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Project No.DP/IRA/85/003

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

## FINAL REPORT

Made by Aluterv-FKI's experts team

Aluterv-FKI , Budapest , December, 1988

## CONTENTS

## LIST OF FIGURES

# LIST OF TABLES

Page

Estimated direct fixed investment costs of the selected technologies:

# EXECUTIVE SUMMARY

## Project Background and History

Producing alumina from domestic ore reserves has become one of the most important Government projects in the Islamic Republic of Iran. For this purpose, one of the potential raw materials is bauxite.

The bauxite deposits are located in the Elburz Mountains. Bauxite reserves have been estimated at about 45 million tons (in category R-3 of UN-classification, which indicates exploration opportunities), sufficient to feed an industrial-scale alumina plant for some 30 years.

The pre-investment activities related to the possible erection of alumina production facilities are within the responsibility of the "Aluminium Raw Materials Programme/ARMP" Tehran set up by the Ministry of Mines and Metals of the Islamic Republic of Iran in 1981. ARMP acts as the national counterpart in this project.

The United Nations Development Programme (UNDP) in response to a request from the GOVERNMENT OF THE ISLAMIC REPUBLIC OF IRAN has agreed to provide assistance to the government in carrying out the project entitled "TECHNO-ECONOMIC OPPORTUNITY STUDY WITH BENCH SCALE TESTING OF BAUXITES" in the Islamic Republic of Iran.

The contract was signed between the UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO), Vienna and HUNGALU ALUTERV-FKI (Engineering and Development Centre of the Hungarian Aluminium Corporation), Budapest.

The aim of this contract was the establishment of the techno-economic viability of industrial-scale production of alumina in the country, using indigenous bauxites. For this purpose chemico-mineralogical and phase-analysis testing of altogether 120 borehole bauxite samples was carried out (and summarized in the Interim Report No.1.delivered to UNIDO and ARMP by the end of December, 1987), followed by bench scale testing of two characteristic bauxite samples (with modules 3.77 and 6.89, respectively) to determine the process parameters of the various alternative routes of technologies for processing of Elburz bauxites. The investigated alternative technologies were:

Bayer autoclave - digestion
Bayer tube - digestion
Sintering

The results of the laboratory simulation of the alternative technologies were summarized in the Interim Report No.2 on the "Bench-scale testing of characteristic Bauxite Samples". (The Interim Report No.2 was delivered to UNIDO and ARMP at the end of June, 1988).

The aim of the present report is the techno-economic evaluation of the mentioned alternative processes for alumina production from Jajarm bauxite on the basis of the bench-scale technological tests and to select the most appropriate and economic technology for further investigation (to prepare a Feasibility Study) and to justify further a detailed, accelerated bauxite prospecting activity, if it is feasible. It was also requested to submit proper data for bauxite processing in order to compare it with the processing of alternative domestic alumina raw materials (alunite, alumosilicates, nepheline).

The industrialisation of the Islamic Republic of Iran, the development of the infrastructure of the given region of the country, the improvement of the employment situation should be also considered as promoting factors to this project.

In the frame of this contract 11 experts of ARMP were acquainted succesfully with the material testing methods and technological testing (process simulation) of bauxite processing at Aluterv-FKI and at the industrial facilities of the Hungarian Aluminium Corporation. A short visit was organised by Aluterv-FKI to the Sinter Alumina Plant in Boksitogorsk (USSR),too, for a few Iranian experts. The very effective and good cooperation should be mentioned between the experts of ARMP and Aluterv-FKI during the whole work. The staff members of the UNDP Office in Tehran were also very helpful.

## Market and Plant Capacity

In 1978, the consumption of aluminium in Iran was about 75,000 tons. Today's restrained demand foi aluminium is around 120,000 tons per year. However, IRALCO'S present capacity and actual production is only close to 45,000 tons per year, which requires an alumina feed of close to 90,000 tons per year - all of which is imported.The expansion of the capacity to 67,000 tons per year is under construction and upon completion the requirements of alumina feed will amount to about 130,000 tons per year. The establishement of further aluminium production capacities is under consideration. According to the forcasted demand for alumina a 200 kt per year plant capacity can be recommended,and is worked out in this study, however, the total investment costs and production costs of alumina has been investigated in the function of the bauxite quality between 75 and 200 kt/year plant capacity. (See Figs. 17-3 and 17-6).

The specific investment and production costs can be reduced significantly by increasing the plant capacity, especially at lower production rates. It seems not to be reasonable to produce alumina in the Islamic Republic of Iran for sale in the world market.

Raw Materials

The bauxite raw material is a diasporic-chamositic-kaolinitic type containing 44 to 60 % of $Al_2O_3$ and 5 to 18 % of $SiO_2$. The real thickness of the bauxite deposit is 3-5 m in general, the recent prospections have also revealed lenses with a thickness of 13-23 m and of a higher grade (higher alumina and lower silica percentages). Presently the deposit is being prospected by the ARMP. The reserves known at present are as follows:

about 45 million tons in category R-3
(potential reserves)
4 million tons in category R-2
(preliminary reserves)

The bauxite is expected to be mined partly by the open cast (40 % of the total), but mainly by the underground method.

Provided that the reserve in category R-2 is analogous to the quality of the ICS-3 composite sample (one of the two characteristic samples selected for the technological investigations) 4 million tons of bauxite is available ($Al_2O_3$ = 44.2 %, $SiO_2$ = 11.7 %, Module = $Al_2O_3/SiO_2$ ratio = 3.77). This bauxite is considered in the Report as "Low Quality Bauxite" (Abbreviation: LQB). In this case the cut-off would be given at the module of 1.3.

