing	-	992
	to mud washing and caustication	-	2271
	to salt causticization	-	98
	to soda ash causticization	-	428
	Direct heating	-	270
	Make-up water	-	2091
	Other consumptions	-	101
	Total	258	9290
	Grand total	9548	
OUT:	Filtered mud: bound	225	-
	liquid phase	-	1200
	Product hydrate: bound	525	-
	adherent	-	176
	Evaporation	-	3588
	Digestion flash vapour	-	3834
	Total	750	8798
	Grand total	9548	

Table A3-6

Technological water balance
High quality bauxite, tube digestion
kg water/t alumina

		solid phase	liquid phase
IN:	Bauxite: bound	257	-
	adhesive moist.	-	124
	Alkaline condensate		
	to lime slaking	-	2842
	to hydrate washing	-	992
	to mud washing and causticization	-	2537
	to salt causticization	-	98
	to soda ash causticization	-	411
	Direct heating	-	270
	Make-up water	-	2001
	Other consumptions	-	101
	Total	257	9376
	Grand total	9663	
OUT:	Filtered mud: bound	224	-
	liquid phase	-	1196
	Product hydrate: bound	525	-
	adherent	-	176
	Evaporation	-	3308
	Digestion flash vapour	-	4234
	Total	749	8914
	Grand total	9663	

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Attachment 4

Main equipment list

MAIN EQUIPMENT LIST

Attachment 4

	Total	Number Operating	Total Weight (t)
MECHANICAL EQUIPMENT FOR SINTERING PROCESS			
1. <u>Bauxite receiving and crushing</u> 1a <u>Bauxite storage</u>			
1. Hammer mill with vibrating screen Cap.: 160 t/h	1	1	24
2. Front end loaders Bucket cap.: 1.3 m^3	3	2	
3. Rubber belt conveyors B = 1000 mm L = 10 m Cap.: 160 t/h	1	1	6
4. Rubber belt conveyor B = 1000 mm L = 150 m Cap.: 160 t/h	1	1	30
5. Rubber belt conveyor with weighing belt B = 1000 mm L = 200 m Cap.: 125 t/h	1	1	40
6. Apron belts with speed control B = 1000 mm L = 8 m Cap.: 160 t/h	1	1	15

	Total	Number Operating	Total Weight (t)
7. Apron belts with speed control B = 800 mm L = 6 m Cap.: 85 t/h	2	1	16
8. Electric hoist Cap.: 5 t	1	1	–

2. Limestone receiving and crushing

2a Limestone storage

	Total	Number Operating	Total Weight (t)
1. Jaw crusher with vibrating screen Cap.: 80 t/h	1	1	25
2. Apron belt with speed control B = 800 mm L = 6 m Cap.: 80 t/h	1	1	8.5
3. Rubber belt conveyor B = 800 mm L = 150 m Cap.: 80 t/h	1	1	26
4. Apron belts with speed control B = 800 mm L = 6 m Cap.: 40 t/h	4	2	20
5. Rubber belt conveyor B = 800 mm L = 110 m Cap.: 40 t/h	1	1	20
6. Rubber belt conveyor with weighing belt B = 800 mm L = 45 m Cap.: 40 t/h	1	1	12
7.*Dust collecting facility with exhaust fan Cap.: 3500 m^3/h	1	1	2.5

	Total	Number Operating	Total Weight (t)
8. Front end loaders Bucket cap.: 1.3 m^3	2	1	
9. Electric hoist Cap.: 5 t	1	1	1

3. Lime burning
3a Lime slaking

	Total	Number Operating	Total Weight (t)
1. Shaft kiln for burning limestone with elevator, exhaust fan, dust collector gas purifier, with burnt lime extractor, vibrating feeder, rubber belt conveyor, with fuel oil supply system, with electrical equipment, process control and instrumentation Cap.: 70 t/day (CaO)	1	1	300
2. Lime slaking drum ∅ 1.8 m x 10 m Cap.: 10 m^3/h slaked lime	1	1	10
3.*Burnt lime silo with feed and discharge facilities Cap.: 100 t Feed and disch. cap.: 5 t/h	1	1	12
4.*Flat bottom tanks Volume: 25 m^3	3	2	10
5. Agitators for tanks with gearboxes, couplings and electric motors	2	1	6
6. Centrifugal pumps for slaked lime Cap.: 10 m^3/h	4	2	2

4. Soda ash receiving and storage

	Total	Number Operating	Total Weight (t)
1.*Soda ash silos with pneumatic feed and discharge facilities ϕ 10 m x 27 m Volume: 2000 m^3	2	2	480

5. Wet grinding

	Total	Number Operating	Total Weight (t)
1. Multi-chamber ball mills with vibrating screens ∅ 2.6 m x 13 m Cap.: 125 t/h	2	1	140
2. Rubber belt conveyors with weighing belts and speed control B = 800 mm L = 8 m Cap.: 125 t/h	2	1	6
3.*Flat bottom tanks Volume: 6.3-50 m^3	5	4	13
4. Agitators for tanks with gearboxes, couplings and electric motors	4	3	6
5. Centrifugal pumps for slurry with speed control Cap.: 180 m^3/h	4	2	4
6. Centrifugal pumps for slurry Cap.: 30 m^3/h	2	2	1.5
7.*Centrifugal pumps for water Cap.: 50 m^3/h	2	1	2

	Total	Number Operating	Total Weight (t)
6. Adjustment tanks			
1.*Tanks with conical bottom ϕ 9 m x 20 m Volume: 1000 m^3	11	11	770

6a High pressure pump station

	Total	Number Operating	Total Weight (t)
1. Piston slurry pumps with suction and delivery dashpot Cap.: 120 m^3/h Head: 30 bar	6	2	156
2. Overhead travelling crane Cap.: 5 t	1	1	12

	Total	Number Operating	Total Weight (t)
7. Sintering			
1. Rotary kilns with coolers, cyclons, gas purification systems and with oil heating system and exhaust fans ∅ 5 x 120 m Cap.: 1600 t/day	3	2	6750
2. Rubber belt conveyors B = 800 mm L = 150 m Cap.: 65 t/h	2	1	60

	Total	Number Operat-ing	Total Weight (t)
8. <u>Sinter crushing</u>			
1. Bucket elevators Cap.: 65 t/h	2	1	30
2. Screen classifiers Cap.: 65 t/h	3	2	18
3. Jaw crushers Cap.: 50 t/h	3	2	54
4. Double deck vibrating screens Screening area: 2.5 m x 6 m	3	2	36
5. Cone crushers Dia: 2200 mm Cap.: 70 t/h	3	2	255
6. Rubber belt conveyors B = 800 mm L = 6 m Cap.: 65 t/h	3	2	12
7. Rubber belt conveyors B = 800 mm L = 8 m Cap.: 60 t/h	3	2	10
8. Rubber belt conveyors B = 600 mm L = 10 m Cap.: 15 t/h	3	2	9

	Total	Number Operating	Total Weight (t)
9. <u>Sinter leaching</u>			
1. Belt extractors Cap.: 70 t/h	2	2	1740
2. Jigging screens Surface: 41.5 m^2	6	6	120
3.*Flat bottom tanks Volume: 6.3-100 m^3	19	14	82
4. Agitators for tanks with gearboxes, couplings and electric motors	19	14	45
5. Centrifugal pumps for slurry with speed control Cap.: 220-300 m^3/h	8	4	12
6. Centrifugal pumps for slurry Cap.: 30-100 m^3/h	22	13	24

10. Autoclave desilication

	Total	Number Operating	Total Weight (t)
1. Autoclaves ϕ 2.5 m x 14 m Volume: 50 m^3	14	14	280
2. Flash tanks ϕ 3.6 m x 5.6 m Volume: 50 m^3	4	4	52
3.*Flat bottom tanks Volume: 6.3-100 m^3/h	4	4	16
4. Agitators for tanks with gearboxes, couplings and electric motors	4	4	7
5. Centrifugal pumps for slurry with speed control Cap.: 150 m^3/h	4	2	4
6. Centrifugal pumps for slurry Cap.: 30 m^3/h	2	2	1

11. White mud No.1 settling

	Total	Number Operating	Total Weight (t)
1. Single chamber settler ϕ 20 m x 4 m Volume: 1500 m^3	1	1	87
2. Vacuum drum filters with filtrate receivers Surface: 10 m^2	2	1	18
3.*Flat bottom tanks Volume: 6.3-200 m^3/h	8	5	39
4. Agitators for tanks with gearboxes, couplings and electric motors	8	5	21
5. Centrifugal pumps for slurry with speed control Cap.: 200 m^3/h	2	1	3
6. Centrifugal pumps for slurry Cap.: 15-100 m^3/h	8	5	6
7.*Centrifugal pumps for water Cap.: 15 m^3/h	2	1	1

	Total	Number Operating	Total Weight (t)
12. Control filtration			
1. Pressure filters Surface: 125 m^2	2	1	22
2.*Flat bottom tanks Volume: 6.3-50 m^3	6	5	23
3. Agitators for tanks with gearboxes, couplings and electric motors	5	4	8
4. Centrifugal pumps for slurry Cap.: 30-100 m^3/h	7	4	5
5. Centrifugal pumps for liquor Cap.: 60 m^3/h	2	1	1.5

13. Flash cooling, precipitation

	Total	Number Operating	Total Weight (t)
1. Vacuum flash vessels ϕ 2 m	3	3	30
2. Shell and tube type heat exchangers Surface: 180 m^2	2	2	36
3.*Hydroseparator ϕ 7 m x 19 m Volume: 400 m^3	1	1	25
4. Vacuum disc filters with filtrate receivers Surface: 100 m^2	2	1	40
5. Pressure filters Surface: 125 m^2	2	1	22
6. Vacuum drum filters with filtrate receivers Surface: 10 m^2	3	2	24
7.*Precipitator tanks with conical bottom Volume: 1000 m^3	7	7	630
8.*Flat bottom tanks Volume: 6.3-50 m^3	15	10	59
9. Agitators for tanks with gearboxes, couplings and electric motors	15	10	19
10. Centrifugal pumps for slurry Cap.: 15-100 m^3/h	16	11	14
11. Centrifugal pumps for liquor Cap.: 15-100 m^3/h	8	4	7

	Total	Number Operating	Total Weight (t)
14. Deep desilication			
1. Single chamber settlers ø 20 m x 4 m Volume: 1500 m^3	2	2	24
2. Pressure filters Surface: 125 m^2	3	2	33
3. Vacuum drum filters with filtrate recievers Surface: 10 m^2	4	2	32
4.*Flat bottom tanks Volume: 6.3-200 m^3	23	17	143
5. Agitators for tanks with gearboxes, couplings and electric motors	23	17	82
6. Centrifugal pumps for slurry, with speed control Cap.: 230 m^3/h	6	3	7
7. Centrifugal pumps for slurry Cap.: 15-25 m^3/h	14	12	10
8. Centrifugal pumps for liquor Cap.: 15 m^3/h	4	2	2

	Total	Number Operating	Total Weight (t)
15. <u>Carbonisation and filtration</u>			
1.*Hydroseparator ϕ 10 m x 28 m Volume: 1000 m^3	1	1	40
2. Vacuum disc filters with filtrate recievers Surface: 100 m^2	3	2	40
3. Vacuum drum filters with filtrate receivers Surface: 20 m^2	3	2	36
4.*Flat bottom tanks Volume: 6.3-250 m^3	25	21	180
5. Agitators for tanks with gearboxes, couplings and electric motors	25	21	105
6. Centrifugal pumps for slurry, with speed control Cap.: 230 m^3/h	6	3	7
7. Centrifugal pumps for slurry Cap.: 30-50 m^3/h	21	13	15

16. Carbonised hydrate filtration

	Total	Number Operating	Total Weight (t)
1. Pressure filters Surface: 125 m^2	3	2	15
2.*Flat bottom tanks Volume: 6.3-160 m^3	7	6	32
3. Agitators for tanks with gearboxes, couplings and electric motors	7	6	20
4. Centrifugal pumps for slurry with speed control Cap.: 200 m^3/h	2	1	2
5. Centrfugal pumps for slurry Cap.: 30-100 m^3/h	6	4	5
6. Centrifugal pumps for liquor Cap.: 60 m^3/h	2	1	1.4

	Total	Number Operating	Total Weight (t)
17. <u>Hydrate storage</u>			
1.*Flat bottom tanks Volume: 6.3 m^3	1	1	3
2. Agitator for tank with gearbox, coupling and electric motor	1	1	1.2
3. Centrifugal pumps for slurry Cap.: 50 m^3/h	2	1	1

	Total	Number Operating	Total Weight (t)
18. Calcination, alumina storage			
1. Pan filters with filtrate receivers interstage pumps, tanks Surface: 25 m^2	2	1	24
2. Fluid bed calcining kiln, with cyclons electrostatic dust precipitator, exhaust fan, alumina cooler, oil heating system Cap.: 700 t/day	1	1	–
3. Centrifugal pumps for liquor Cap.: 20 m^3/h	4	2	2
4. Alumina silo feed and discharge units	2	2	7
5. Vaggon feed units	2	2	1.6