When a better quality of reserves is taken into consideration, with the module of 4.9 (with 48.7 % $Al_2O_3$ and 9.9 % $SiO_2$ contents), 2.2 million tons of bauxite can be estimated actually in category R-2.

The other characteristic sample for the technological investigations has been selected with 52.4 % $Al_2O_3$ and 7.6 % $SiO_2$ contents (Module 6.89, marked as ICS-2). This bauxite is considered in the Report as "High Quality Bauxite" (Abbreviation: HQB).Although this bauxite quality is not justified yet in a proper amount by the prospecting, it should be mentioned, that recently very good bauxite was revealed in boreholes B4-31 and B4-45, where the alumina content is more than 60 % and the silica less than 5 %. These boreholes indicate bauxite of extremely good quality, which offers better prospects than it was expected before. It is necessary to emphasize the utmost importance of the accelerating of the geological prospections at the Jajarm area with the aim of the justification of a higher grade bauxite in a more significant amount, because the bauxite quality is the most determining factor of the profitability of bauxite processing. It can be supposed that by means of further detailed prospecting bauxite with module about 5 or higher will be found, sufficient to feed an alumina refinery of 100-200 kt per year capacity.

As a caustic soda source for the Bayer process, imported sodium carbonate is considered from economic point of view. The time of return of the causticization plant (to convert $Na_2CO_3$ into NaOH by lime addition) is about 2 months only. $Na_2CO_3$ is also required for the sintering process.

High quality limestone is available near to the expected plant site. This limestone can be used directly for the sintering process and after burning as CaO for the Bayer process.

The very low price of domestic fuel oil is one of the most important factors to justify this project. The total energy demand can be covered by fuel oil at two variants of the Bayer process (Autoclave and Tube digestion, respectively), however, in the sintering process natural gas is also required for bauxite sintering. (Fuel oil can not be accepted for this purpose because of its high (max. 3 %) sulphur content. The required supply of natural gas and the excess investment requirement would be a further disadvantage for the sintering process compared with the Bayer technology.

## Process technology

The following alternative routes of technologies for processing the Jajarm bauxite" have been investigated and compared from techno-economic point of view:

A. Low quality bauxite, sintering process (LQBSP)
B. Low quality bauxite, autoclave digestion (LQBAD)
C. Low quality bauxite, tube digestion (LQBTD)
D. High quality bauxite, autoclave digestion (HQBAD)
E. High quality bauxite, tube digestion (HQBTD)

(Low quality bauxite:
$Al_2O_3$ = 44.2 %, $SiO_2$ = 11.7 %, M = 3.77)
(High quality bauxite:
$Al_2O_3$ = 52.4 %, $SiO_2$ = 7.6 %, M = 6.89)

The process technology of the sintering method was elaborated by the experts of the Institute of VAMI, Leningrad for the low quality bauxite only. The technology recommended is adequate to the plant techrology applied in Boksitogorsk (USSR) processing Tihvin bauxite.

The selected Bayer technology has the following special process stages:

- Causticization of the sodium carbonate which has been selected as the source of caustics.

- Lime burning and slaking facility.

- Red mud causticization to reduce the caustic soda losses.

- Digestion with a catalytic additive (hydrogarnet catalyst formed from CaO).

The tube digestion is characterized by the molten salt heating unit to achieve the maximum temperature of 280 °C and by the multi-stream (3 tube in one tube) heat-exchanger system according to the facility installed at the Magyaróvár Alumina Plant, Hungary.

The selected main process parameters are as follows:
For the sintering process:

| | |
|---|---|
| - Moisture content of the mixture to be sintered | 39-40 % |
| - Temperature of sintering | 1175-1200 °C |
| - Time requirement of sintering | 45 min. |
| - Leaching temperature | 85-90 °C |

Under optimum parameters the attainable $Na_2O$ recovery comes to 94-96 %, that for $Al_2O_3$ to 89-91 %.

For the Bayer process

| | autoclave digestion | tube digestion |
|---|---|---|
| - Digestion temperature | 260 °C | 280 °C |
| - Retention time at digestion temperature | 1 hour | 20 min. |
| - Digestion liquor concentration | 160 g/l $Na_2O$ | 160 g/l $Na_2O$ |
| - CaO addition to bauxite for digestion | 7 % | 7 % |
| - Molar ratio after digestion | 1.55 | 1.50 |

For the low quality bauxite (ICS-3) a digestion yield of 59-70 % and for the high quality bauxite (ICS-2) that of 82-83 % can be achieved.

The specific consumption data are given in the function of the bauxite quality for sintering in Fig. 17-1/A and for Bayer Tube Digestion in Fig. 17-1/B.

It is evident that the sintering process is much less sensitive to the bauxite quality than the Bayer process.

## Alumina Quality

The alumina produced by the Bayer process contains much less contaminants than that manufactured by the sintering process. E.g. the $SiO_2$ content is 0.020-0.030 % and the $Fe_2O_3$ content is about the same in Bayer alumina in contrast with the product of the sintering process where 0.03-0.05 % $SiO_2$ and 0.05-0.06 % $Fe_2O_3$ are characteristic. Only floury type alumina can be produced by the sintering process, which is not suitable for dry gas cleaning in smelters. The alumina quality has an increasing importance from the point of view of the production of higher grade, less contaminated primary aluminium metal directly in the pots. The up-to-date dry scrubbing systems promote the enriching of some contaminants in the alumina and as a consequence in the metal, too, therefore the requirements for the metal grade alumina are rather increasing.

Based on the above facts from point of view of alumina quality the sintering process can not be preferred, however the quality of the alumina produced by sintering process can meet the requirements of the IRALCO Smelter in Iran according to the information submitted, by the experts of ARMP, considering that the aluminium produced there is used mainly for silicon-containing aluminium alloys. According to the international experiences, however, the alumina containing higher amount of impurities (e.g., $SiO_2$ and $Fe_2O_3$) is not suitable for the production of aluminium with high electrical conductivity and that of some speciality aluminas, and can cause operational difficulties during feeding and dry scrubbing in an up-to-date smelter.

## Non-technological Units

As non-technological units the power plant, the process control system and the electric energy supply are discussed in details, separately for each variant. It should be mentioned that back-pressure steam turbine-generators are preferred for cogenaration of steam and electric power which is the most economic solution for energy supply in alumina refineries.

## Plant Location and Civil Engineering

The alumina plant will be located in the Jajarm area, where the bauxite deposit was discovered. The final plant site has not been determined yet, so infrastructural connections and transporting problems are not discussed in the present Opportunity Study. Consequently only the plant inside the fence was examined as an independent unit.

The plant consists from the civil engineering point of view of technological buildings, outdoor units and non-technological buildings.

For water supply, 3 systems are expected, namely an industrial and fire-fighting system, and two recirculating cooling water systems (separately for alkali-contaminated and alkali-free water).
Dry disposal of the red mud is considered using the filtered mud to avoid the contamination of the karstic surrounding area by alkali-solutions.

## Implementation Schedule

Most of the activities of the investment work should be concluded by the deadline to start producing alumina between the 38th and 39th months.
The 200 ktpy full capacity of the alumina plant can be attained in the 44th month.

## Total investment costs

The total investment costs of an alumina plant with 200 kt/year capacity amounts to 34,640 millions of Rls for the sintering process and 25,517 millions of Rls for Bayer Tube Digestion processing low quality bauxite (Fig. 17-2). The total investment costs can be reduced slowly only with the improved bauxite quality (Fig. 17-2). The specific investment costs per ton of alumina produced, however, is increasing significantly by lowering the capacity. (Figs. 17-4, and 17-6) Therefore, a capacity of 200 kt/year may be recommended, however, taking into consideration the bauxite reserves known at present and some other aspects of ARMP a plant capacity of about 100 kt/year can also be accepted as a first stage.

The significantly higher investment costs for the sintering process are in agreement with the published data of Russian experts, where the Bayer process using high grade bauxite was compared with the sinter process and the combined Bayer-sinter process using low grade bauxite. The investment costs per unit production was found by them to be 1.9 times higher the production costs 1.82 times higher and the labour requirement per ton $Al_2O_3$ 1.63 times higher for the sinter process than for the Bayer one. For the series combined Bayer-sinter process the proper figures were: 1.50, 1.46 and 1.36, respectively. (TRAVAUX de l'ICSOBA, 1974 No.12. pp. 237-244).

## Production Costs

The alumina can be produced at the minimum production costs by means of the Bayer tube digestion technology, even if processing low quality bauxite. (39,235 Rls/t in contrast with sintering process, were this value is 41,378 Rls/t) (See Fig. 17-5). The production costs are steeply decreasing with improving bauxite quality when using the Bayer process, however, only slowly when using the sintering method. This means that the Bayer tube digestion technology should be preferred for processing Iranian bauxites. There is a good potential to increase the profitability in the function of the better bauxite quality (Fig. 17-6). Furthermore, the tube digestion is the most up-to-date and flexible technology to optimize the caustic liquor concentrations in the process cycle and to minimize the water amount to be evaporated, which results energy saving and lower investment requirements.

## Foreign exchange requirements

The estimated domestic and foreign supply is differing according to the investigated variants. The estimated domestic supply is varying between 8,882 and 11,796 million Rials, while the foreign supply is 19,847 million Rls for the sintering process and 11,110 to 12,709 million Rials only for the Bayer process variants. Consequently, the ratio between the domestic and foreign supply is the minimum one for the sintering process (39.5 % to 60.5 %) and for the Bayer variants (46-48 % to 54-52 %). For the sitering process an approximately 7,000 millions Rials higher foreign supply is required than for the Bayer variants processing low quality bauxite.

## Financial evaluation

The actual exchange rate in the Islamic Republic of Iran is 66 Rials per USD. Although any change in this exchange rate is depending on the decision of the Government, however, the international comparison (chapter 15.3) and the economic estimation of the Jajarm project confirm the reality of the use of a higher exchange rate to evaluate more exactly and adequately the erection of industrial facilities. Therefore, the economic analysis has been prepared with the following, different exchange rates: Rls 66, 160, 200 and 400 per USD.

The cumulated cash balance in the 20th year of production very sensitively reacts and steeply increases with the increasing of the exchange rate. Furthermore, all three variants give results of the same order of magnitude for the low quality bauxite. The cumulated cash balance increases only with the improvement of the bauxite quality significantly

The sum of the accumulated profit at an exchange rate of 66 Rls/USD is negative for all variants. At an exchange rate of 160 Rls/USD the processing of high quality bauxite is already profitable. At an exchange rate of 200 Rls/USD the sinter process is the only non-profitable variant.