	Total	Number Operating	Total Weight (t)
19. <u>Evaporation</u>			
1. Five effects, counter current, forced circulation evaporator units with flash tanks, preheaters fead and circulation pumps Cap.: 65 t/h evaporated water	2	2	400
2.*Flat bottom tanks Volume: 6.3-200 m^3	13	13	80
3. Agitators for tanks with gearboxes, couplings and electric motors	8	8	30
4. Centrifugal pumps for liquor Cap.: 65-100 m^3/h	8	5	7
5.*Centrifugal pumps for condensate water Cap.: 60-100 m^3/h	7	4	6

	Total	Number Operating	Total Weight (t)
20. <u>Vacuum station</u>			
1. Water ring vacuum pumps Cap.: 7500 m^3/h	3	2	14
2. Air blowers Cap.: 2000 m^3/h	3	2	3.6
3. Electric overhead travelling crane Cap.:5 t	1	1	12

	Total	Number Operating	Total Weight (t)
21. Compressor station			
1. Turbo-compressors Cap.: 15000 Nm^3/h Pressure: 5 bar	3	2	24
2. Air tanks Volume: 50 m^3/h Pressure: 5 bar	3	3	15
3. Electric overhead travelling crane Cap.: 12.5 t	1	1	14

MECHNAICAL EQUIPMENT FOR BAYER PROCESS

1. <u>Bauxite receiving and crushing</u>

1a. <u>Bauxite storage</u>

Low quality bauxite

Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Jaw crusher with vibrating screen Cap.: 140 t/h	1	1	31
2.	Hammer mill with vibrating screen Cap.: 140 t/h	1	1	23
3.	Apron belt with speed control B = 1000 mm L = 8 m Cap.: 140 t/h	1	1	18
4.	Rubber belt conveyor B = 1000 mm L = 10 m Cap.: 140 t/h	1	1	8
5.	Rubber belt conveyor B = 800 mm L = 10 m Cap.: 100 t/h	1	1	8
6.	Rubber belt conveyor B = 1000 mm L = 220 m Cap.: 140 t/h	1	1	48

		Total	Number Operating	Total Weight (t)
7.	Apron belts with speed control B = 800 mm L = 6 m Cap.: 110 t/h	4	1	32
8.	Rubber belt conveyor B = 800 mm L = 250 m Cap.: 110 t/h	1	1	50
9.	Rubber belt conveyor with weighing belt B = 800 mm L = 6 m Cap.: 75 t/h	1	1	4
10.	Front end loaders Bucket cap.: 1.3 m^3	3	2	
11.	Electric hoist Cap.: 5 t	1	1	0.8

1. <u>Bauxite receiving and crushing</u>

1a. <u>Bauxite storage</u>

High quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Jaw crusher with vibrating screen Cap.: 100 t/h	1	1	28
2.	Hammer mill with vibrating screen Cap.: 100 t/h	1	1	20
3.	Apron belt with speed control B = 800 mm L = 8 m Cap.: 100 t/h	1	1	16
4.	Rubber belt conveyor B = 800 mm L = 10 m Cap.: 100 t/h	1	1	6
5.	Rubber belt conveyor B = 800 mm L = 10 m Cap.: 100 t/h	1	1	6
6.	Rubber belt conveyor B = 800 mm L = 150 m Cap.: 100 t/h	1	1	30

		Total	Number Operating	Total Weight (t)
7.	Apron belts with speed control B = 800 mm L = 6 m Cap.: 75 t/h	2	1	15
8.	Rubber belt conveyor B = 800 mm L = 200 m Cap.: 75 t/h	1	1	40
9.	Rubber belt conveyor with weighing belt B = 800 mm L = 6 m Cap.: 75 t/h	1	1	4
10.	Front end loaders Bucket cap.: 1.3 m^3	3	2	
11.	Electric hoist Cap.: 5 t	1	1	0.8

2. Limestone receiving and crushing

2a. Limestone storage

Low quality bauxite

Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Jaw crusher with vibrating screen Cap.: 100 t/h	1	1	27
2.	Apron belt with speed control B = 800 mm L = 6 m Cap.: 100 t/h	1	1	8.5
3.	Rubber belt conveyor with speed control B = 800 mm L = 220 m Cap.: 100 t/h	1	1	45
4.	Apron belts with speed control B = 800 mm L = 6 m Cap.: 80 t/h	4	1	28
5.	Rubber belt conveyor with weighing belt B = 800 mm L = 180 m Cap.: 80 t/h	1	1	31
6.*	Dust collecting facility with exhaust fan Cap.: 3500 m^3/h	1	1	2.5
7.	Front end loaders Bucket cap.: 1.3 m^3	2	1	
8.	Electric hoist Cap.: 5 t	1	1	1

2. Limestone receiving and crushing

2a. Limestone storage

High quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Jaw crusher with vibrating screen Cap.: 80 t/h	1	1	25
2.	Apron belt with speed control B = 800 mm L = 6 m Cap.: 80 t/h	1	1	8.5
3.	Rubber belt conveyor with speed control B = 800 mm L = 150 m Cap.: 80 t/h	1	1	30
4.	Apron belts with speed control B = 600 mm L = 6 m Cap.: 40 t/h	2	1	12
5.	Rubber belt conveyor with weighing belt B = 600 mm L = 130 m Cap.: 40 t/h	1	1	21
6.*	Dust collecting facility with exhaust fan Cap.: 3500 m^3/h	1	1	2.5
7.	Front end loaders Bucket cap.: 1.3 m^3	2	1	
8.	Electric hoist Cap.: 5 t	1	1	1

3. Lime burning

3a. Lime slaking

Low quality bauxite

Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Shaft kiln for burning limestone with elevators, exhaust fans, dust collectors, gas purifiers, with burnt lime extractors, vibrating feeders, rubber belt conveyors, with fuel oil supply system, with electrical equipment, process control and instrumentation. Cap.: 250 t/day	3	3	1200
2.*	Burnt lime silo with feed and discharge facilities ∅ 8.5 m x 12 m s.s. conical bottom Cap.: 750 t Feed and disch.cap.: 16 t/h	1	1	45
3.	Lime settler ∅ 20 m x 5 m s.s. 1:3 slope bottom	1	1	100
4.	Lime slaking drums ∅ 1.8 m x 10 m Cap.: 80 m^3/h slaked lime	2	2	20
5.	Rubber belt conveyor with weighing belt B = 600 mm L = 15 m Cap.: 20 t/h	2	2	12
6.*	Flat bottom tanks Volume: 6.3-100 m^3	4	3	27

		Total	Number Operating	Total Weight (t)
7.	Agitators for tanks with gearboxes, couplings and electric motors	3	2	6
8.	Centrifugal pumps for slurry with speed control Cap.: 10-95 m^3/h	10	5	6
9.	Centrifugal pump for slurry Cap.: 30 m^3/h	1	1	1
10.*	Centrifugal pump for water Cap.: 65 m^3/h	2	1	2

3. <u>Lime burning</u>

3a. <u>Lime slaking</u>

High quality bauxite
Autoclave and tube digestion

	Total	Number Operating	Total Weight (t)
1. Shaft kiln for burning limestone with elevators, exhaust fans, dust collectors, gas purifiers, with burnt lime extractors, vibrating feeders, rubber belt conveyors, with fuel oil supply system, with electrical equipment, process control and instrumentation. Cap.: 175 t/day	2	2	700
2.* Burnt lime silo with feed and discharge facilities ϕ 8 m x 10 m s.s. conical bottom Cap.: 500 t Feed and disch.cap.: 16 t/h	1	1	35
3. Lime settler ϕ 20 m x 5 m s.s. 1:3 slope bottom	1	1	100
4. Lime slaking drum ϕ 1.8 m x 10 m Cap.: 80 m^3/h slaked lime	1	1	10
5. Rubber belt conveyor with weighing belt B = 600 mm L = 15 m Cap.: 16 t/h	1	1	6
6.* Flat bottom tanks Volume: 6.3-50 m^3	4	3	18

		Total	Number Operating	Total Weight (t)
7.	Agitators for tanks with gearboxes, couplings and electric motors	3	2	4.5
8.	Centrifugal pumps for slurry with speed control Cap.: 10-65 m^3/h	10	5	4.5
9.	Centrifugal pump for slurry Cap.: 30 m^3/h	1	1	1
10.*	Centrifugal pump for water Cap.: 65 m^3/h	2	1	2

4. Soda ash handling and causticization

Low quality bauxite
Autoclave and tube digestion

	Total	Number Operating	Total Weight (t)
1.* Soda ash silos with pneumatic feed and discharge facilities ɸ 10 m x 18 m with conical bottom Volume: 1400 m^3	2	2	140
2.* Day bin with feed and discharge facilities ɸ 4 m x 8 m with conical bottom Volume: 50 m^3 Feed and disch.cap.: 10 t/h	1	1	10
3. Pressure belt filter Filtration area 20 m^2 Cap.: 5 t/h	1	1	6.5
4. Rubber belt conveyor with weighing belt B = 500 mm L = 5 m Cap.: 10 t/h	1	1	1.5
5.* Flat bottom tanks Volume: 50 m^3	5	5	26
6. Agitators for tanks with gearboxes, couplings and electric motors	5	5	7
7. Centrifugal pumps for slurry Cap.: 25 m^3/h	2	1	1.5
8. Centrifugal pumps for liquor Cap.: 25 m^3/h	4	2	3

4. Soda ash handling and causticization

High quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.*	Soda ash silos with pneumatic feed and discharge facilities ϕ 8 m x 14 m with conical bottom Volume: 700 m^3	2	2	90
2.*	Day bin with feed and discharge facilities ϕ 3.5 m x 8 m with conical bottom Volume: 50 m^3 Feed and disch.cap.: 6 t/h	1	1	8
3.	Pressure belt filter Filtration area 20 m^2 cap.: 5 t/h	1	1	6.5
4.	Rubber belt conveyor with weighing belt B = 500 mm L = 5 m Cap.: 6 t/h	1	1	1.5
5.*	Flat bottom tanks Volume: 25 m^3	5	5	21
6.	Agitators for tanks with gearboxes, couplings and electric motors	5	5	6
7.	Centrifugal pumps for slurry Cap.: 25 m^3/h	2	1	1.5
8.	Centrifugal pumps for liquor Cap.: 25 m^3/h	4	2	3

5. Wet grinding

Low quality bauxite

Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Rubber belt conveyors with weighing belts B = 800 mm L = 50 m Cap.: 50 t/h	3	2	6
2.	Multi-chamber ball mills with conical screens ∅ 2.6 m x 13 m Cap.: 50 t/h	3	2	360
3.	Classifier screens	9	6	11
4.*	Flat bottom tanks Volume: 200 m^3	2	2	20
5.*	Flat bottom tanks Volume: 6.3-50 m^3	6	5	19
6.	Agitators for tanks with gearboxes, couplings and electric motors	7	6	19
7.	Centrifugal pumps for slurry with speed control Cap.: 70-200 m^3/h	8	3	10
8.	Centrifugal pumps for slurry Cap.: 30 m^3/h	2	2	2
9.*	Centrifugal pumps for water Cap.: 60 m^3/h	2	1	1.5

5. Wet grinding

High quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Rubber belt conveyors with weighing belts B = 800 mm L = 50 m Cap.: 35 t/h	3	2	6
2.	Multi-chamber ball mills with conical screens ø 2.2 m x 13 m Cap.: 35 t/h	3	2	315
3.	Classifier screens	9	6	11
4.*	Flat bottom tanks Volume: 200 m^3	2	2	20
5.*	Flat bottom tanks Volume: 6.3-50 m^3	6	5	19
6.	Agitators for tanks with gearboxes, couplings and electric motors	7	6	19
7.	Centrifugal pumps for slurry with speed control Cap.: 70-140 m^3/h	8	3	8
8.	Centrifugal pumps for slurry Cap.: 30 m^3/h	2	2	2
9.*	Centrifugal pumps for water Cap.: 60 m^3/h	2	1	1.5

6. Slurry storage and predesilication

Low quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Shell and tube type heat exchangers Shell dia: ∅ 273 x 6.3 mm Heating tubes: 3 x ∅ 108 x 4 mm Surface: 12 m^2	18	12	22
2.*	Flat bottom tanks Volume: 500 m^3	5	4	85
3.*	Flat bottom tanks Volume: 6.3-200 m^3	3	3	22
4.	Agitators for tanks with gearboxes, couplings and electric motors	8	7	55

6. Slurry storage and predesilication

High quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Shell and tube type heat exchangers Shell dia: ∅ 219 x 6.3 mm Heating tubes: 3 x ∅ 76 x 2.9 mm Surface: 10 m^2	18	12	22
2.*	Flat bottom tanks Volume: 500 m^3	4	3	68
3.*	Flat bottom tanks Volume: 6.3-200 m^3	3	3	22
4.	Agitators for tanks with gearboxes, couplings and electric motors	7	6	47
5.	Centrifugal pumps for slurry with speed control Cap.: 210 m^3/h	3	2	3.3
6.	Centrifugal pumps for liquor with speed control Cap.: 120-250 m^3	4	2	4.4
7.	Centrifugal pumps for slurry Cap.: 30 m^3/h	1	1	0.8

		Total	Number Operating	Total Weight (t)
7.	**H.P. pump station** Low and high quality bauxite Autoclave digestion			
1.	H.P. diaphragm pumps with speed control, with suction and delivery dashpots Cap.: 230 m^3/h Head: 70 bar	3	2	165
2.*	Flat bottom tank Volume: 6.3 m^3	1	1	1.6
3.	Agitator for tank with gearboxe, coupling and electric motor	1	1	0.9
4.	Overhead travelling crane Cap.: 5 t	1	1	15