The ratio of the net profit to the equity is at lower Rials/USD exchange rates quite modest at the processing of high quality bauxite as well, however, at the exchange rate of 400 Rials/USD - with the exception of the sinter process - it attain values expected from big industrial facilities.

The foreign exchange savings were calculated supposing that the total amount of the 200 kt alumina will substitute imported alumina or the excess can be exported. The net foreign exchange gain is varying between 35.6 and 43.2 million USD per year (considering the imported sodium carbonate and the export value of the consumed fuel oil) according to the process variants, while the pay-back period for the sintering process is 7.6 years (because of the higher investment costs with higher foreign supply) and 5.4 and 5.2 years for the Bayer process variants processing low quality bauxite and 4.2 and 3.9 years for those processing higher quality bauxite.

The break-even point analysis was prepared for determining that alumina selling price, at which the alumina refinery can just run without losses. These balanced prices of alumina for internal use are changing between 30,570 and 42,110 Rials/ton in the function of bauxite quality and selected technology. These prices are corresponding to the alumina market price of 280 USD/t at exchange rates between 150 and 109 Rls per USD.

The comparison of the Jajarm project with existing foreign alumina plants confirms the supposition that the real exchange rate for industrial facilities should be around Rls 200 per USD. Under this condition the Jajarm project can be compared with foreign alumina plants and this comparison is acceptable for the Iranian project.

The Jajarm project has a significant advantage compared with other alumina refineries related to the energy costs. Though it is burdened by the costs due to the inevitably higher investment costs of newly erected facilities, it can be competitive, especially considering the general policy and aims of the Government of the Islamic Republic of Iran.

## CONCLUSIONS

1. According to the techno-economic comparison of the variants of bauxite processing technology the Bayer tube digestion was found as the most feasible for processing Jajarm bauxite of any investigated quality, therefore, this technology can be selected for further detailed investigations to prepare a Feasibility Study.

2. Considering a real exchange rate of Rials/USD - which would be 200 Rials/USD based on the international comparison - the bauxite project can be profitable and seens to be competitive with the processing of alternative domestic raw materials (i.e. alunite, alumosilicates and nepheline) in the Islamic Republic of Iran. Consequently, further activity in this field can be recommended.

3. From the point of view of the total investment costs and production costs, furthermore related to the foreign exchange saving as well, the Bayer tube digestion technology was found as the most profitable variant, where steeply increasing economic result is expected with the improving bauxite quality.

4. The quality of the alumina produced by sintering process can meet the requirements of the IRALCO Smelter in Iran according to the information submitted by the experts of ARMP, considering that the aluminium produced there is used mainly for silicon-containing aluminium alloys. According to the international experiences, however, the alumina containing higher amount of impurities (e.g., $SiO_2$ and $Fe_2O_3$) is not suitable for the production of

aluminium with high electrical conductivity and that of some speciality aluminas, and can cause operational difficulties during feeding and dry scrubbing in an up-to-date smelter.

5. Regarding the present preliminary stage of geological prospecting, the ore reserves, subject to taking into account different cut off quality, are estimated as follows:

| Average modulus ($Al_2O_3/SiO_2$ weight ratio) | Ore reserves, million tons |
|---|---|
| 3.5 | 15-18 |
| 5.0 | 7-9 |
| 7.0 | 3-7 |

In the light of the results of the present Opportunity Study the above-mentioned reserves can justify a plant size of around 100,000 tpy (75,000-125,000 tpy) supposing a bauxite quality of modulus about 5 (with an alumina content of about 50 % and with a silica content of about 10 %) only.

## RECOMMENDATIONS

1. Based on the results obtained in this Opportunity Study it is recommended to prepare a Feasibility Study for processing the Iranian bauxite by means of the Bayer tube digestion technology which seems to be the most profitable variant and can produce high quality and less contaminated alumina suitable for an up-to-date dry scrubbing system for the smelter operation. The Feasibility Study should contain the techno-economic evaluation of the erection of an alumina plant based on the mentioned technology completed by all aspects of the imfrastructure, as well. The Feasibility Study will allow the Iranian authorites to decide upon the desirability of further pursuance of the project of industrial-scale alumina production based on Iranian bauxites in comparison with the alunite project, at the same level of elaboration.

2. Considering the determining effect of the bauxite quality on the profitability of the project by all means it is recommended to accelerate the bauxite prospecting activity with the aim of the justification of a higher grade bauxite in a proper amount. The good results of the present opportunity study justify the costly bauxite prospecting.

3. The Feasibility Study can be prepared based on the detailed physico-chemical investigation of the selected characteristic (only more or less representative) bauxite sample followed by the laboratory process simulation of its processing (sometimes called as bench scale testing), however, it is recommended to complete these tests by the

pilot scale tube digestion technological testing. The necessity of the pilot scale tube digestion test can be justified by the following arguments:

- The high turbulency of the slurry influences the digestion kinetics, the equilibrium molar ratio after the digestion and the required retention time at the given selected end temperature. The possible reduction of the caustic liquor concentration to digestion can also be studied. Consequently, the determination of the optimum parameters of the digestion can only be carried out with a high accuracy in the tube digestion pilot facility.
- The other main argument for realizing pilot scale tube digestion tests is the determination of the filterability and washability of the red mud obtained in the function of the digestion temperature.