7. H.P. pump station

Low and high quality bauxite

Tube digestion

		Total	Number Operating	Total Weight (t)
1.	H.P. diaphragm pumps with speed control, with suction and delivery dashpots Cap.: 80-150 m^3/h Head: 120 bar	6	4	276
2.*	Flat bottom tank Volume: 6.3 m^3	1	1	1.6
3.	Agitator for tank with gearboxe, coupling and electric motor	1	1	0.9
4.	Overhead travelling crane Cap.: 5 t	1	1	15

8. Autoclave digestion

Low and high quality bauxite

		Total	Number Operating	Total Weight (t)
1.	Autoclaves for heating bauxite slurry with flash steam ϕ 2.5 m x 14 m p = 60/35 bar Volume: 50 m^3	22	22	1496
2.	Autoclaves for heating bauxite slurry with life steam ϕ 2.5 m x 14 m p = 60/80 bar Volume: 50 m^3	8	8	544
3.	Autoclaves for ensuring the required holding time ϕ 2.5 m x 14 m p = 60 bar Volume: 50 m^3	4	4	244
4.	Flash tanks ϕ 2.8 m x 5 m p = 6-25 bar Volume: 25 m^3	20	20	223
4.	Flash tanks ϕ 2.8 m x 5.5 m P = 6 bar Volume: 30 m^3	2	2	18
5.	Condensate blow-off vessels Volume: 0.22-2,2 m^3	22	22	9

		Total	Number Operating	Total Weight (t)
6.	Condensers Volume: 3 m^3	2	2	3.7
7.*	Flat bottom tanks Volume: 6.3-100 m^3	6	6	23
8.	Agitators for tanks with gearboxes, couplings and electric motors	6	6	18
9.	Centrifugal pumps for slurry with speed control Cap.: 270 m^3/h	4	2	4.4
10.	Centrifugal pumps for slurry Cap.: 30 m^3/h	2	2	2
11.*	Centrifugal pumps for water Cap.: 60 m^3/h	4	2	4

8. Tube digestion

Low and high quality bauxite

		Total	Number Operating	Total Weight (t)
1.	Shell and tube type heat exchangers for heating the bauxite slurry and adjusting liquor using law pressure steam Shell dia: 368 x 14 mm Heating tubes: 3x ϕ 108 x 8 mm Surface: 14 m^2	4	4	13
2.	Shell and tube type heat exchanger for heating the bauxite slurry and adjusting liquor using flash steam Shell dia: 368 x 14 mm Heating tubes: 3xϕ 108 x 8 mm Surface: 14 m^2	156	156	493
3.	Shell and tube type heat exchanger for heating the bauxite slurry with molten salt. Shell dia: 368 x 14 mm Heating tubes: 3xϕ 108 x 8 mm	40	40	126
4.	Holding tubes ϕ 273x16 mm - 1600 m	2	2	320
5.	Flash tanks ϕ 2.8 m x 5 m Volume: 25 m^3	24	24	158
6.	Flash tanks ϕ 2.8 m x 5.5 m Volume: 30 m^3	2	2	18

		Total	Number Operating	Total Weight (t)
7.	Condensate blow-off vessels ϕ 1.6 m x 2.7 m Volume: m^3	2	2	4.8
8.	Condensers ϕ 0.9 m x 4.9 m Volume: 3 m^3	2	2	3.7
9.*	Flat bottom tanks Volume: 6.3-100 m^3	6	6	23
10.	Agitators for tanks with gearboxes, couplings and electric motors	6	6	18
11.	Centrifugal pumps for slurry with speed control Cap.: 300 m^3/h	8	8	10
12.	Centrifugal pumps for slurry Cap.: 30 m^3/h	2	2	2
13.*	Centrifugal pumps for water Cap.: 60 m^3/h	4	2	4
14.	Molten salt heating units with molten salt heaters, fuel oil burner plants, combustion air preheaters, ducts, self-supporting stacks, with salt storage tanks, molten salt circulating pumps, instrumentation Cap.: 65 GJ/h Molten salt outlet temp.: 330 °C Molten salt inlet temp.: 280 °C	2	2	

9. Red mud settling and washing

Low quality bauxite

Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Single chamber settlers with slope bottom and cable torque rakes ϕ 30 m x 6.6 m 1:16 slope bottom Volume: 4300 m^3	2	2	270
2.	Single chamber washers with slope bottom and cable torque rake, equiped with feed tanks ϕ 30 x 6.6 m 1:16 slope bottom Volume: 4300 m^3	6	5	810
3.*	Flat bottom tanks ϕ 10 m x 6 m Volume: 500 m^3	2	2	50
4.*	Flat bottom tanks Volume: 6.3-200 m^3	7	7	35
5.	Agitators for tanks with gearboxes, couplings and electric motors	9	9	25
6.*	Tanks with conical bottom ϕ 2 m x 6.5 m Volume: 15 m^3/h	5	4	20

		Total	Number Operating	Total Weight (t)
7.	Centrifugal pumps for slurry with speed control Cap.: 50-140 m^3/h	21	10	26
8.	Centrifugal pumps for liquor with speed control Cap.: 90-320 m^3/h	14	6	16
9.	Centrifugal pumps for slurry Cap.: 30 m^3/h	4	4	4

9. Red mud settling and washing

High quality bauxite
Autoclave and tube digestion

	Total	Number Operating	Total Weight (t)
1. Single chamber settlers with slope bottom and cable torque rakes ϕ 30 m x 6.6 m 1:16 slope bottom Volume: 4300 m^3	2	2	270
2. Single chamber washers with slope bottom and cable torque rake, equiped with feed tanks ϕ 30 x 6.6 m 1:16 slope bottom Volume: 4300 m^3	6	5	810
3.* Flat bottom tanks ϕ 10 m x 6 m Volume: 500 m^3	2	2	50
4.* Flat bottom tanks Volume: 6.3-200 m^3	7	7	35
5. Agitators for tanks with gearboxes, couplings and electric motors	9	9	25
6.* Tanks with conical bottom ϕ 2 m x 6.5 m Volume: 15 m^3/h	5	4	20

		Total	Number Operating	Total Weight (t)
7.	Centrifugal pumps for slurry with speed control Cap.: 50-130 m^3/h	21	10	26
8.	Centrifugal pumps for liquor with speed control Cap.: 90-210 m^3/h	14	6	16
9.	Centrifugal pumps for slurry Cap.: 30 m^3/h	4	4	4