4. At the present level of informations concerning the Jajarm bauxite deposits, it is recommended to use a bauxite quality with the following composition as a base for the suggested Feasibility Study: $Al_2O_3$ = 50 %, $SiO_2$ = 10 % which only presumably can represent a part of the known reserves only because of the huge variations of the ore quality and the large amount of cut-off. In this case all data can be easily extrapolated for the occasionally lower or higher grade bauxite. For pilot scale tube digestion tests 30 to 40 tons of bauxite would be required.

Budapest, 15th December 1988.

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# 1. PROJECT BACKGROUND

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In 1978, the consumption of aluminium in Iran was about 75,000 tons. Today's restrained demand for aluminium is around 120,000 tons per year. However, IRALCO's present capacity and actual production is close to 45,000 tons per year, which requires an alumina feed of close to 90,000 tons/year - all of which is imported. The expansion of capacity to 67,000 tons/year is under construction and upon completion the requirements of alumina feed will amount to about 130,000 tons per year. The establishment of further aluminium production capacity is under consideration. Consequently, producing alumina from domestic ore reserves has become one of the most important Government projects.

Concerning bauxite, the deposits of the Elburz Mountains constitute a potential local raw material for the production of alumina. Bauxite reserves have been estimated at about 54 million tons (in category R-3 of UN-classification, which indicates exploration opportunities), enough to feed an industrial-scale alumina plant for some 30 years.

The bauxite ores are of diasporic-chamositic-kaolinitic type containing 44-50 % of $Al_2O_3$ and 10-18 % of $SiO_2$. Preliminary technological tests made on Elburz bauxite indicate the possibility of recovery of alumina from these bauxites.

The pre-investment activities related to the possible erection of alumina production facilities are within the responsibility of the "Aluminium Raw Materials Programme/ARMP", set up by the Ministry of Mines and Metals of Islamic Republic of Iran in 1981. ARMP acts as the national counterpart in this project.

The first task was to establish the technical viability of industrial-scale production of alumina in the country, using the indigenous bauxites.

For this purpose a Contract No. 87/42 has been entered into between UNITED NATIONS INDUSTRIAL DEVELOPMEN ORGANIZATION (UNIDO), having its headquarters located at Wagramerstrasse 5, A-1220 Vienna, Austria and Aluterv-FKI having its principle office located at Pozsonyi ut 56, H-1389 Budapest, Hungary. Within the framework of the UNIDO Contract, project No. DP/IRA/85/003 Aluterv-FKI carried out the chemico-mineralogical and phase-analysis testing of bauxite samples followed by bench-scale technological testing of characteristic bauxite samples.

Based on the results of these tests Aluterv-FKI has prepared the Opportunity Study. The aim of this Study is to make a comparative economic evaluation of the various alternative routes of technologies for processing of Iranian bauxites.

The alternatives are

A. Low quality bauxite, sintering process (LQBSP)
B. Low quality bauxite, autoclave digestion (LQBAD)
C. Low quality bauxite, tube digestion (LQBTD)
D. Higher quality bauxite, autoclave digestion (HQBAD)
E. Higher quality bauxite, tube digestion (HQBTD)

# 2. BAUXITE RESOURCES AND RAW MATERIALS

# 2. BAUXITE RESOURCES AND RAW MATERIALS

## 2.1. Bauxite resources

Among the number of bauxite occurrences of the Islamic Republic of Iran the B horizon of the Jajarm area has been selected by ARMP as the mineral resource of an alumina plant to be established at the region.

The present Opportunity Study is based on individual and composite (characteristic) samples. Material testings of wide range were carried out by the laboratory of the ALUTERV-FKI in order to learn the value of the mentioned bauxite deposit. The detailed data of the chemical and mineralogical composition of the 120 individual samples can be found in our Interim Report 1. (edited in Dec. 1987). The following establishments are based on the ARMP's geological documentations, the reports on field trips of dr. I. Voros (1986) and Gy. Vecsernyes (1987), and their reports.

### 2.1.1. Location and depositional characters

Geografically the deposit is located on the northern flank of the Tagai Range, in a distance of about 15 km NNE from Jajarm.

At this area two bauxite horizons can be found, namely:

- horizon A between the Elika (Triassic) and Ruteh (Permian) Formations,
- horizon B between the Shemshak (Jurassic) and Elika Formations.

The horizon A actually does not show any industrial importance.

The outcrops of the bauxite deposit of horizon B can be traced 12 km long on the surface, their topographical height is between 1100-1700 m above sea level. As a rule the ore body dips 45 ° to the north. The real thickness of the deposit is 3-5 m in general, however, the recent prospections have revealed lenses with a thickness of 13-23 m, too.

The bedrock of the ore body is Triassic dolomite (Elika Formation), the covering strata consist of coal bearing marls and sand-stone (Shemshak Formation). On the carbonatic bedrock no significant karst phenomena can be found along the outcrops, however, their presence is supposed to be below the surface where bauxite of greater thickness was revealed by some bore holes which may be the manifestation of karstic sik-holes.

Lateral extension of the deposit can be traced along the outcrops, along the strike. In the direction of its dip the extension is unknown as the prospections obviously restrict to the superficial and near surface area.

The deposit is a highly complex one. In point of petrographical view made up by hard bauxite and soft clay layers. The bauxitic complex is divided one ore more clayey strata. The significant heterogenity has been manifested in its chemical (and mineralogical) composition. Petrographically that part of the formation can be regarded as bauxite in which the total amount of the Al, Fe and Ti-oxides and hydroxides is more than 50 % with the dominance of Al minerals, while the other part consists of bauxitic clay, clayey bauxite or clay.