		Total	Number Operating	Total Weight (t)
10.	<u>Additive preparation</u> Low quality bauxite Autoclave and tube digestion			
1.	Flocculant (starch) preparing equipment complete with feed and discharge facilities, with bins, repulping and control units Cap.: 170 kg/h	1	1	7
2.	Synthetic flocculent (ALCLAR) preparing and charging unit complete with tanks pumps, fittings and control system Cap.: 6 kg/h	1	1	2
3.*	Flat bottom tanks Volume: 63 m^3	2	2	9
4.	Agitators for tanks with gearboxes, couplings and electric motors	2	2	4.2
5.	Centrifugal pumps for slurry Cap.: 10 m^3/h	2	1	1.2

		Total	Number Operating	Total Weight (t)
10.	<u>Additive preparation</u> High quality bauxite Autoclave and tube digestion			
1.	Flocculant (starch) preparing equipment complete with feed and discharge facilities, with bins, repulping and control units Cap.: 100 kg/h	1	1	4.5
2.	Synthetic flocculent (ALCLAR) preparing and charging unit complete with tanks pumps, fittings and control system Cap.: 4 kg/h	1	1	1.5
3.*	Flat bottom tanks Volume: 63 m^3	2	2	9
4.	Agitators for tanks with gearboxes, couplings and electric motors	2	2	4.2
5.	Centrifugal pumps for slurry Cap.: 10 m^3/h	2	1	1.2

11. Mud causticization and red mud filtration

Low quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Vibrating screens Feed cap.: 75 m^3/h	6	4	4.8
2.	Red mud filters with receivers and with roller discharges Surface: 100 m^2	14	12	490
3.	Screw conveyors Cap.: 45 t/h	4	4	32
4.	Reactors for decreasing the red mud viscosity	4	2	14
5.	H.P. diaphragm pumps with speed control, with suction and delivery dashpots Cap.: 110 m^3/h Head: 65 bar	2	1	92
6.	Water ring vacuum pumps Cap.: 9000 m^3/h	4	3	18
7.	Air blowers Cap.: 2400 m^3/h	2	1	5
8.	Condenser with moisture trap ϕ 2.2 m x 5 m	1	1	8
9.*	Flat bottom tanks Volume: 3.2-200 m^3	23	20	147
10.	Agitators for tanks with gearboxes, couplings and electric motors	20	17	68

		Total	Number Operating	Total Weight (t)
11.	Centrifugal pumps for slurry with speed control Cap.: 280 m^3/h	2	1	3
12.	Centrifugal pumps for liquor with speed control Cap.: 260 m^3/h	2	1	3
13.	Centrifugal pumps for slurry Cap.: 50 m^3/h	6	5	6
14.*	Centrifugal pumps for water Cap.: 20-120 m^3/h	3	2	3
15.	Overhead travelling cranes Cap.: 5 t	3	3	24

11. Mud causticization and red mud filtration

High quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Vibrating screens Feed cap.: 75 m^3/h	3	2	2.4
2.	Red mud filters with receivers and with roller discharges Surface: 100 m^2	5	4	175
3.	Screw conveyors Cap.: 45 t/h	2	2	16
4.	Reactors for decreasing the red mud viscosity	2	1	7
5.	H.P. diaphragm pumps with speed control, with suction and delivery dashpots Cap.: 55 m^3/h Head: 65 bar	2	1	56
6.	Water ring vacuum pumps Cap.: 5000 m^3/h	3	2	9
7.	Air blowers Cap.: 1000 m^3/h	2	1	3
8.	Condenser with moisture trap ϕ 2.2 m x 5 m	1	1	8
9.*	Flat bottom tanks Volume: 3.2-200 m^3	18	16	102
10.	Agitators for tanks with gearboxes, couplings and electric motors	16	14	38

		Total	Number Operating	Total Weight (t)
11.	Centrifugal pumps for slurry with speed control Cap.: 150 m^3/h	2	1	2.2
12.	Centrifugal pumps for liquor with speed control Cap.: 150 m^3/h	2	1	2.2
13.	Centrifugal pumps for slurry Cap.: 50 m^3/h	6	5	6
14.*	Centrifugal pumps for water Cap.: 20-120 m^3/h	3	2	3
15.	Overhead travelling cranes Cap.: 5 t	3	3	24

		Total	Number Operating	Total Weight (t)
12.	<u>Control filtration</u> Low and high quality bauxite Autoclave and tube digestion			
1.	Pressure filters Surface: 125 m^2	4	3	44
2.*	Flat bottom tanks Volume: 6.3–200 m^2	5	5	27
3.	Agitators for tanks with gearboxes, couplings and electric motors	5	5	16
4.	Centrifugal pumps for liquor with speed control Cap.: 410 m^3/h	2	1	4
5.	Centrifugal pumps for slurry Cap.: 30–150 m^3/h	5	3	5

13. Heat interchange

Low and high quality bauxite
Autoclave and tube digestion

		Total	Operating	Total Weight (t)
1.	Plate heat exchangers Surface: 300 m^2	3	2	14.4
2.*	Flat bottom tanks Volume: 200 m^3	3	3	30
3.	Agitators for tanks with gearboxes, couplings and electric motors	3	3	18
4.	Centrifugal pumps for liquor Cap.: 410 m^3/h	4	2	8

14. Precipitation and hydrate classification

Low and high quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.*	Precipitator tanks with conical bottom, air agitated ϕ 10 m x 31.5 m Volume: 2000 m^3/h	16	15	2896
2.	Wash liquor preheater Surface: 160 m^2	1	1	5.1
3.	Interstage coolers Surface: 150 m^2	2	2	40
4.*	Hydroseparators with 60° cone bottom ϕ 10 m x 18 m s.s.	2	1	192
5.*	Flat bottom tanks Volume: 6.3-200 m^3	7	6	20
6.	Agitators for tanks with gearboxes, couplings and electric motors	6	5	8
7.	Centrifugal pumps for slurry with speed control Cap.: 170-600 m^3/h	4	2	9
8.	Centrifugal pumps for slurry Cap.: 160-320 m^3/h	8	5	14
9.	Centrifugal pumps for slurry Cap.: 30-60 m^3/h	5	4	5

	Total	Number Operating	Total Weight (t)
10.* Centrifugal pumps for water Cap.: 210 m^3/h	2	1	3

		Total	Number Operating	Total Weight (t)
15.	<u>Hydrate filtration</u> Low and high quality bauxite Autoclave and tube digestion			
1.	Disc filters with receivers Surface: 100 m^2	5	4	100
2.	Pan filters with receivers, interstage pumps, tanks Surface: 20 m^2	2	2	30
3.	Rubber belt conveyors B = 800 mm L = 15 m Cap.: 35 t/h	2	2	12
4.	Rubber belt conveyor with weighing belt B = 800 mm L = 60 m Cap.: 50 t/h	1	1	15
5.	Condenser with moisture trap ϕ 2 m x 5 m Volume: 15 m^3	1	1	10
6.*	Flat bottom tanks Volume: 6.3-120 m^3	11	11	70
7.	Agitators for tanks with gearboxes, couplings and electric motors	9	9	17
8.	Centrifugal pumps for slurry with speed control Cap.: 320 m^3/h	3	2	5
9.	Centrifugal pumps for slurry Cap.: 30-120 m^3/h	4	3	4