### 2.1.2. The mineralogy of the deposite

The bauxite is a typical diasporic-chamositic ore which indicates the accumulation (or formation) of the bauxite in a lagoonar facies in reducing environment.

The mineralogical composition of the characteristic samples is as follows:

| Minerals,%/samples | ICS-2 | ICS-3 |
|---|---|---|
| diaspore | 50.8-52.2 | 36.2-37.2 |
| gibbsite | - | 2.1 |
| kaolinite | 11.5-12.5 | 21.0-22.5 |
| chamosite | 11.0-12.0 | 7.0-9.0 |
| hematite | 10.6 | 14.4 |
| goethite | 1.1 | 2.2 |
| siderite | 1.3 | 2.9 |
| anatase | 4.7 | 4.1 |
| rutile | 1.6 | 1.5 |

Chamosite belongs to the group of clorites, more exactly the subgroup of semiclorites. The theoretical formula of the primary mineral is as follows:

$$/Fe_4^{2+}, Al_2/Al_2Si_2O_{10}(OH)_8$$

in which the Fe may be replaced by Mg and the Al by $Fe^{3+}$.

Although chamosite can be detected qualitatively on the X-ray diffractograms, because of its high variety in crystal lattice and chemical composition the quantitative determination of this mineral is very difficult.

The chamosite may occur in different oxidized (secondary) forms - with different chemical compositions - in the Jajarm bauxite complex.

The detailed textural description of 15 individual bauxite samples is given in the Interim Report 1. in Annex I.

### 2.1.3. Reserves

The Jajarm bauxite deposit is divided into three sectors such as the Golbini, the Zoo and Tagui. The deposit has been prospected at a very low level and in 1986 (and even at present) it was not adequately prepared for taking representative samples as the quantity and quality of the bauxite was not known sufficiently. For that reason no representative but characteristic samples could be composed.

Recently the deposit is being prospected by the ARMP with two drilling machines and the preparatory bauxite geological mapping is actually in course, too.

The reserves known at present are as follows:

about 45 million tons in category R-3
(potential reserves)
4 million tons in category R-2
(preliminary reserves)

These reserves mean geological ones. The part (the quality) of the geological reserves, which satisfies the demand of a viable (profitable) alumina plant can be determined on the bases of the technological tests and economical evaluations. Consequently the term of the industrial grade ore can be given. In some cases certain political considerations may emerge, when some losses in the aluminium industry can be tolerated in a national economy. In this case the tolerable loss determines the quality of the "industrial grade" ore.

Bauxite reserves in R-2 category (on the bases of preliminary prospections) estimated by the ARMP recently are as follows:

| Average modulus ($Al_2O_3/SiO_2$ ratio) | Ore reserves million tons |
|---|---|
| 3.5 | 15-18 |
| 5.0 | 7-9 |
| 7.0 | 3-7 |

Because of the 45 ° of dip of the deposit about 1/3 of the reserves can be mined out by open pit method. About 25 % of mining loss can be estimated at the underground mining.

According to the latest data of prospection, very good bauxite was revealed by bore holes of BH-31 and BH-45 where the alumina is more than 60 % and silica less than 5 %. These bore holes indicate bauxite of extremely good quality which offers a better prospectivity than it was expected before.

The above described facts emphasize the utmost importance of the accelerating of the geological prospections at the Jajarm area. First of all the drilling activity has to be mentioned, supported by geophysical surveying in order to gain more reliable data for the localization of the productive bore holes.

It is highly recommendable to extend the exploration to other areas e.g. Shahmirzad, too, where the bauxite geological features are analogous to Jajarm.

## 2.2.RAW MATERIALS

<u>Bauxite</u> (Jajarm area bauxite)

| | Low quality (ICS-3) | High quality (ICS-2) |
|---|---|---|
| Chemical compositions (in percents on dry basis), % | | |
| $Al_2O_3$ | 44.2 | 52.4 |
| $SiO_2$ | 11.7 | 7.6 |
| $Fe_2O_3$(total) | 22.1 | 17.5 |
| CaO | 1.6 | 1.5 |
| MgO | 0.3 | 0.4 |
| $Na_2O$ | 0.06 | 0.12 |
| $K_2O$ | 0.40 | 0.20 |
| S(total) | 0.08 | 0.04 |
| $TiO_2$ | 5.6 | 6.3 |
| $CO_2$ | 2.57 | 1.60 |

| | | |
|---|---|---|
| $P_2O_5$ | 0.16 | 0.20 |
| $V_2O_5$ | 0.11 | 0.12 |
| $Cr_2O_3$ | 0.03 | 0.006 |
| Loss on Ignition (L.O.I.) | 12.4 | 12.5 |
| $C_{org}$ | 0.12 | 0.14 |
| $Al_2O_3/SiO_2$ module | 3.77 | 6.89 |
| Adhesive moisture (on wet basis) | 5.0 | 5.0 |