		Total	Number Operating	Total Weight (t)
10.	Centrifugal pumps for liquor Cap.: 400 m^3/h	2	1	3
11.	Centrifugal pumps for liquor Cap.: 30-120 m^3/h	5	3	5
12.	Centrifugal pumps for water with speed control Cap.: 200 m^3/h	2	1	2.2
13.*	Pulley-blocks Cap.: 2 t	6	6	3
14.	Electric hoists Cap.: 5 t	2	2	2
15.	Elevator Cap.: 1 t	1	1	4

		Total	Number Operating	Total Weight (t)
16.	<u>Calcination, alumina storage</u> Low and high quality bauxite Autoclave and tube digestion			
1.	Rotary kilns with cyclons, bucket-elevators, electrostatic dust precipitators, exhaust fans, alumina coolers, oil heating system and diesel emergency drive units Cap.: 350 t/day	2	2	
2.	Alumina silo feed and discharge units	2	2	7
3.	Waggon feed units	2	2	1.6

17. Evaporation

Low quality bauxite
Autoclave and tube digestion

		Total	Operating	Weight (t)
1.	Five effect counter-current forced circulation evaporators, with flash tanks, preheaters, feed and circulation pumps Cap.: 60 t/h evaporated water	2	2	380
2.	Superconcentrator with feed and cirulation pumps, preheaters and flash tanks Cap.: 15 t/h evaporated water	1	1	45
3.	Strong liquor preheater Surface: 50 m^2	1	1	4
4.*	Flat bottom tanks Volume: 6.3-200 m^3	11	11	72
5.	Agitators for tanks with gearboxes, couplings and electric motors	6	6	26
6.	Centrifugal pumps for liquor Cap.: 30-70 m^3/h	8	5	8
7.	Centrifugal pumps for water with speed control Cap.: 700 m^3/h	2	1	4
8.*	Centrifugal pumps for water Cap.: 25-80 m^3/h	8	4	5

17. Evaporation
High quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Five effect counter current evaporators, with flash tanks, preheaters, feed and circulation pumps Cap.: 50 t/h evaporated water	2	2	360
2.	Superconcentrator with feed and cirulation pumps, preheaters and flash tanks Cap.: 15 t/h evaporated water	1	1	45
3.	Strong liquor preheater Surface: 50 m^2	1	1	4
4.*	Flat bottom tanks Volume: 6.3-200 m^3	11	11	72
5.	Agitators for tanks with gearboxes, couplings and electric motors	6	6	26
6.	Centrifugal pumps for liquor Cap.: 30-70 m^3/h	8	5	8
7.	Centrifugal pumps for water with speed control Cap.: 600 m^3/h	2	1	4
8.*	Centrifugal pumps for water Cap.: 25-50 m^3/h	8	4	5

		Total	Number Operating	Total Weight
18.	Salt removal Low quality bauxite Autoclave and tube digestion			
1.	Pressure filters Surface: 125 m^2	2	1	16
2.	Vacuum drum filter with receiver Surface: 12 m^2	1	1	8
3.*	Flat bottom tanks Volume: 6.3-200 m^3	8	8	41
4.	Agitators for tanks with gearboxes, couplings and electric motors	8	8	17
5.	Centrifugal pumps for slurry Cap.: 10-30 m^3/h	5	4	3
6.	Centrifugal pumps for liquor Cap.: 20-100 m^3/h	3	2	2

18. Salt removal
High quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight
1.	Pressure filters Surface: 80 m^2	2	1	16
2.	Vacuum drum filter with receiver Surface: 12 m^2	1	1	8
3.*	Flat bottom tanks Volume: 6.3-200 m^3	8	8	41
4.	Agitators for tanks with gearboxes, couplings and electric motors	8	8	17
5.	Centrifugal pumps for slurry Cap.: 10-30 m^3/h	5	4	3
6.	Centrifugal pumps for liquor Cap.: 20-50 m^3/h	3	2	2

		Total	Number Operating	Total Weight (t)
19.	**Vacuum station** Low and high quality bauxite Autoclave and tube digestion			
1.	Water ring vacuum pumps Cap.: 11000 m^3/h	3	2	17
2.	Air blowers Cap.: 2000 m^3/h	3	2	3.6
3.	Electric overhead travelling crane Cap.: 5 t	1	1	12

		Total	Number Operating	Total Weight (t)
20.	Compressor station Low and high quality bauxite Autoclave and tube digestion			
1.	Screw compressors with air filters, interstage and after coolers Cap.: 8000 Nm^3/h	2	1	12
2.	Air tanks Volume: 50 m^3	2	2	5
3.	Electric overhead travelling crane Cap.: 12.5 t	1	1	14

21. Oil storage

Low and high quality bauxite
Autoclave and tube digestion

		Total	Number Operating	Total Weight (t)
1.	Oil storage tanks ϕ 18.5 m x 13.5 m Volume: 3000 m^3	2	2	15
2.	Oil unloading facilities	4	4	2
3.	Gear pumps Cap.: 10-65 m^3/h	6	3	3

22. Workshop and open air storage

		Total	Number Operating
1.	Engine lathe	8	8
2.	Vertical boring and turning machine	1	1
3.	Universal milling machine	3	3
4.	Horizontal boring mill	1	1
5.	Ventical milling machine	1	1
6.	Shaping machine	2	2
7.	Hydraulic slotting machine	1	1
8.	Universal surface grinding machine	2	2
9.	Multiple profiling machine	1	1
10.	Radial drilling machines	2	2
11.	Upright drilling machine	1	1
12.	Universal tool grinding machine	1	1
13.	Radial drilling machine (portable)	1	1
14.	Framed saws	2	2
15.	Hydraulic press	1	1
16.	Hydraulic horizontal combination die	1	1
17.	Laying out benches	2	2
18.	Manually operated pipe bending machines	2	2
19.	Smith's earth	1	1
20.	Hand pumps for hydraulic test	2	2
21.	Air forging hammer	1	1
22.	Carbide speeder	1	1
23.	Winding machine	1	1

		Total	Number Operating
24.	Vacuum impregnating unit with vacuum pump	1	1
25.	Table drilling machines	3	3
26.	Table grinding machines	2	2
27.	Pedestal grinding machines	3	3
28.	Vulkanizer sets	3	3
29.	Welding machines	3	3
30.	Portable welding machines	8	8
31.	Electric overhead travelling cranes Cap.: 8 t and 5 t	2	2
32.	Frame crane Cap.: 12.5 t	1	1