Mineralogical composition

| | | | |
|---|---|---|---|
| $Al_2O_3$ % in | gibbsite | 1.4 | - |
| | diaspore | 31.5-32.2 | 44.2-45.1 |
| | kaolinite | 8.2-8.8 | 4.2-4.7 |
| | chamosite | 2.0-2.1 | 2.7-3.1 |
| | hematite | 0.2 | 0.2 |
| | crandallite | 0.2 | 0.2 |
| | total | 44.2 | 52.4 |
| $SiO_2$% in | kaolinitee | 9.7-10.4 | 4.9-5.6 |
| | chamosite | 1.3-2.0 | 2.0-2.7 |
| | total | 11.7 | 7.6 |
| $Fe_2O_3$ % in | chamosite | 3.7 | 5.0 |
| | goethite | 2.0 | 1.0 |
| | hematite | 14.4 | 10.6 |
| | siderite | 2.0 | 0.9 |
| | total | 22.1 | 17.5 |
| $TiO_2$ % in | anatase | 4.1 | 4.7 |
| | rutile | 1.5 | 1.6 |
| | total | 5.6 | 6.3 |

| | | | |
|---|---|---|---|
| CaO % in | calcite | 1.5 | 0.8 |
| | dolomite | - | 0.2 |
| | crandallite | 0.1 | 0.1 |
| | total | 1.6 | 1.1 |
| MgO % in | dolomite | - | 0.1 |
| | chamosite | 0.3 | 0.4 |
| | total | 0.3 | 0.5 |
| $P_2O_5$ % in | crandallite | 0.2 | 0.2 |

The quality data are based on analyses made by ALUTERV-FKI. It has to be emphasized that the sample referred as high quality bauxite in this Opportunity Study is actually a middle-quality bauxite if the Jajarm bauxite is compared to that of the world's bauxite reserves.

The bauxite is expected to be mined partly by open cast, but mainly (2/3 of the total) by underground method. The bauxite is delivered into the plant site by dump-trucks. The maximum lump size of the bauxite is 250 mm.

Soda ash

| | | |
|---|---|---|
| $Na_2CO_3$ | 99 | % |
| NaCl | 0.6 | % |
| Fe | 50 | ppm |
| Insoluble material | 0.3 | % |
| $SO_4$ | trace | |

| | |
|---|---|
| Light grade | bulk density = 0.5 gr/cm$^3$ |
| 1. Heavy grade | bulk density = 0.97 gr/cm$^3$ |
| | grain size = 0.2-1 mm |
| 2. Heavy grade | bulk density = 0.985 gr/cm$^3$ |
| | grain size: 0.3-2 mm |

Quality data were handed over by ARMP in Tehran on 29.08.1988. The soda ash will be transported by trucks from a distance of 1506 km.

<u>Limestone</u> (in percents on dry basis)

| | |
|---|---|
| CaO | 54.57 |
| L.O.I. | 42.77 |
| $SiO_2$ | 0.66 |
| $Al_2O_3$ | 0.27 |
| MgO | 0.16 |
| $Fe_2O_3$ | 0.10 |
| Adhesive moisture(on wet basis) | 5.0 |

Quality data were handed over by ARMP on March 1988. Limestone will be transported by dump-trucks from an open cast mine close to the plant site. The maximum lump-size of the limestone is 250 mm.

**FUEL** (NIOC FUEL OIL 830)

### NATIONAL IRANIAN OIL COMPANY
### 1100 SEG FUEL OIL

| | | SPECIFICATION | | TEST METHOD |
|---|---|---|---|---|
| Specific Gravity | 60 °F/60°F | To be reported | | D. 1298 |
| Viscosity.Kinematic | 122 °F cs | 136 | Max. | D. 445 |
| Viscosity.Redwood 1 | 100 °F Secs | 1100 | Max. | Calculated |
| Pour Point. °F | Winter | 30 | Max. | D. 97 |
| | Summer | 50 | Max. | D. 97 |
| Flash Point °F | | 145 | Min. | D. 93 |
| Sulphur. Total | %wt | 3.0 | Max. | D. 1552 |
| Carbon Residue (Conradson) | % wt | 13 | Max. | D. 189 |
| Ash | %wt | 0.05 | Max. | D. 482 |
| Water, Sediment | %vol | 0.5 | Max. | D. 1796 |
| Calorific Value (Higher) | Btu/lb | 18,200 | Min. | Calculated |
| Carbon (C) | %wt | 85 | | |
| Hydrogen (H) | %wt | 11.5 | | |
| Vanadium (V) | P.P.M. | 64 | Approx | |
| Sodium (Na) | P.P.M. | 20 | Approx | |

Quality data were handed over by ARMP in Tehran on 29.08.1988. A net heating value of 39 GJ/ton (9315 kcal/kg) was estimated for the fuel oil because of the lack of the relevant value.

Fuel transport is envisaged by railway tankers provided that a secondary railway track will be constructed.

## NATURAL GAS

| Constituents | |
|---|---|
| Methane | 98.77 |
| Ethane | 0.52 |
| Propane | 0.6 |
| Isobutane | 0.2 |
| Normal butane | 0.2 |
| Isopenthane | 0.2 |
| Hexane and heavier materials | 0.2 |
| Carbon dioxide | 0.6 |
| Nitrogen | 0.1 |
| Others | 0.5 |
| Total | 100 % |

| | |
|---|---|
| Net heating value | 7347 kcal/m$^3$ (30.76 GJ/m$^3$) |
| Gross heating value | 8147 kcal/m$^3$ |
| Hydrogen sulphur | 4 ppm |
| Mercaptane | - |
| Water | - |
| Molecular weight | - |
| Specific gravity in proportion to air | 0.64 |

There is an existing gas pipeline about 50 km far from the envisaged plant site. An extension of the pipeline should be built in the future if natural gas will be used in the alumina plant.