Motor vehicles	Total	Number Operating	Spare
1. Autocrane Cap.: 40 t	1	1	-
2. Autocrane Cap.: 10 t	1	1	-
3. Autocrane Cap.: 6.3 t	1	1	-
4. Trucks Cap.: 3.5 t	4	4	-
5. Tilting-platforms trucks Cap.: 6 m^3	2	2	-
6. Trucks with electric platform Cap.: 3 t	3	3	-
7. Trucks with electric platform Cap.: 2 t	3	3	-
8. Trucks with electric forks Cap.: 2 t	2	2	-
9. Trolley trucks with electric forks Cap.: 2 t	2	2	-
10. Trailers for trucks Cap.: 2 t	4	4	-

Attachment 5

Price list of the main equipment

Attachment 5

PRICE LIST OF THE MAIN EQUIPMENT

Informative prices (FOB at European Port) are given for each of the main equipment listed below:

1. Sintering process

		million of Rls
1.	Hammer mill with vibrating screen Cap.: 160 t/h	15
2.	Jaw crusher with vibrating screen Cap.: 80 t/h	18
	Cap.: 50 t/h	13
3.	Shaft kiln for burning limestone with elevator, exhaust fan, dust collector, gas purifier, with burnt lime extractor, vibrating feeder, rubber belt conveyor, with fuel oil supply system, with electrical equipment, process control and instrumentation Cap.: 70 t/day CaO	120
4.	Lime slaking drum ϕ 1.8 m x 10 m Cap.: 10 m^3/h slaked lime	8
5.	Multi-chamber ball mill with vibrating screen ϕ 2.6 m x 13 m Cap.: 125 t/h	54

	million of Rls
6. Tank with conical bottom ϕ 9 m x 20 m Volume: 1000 m^3	15
7. Piston slurry pump with suction and delivery dashpot Cap.: 120 m^3/h Head: 30 bar	27
8. Rotary kiln with cooler, cyclon, gas purification system and exhaust fan ϕ 5 m x 120 m Cap.: 1600 t/day	587
9. Double deck vibrating screen Screening area: 2.5 m x 6 m	7
10. Cone cruscher Dia: 220 mm Cap.: 70 t/h	61
11. Belt extractor Cap.: 70 t/h	306
12. Jigging screen Surface: 41.5 m^2	9
13. Autoclave ϕ 2.5 m x 14 m Volume: 50 m^3	8
14. Flash tank ϕ 3.6 m x 5.6 m Volume: 50 m^3	5
15. Single chamber settler ϕ 20 m x 4 m Volume: 1500 m^3	25

	million of Rls
16. Vacuum drum filter with filtrate receiver	
Surface: 10 m^2	5
Surface: 20 m^2	8
17. Pressure filter	
Surface: 125 m^2	12
18. Vacuum disc filter with filtrate receiver	
Surface: 100 m^2	13
19. Shell and tube type heat exchanger	
Surface: 180 m^2	16
20. Hydroseparator	
ϕ 7 m x 19 m	
Volume: 400 m^3	7
21. Hydroseparator	
ϕ 10 m x 28 m	
Volume: 1000 m^3	27
22. Pan filter with filtrate receivers, interstage pumps, tanks	
Surface: 25 m^2	15
23. Fluid bed calcining kiln with cyclons, electrostatic precipitator, exhaust fan, alumina cooler, oil heating system	
Cap.: 700 t/day	444

	million of Rls
24. Five effects, counter current forced circulation evaporator unit, with flash tanks, preheaters, feed and circulation pumps Cap.: 65 t/day evaporated water	151
25. Water ring vacuum pumps Cap.: 7500 m^3/h	22
26. Turbo-compressor Cap.: 15000 Nm^3/h Pressure: 5 bar	43

2. Bayer process

		million of Rls
1.	Jaw crusher with vibrating screen Cap.: 140 t/h	22
2.	Hammer mill with vibrating screen Cap.: 140 t/h	15
3.	Shaft kiln for burning limestone with elevator, exhaust fan, dust collector, gas purifier, with burnt lime extractor, vibrating feeder, rubber belt conveyor, with fuel oil system, with electrical equipment, process control and instrumentation	
	Cap.: 250 t/day	160
	Cap.: 175 t/day	140
4.	Lime settler ϕ 20 m x 5 m s.s. 1:3 slope bottom	17
5.	Lime slaking drum ϕ 1.8 m x 10 m Cap.: 80 m^3/h slaked lime	8
6.	Pressure belt filter Filtration area: 20 m^2 Cap.: 5 t/h	18
7.	Multi-chamber ball mill with conical screen ϕ 2.6 m x 13 m Cap.: 50 t/h	54

		million of Rls
8.	H.P. diaphragm pump with speed control, with suction and delivery dashpot Cap.: 230 m^3/h Head: 70 bar	97
	Cap.: 150 m^3/h Head: 120 bar	92
9.	Autoclave for heating bauxite slurry with life steam ϕ 2.5 m x 14 m p = 60/80 bar	29
10.	Molten salt heating unit with molten salt heater, ducts, self-supporting stack, with salt storage tank, molten salt circulating pumps, instrumentation Cap.: 65 GJ/h	98
11.	Single chamber settler with slope bottom and cable torque rake ϕ 30 m x 6.6 m 1:16 slope bottom	22
12.	Vacuum drum filter for filtering red mud with receivers and with roller discharge Surface: 100 m^2	15
13.	Vacuum drum filter with receivers Surface: 12 m2	6

	million of Rls
14. Disc filter with receiver Surface: 100 m^2	15
15. Pan filter with receivers, interstage pumps, tanks Surface: 20 m^2	14
16. Pressure filter Surface: 125 m^2	12
Surface: 80 m^2	9
17. Precipitator tank with conical bottom, air agitated ϕ 10 m x 31.5 m Volume: 2000 m^3/h	29
18. Hydroseparator with 60^{o} con bottom ϕ 10 m x 18 m s.s.	27
19. Rotary kiln with cyclon, bucket-elevator, electrostatic dust precipitator, exhaust fan, alumina cooler, oil heating system and diesel emergency drive unit Cap.: 350 t/day	311
20. Five effect counter-current forced circulation evaporator, with flash tanks, preheaters, feed end circulation pumps Cap.: 60 t/h evaporated water	151
21. Superconcentrator with feed and circulation pumps, preheaters and flash tanks Cap.: 15 t/h evaporated water	72

	million of Rls
22. Water ring vacuum pump	
Cap.: 11000 m^3/h	25
Cap.: 9000 m^3/h	23
23. Screw compressor with air filter, interstage and after cooler	
Cap.: 8000 Nm^3/h	40
24. Plate heat exchanger	
Surface: 300 m^2	42