# 3. PROCESS TECHNOLOGY

# 3.PROCESS TECHNOLOGY

In the present phase of the bauxite investigation the available data about the quality-quantity relationship of the 4 million ton R-2 resources can not be extended to the potential resources. Only when geological explorations will have been finished the actual quantity of the resources and the quality distribution of the bauxite will be clarified, on the basis of which the optimum plant capacity can be calculated in connection with the the most economical bauxite supply of the alumina plant. Conseqently at present, when the Opportunity Study is elaborated, the optimal capacity of the alumina plant can not be predicted.

## 3.1. Summary of the laboratory and bench-scale tests

Interim Report 1 of December 1987 contains the results of chemical and mineralogical analysis of the 120 individual bore hole samples, of their laboratory digestion tests carried out under standard circumstances, of detailed analysis by up-to-date test equipment such as Scanning Electron Microscopy (SEM) and Electron Microprobe analysis (EMPA) of 15 selected samples.

On the basis of the results of Interim Report 1 two characteristic samples of individual bore hole samples have been composed.

The lower-grade sample ICS-3 represents such grade (44.2 % of $Al_2O_3$, 11.7 % of $SiO_2$. $Al_2O_3/SiO_2$ ratio of 3.77), where both the sintering and the Bayer-process can be considered. Only two of the world's alumina plants use pure sintering process, one in Boxitogorsk, USSR and the other in Ziar, Czechoslovakia. Such grade of bauxites are not processed in other countries.

The higher grade sample ICS-2 represents the grade (52.4 % of $Al_2O_3$, 7.6 % of $SiO_2$, $Al_2O_3/SiO_2$ ratio of 6.89) of bauxite similar to that of processed in many alumina plants worldwide by Bayer-process ((Seydisehir Turkey, Tulcea Rumania, St. Nicholas Greece), if only those alumina plants are considered, where diasporic bauxites are processed. If plants processing boehmitic bauxites are included, further alumina plants, such as the ones in Hungary can be mentioned.

Detailed chemical and mineralogical composition and the bench-scale tests of the two characteristic samples can be found in Interim Report 2 of June 1983.

Grinding bench-scale tests refer to both sinter and Bayer processes.

Regarding the sintering process the following tests were carried out:

- reological tests of the composite to be sintered
- dilatometrical and thermogravimetrical tests during sintering
- porosity of the sinter
- leaching of the sinter

For the bench-scale tests of the sintering process the Institute VAMI, USSR, was invited to carry out them only with lower-grade bauxite sample. Interim Report 2 contains the general informations about the sintering process, as well.

The following tests were carried out on the Bayer-process:

- digestion tests in the function of the
  CaO dosage
  caustic $Na_2O$-concentration of digestion liquor
  digestion temperature
  bauxite dosage
  digestion time
- settling tests
- NaOH and $Al_2O_3$ recovery tests.

Main conclusions based on the bench-scale tests could be summarized as follows:

1. Both characteristic bauxite samples (ICS-2 and ICS-3) represent basically diaspore hematite ores. High $TiO_2$-content, various silicate minerals (kaolinite, chamosite) are characteristic for both samples.

2. Both characteristic bauxite samples are of similar behaviour as far as chrushability and grindability are concerned. On the basis of the Hardgrove number ($H_i$:58) measured, the materials are hard to grind, consequently when industrially processed, heavy wear of crushing and grinding equipment has to be reckoned with.

3. For processing bauxite sample ICS-3 (M=3.77) by the sintering process the optimum parameters are as follows:

| | |
|---|---|
| Moisture content of the mixture to be sintered: | 39-40 % |
| Temperature of sintering: | 1175-1200°C |
| Time requirement of sintering: | 45 minutes |
| Leaching temperature: | 85-90°C |

Under optimum parameters the attainable $Na_2O$-recovery comes to 94-96 %, that for the $Al_2O_3$ 89-91 %.

4. In the course of tests carried out on the Bayer process as optimum parameters the following ones were found:

| | |
|---|---|
| Digestion temperature | 260°C and 280°C |
| Digestion liquor concentration | 160 g/l $Na_2O$ |
| CaO addition to bauxite for digestion | 7 % |
| Molar ratio after digestion | 1.50-1.55 |

For the low-quality bauxite (ICS-3) a digestion yield of 69-70 % and for the high quality bauxite (ICS-2) that of 82-83 % were achieved.

5. Settling characteristics of red muds obtained from the Bayer digestion tests by the addition of flour and the synthetic settling aid ALCLAR-600 has been investigated. Separability of red mud proved to be similar or even better than that of red muds resulting in the Hungarian alumina plants.

6. In favour of the efficiency of the Bayer liquor circuit it is expedient to take a precipitation procedure by high concentration into consideration. In the course of elaborating the opportunity study a concentration of 140-150 gpl $Na_2O_c$ should be taken into account for the aluminate liquor.

7. Tests were carried out on the red muds of the two characteristic bauxite samples for the recovery of bound $Na_2O$-losses. In the atmospheric causticization a sodium recovery of 50.7 % was achieved on sample ICS-2 and 45.8 % on sample ICS-3.

In the high-temperature hydrothermal treatment 86.8 % of the $Al_2O_3$-content and 92.0 % of the bound $Na_2O$-content could be recovered,respectively, from both kind of red muds.

## 3.2. Description of the sintering process

As the tests showed the low-grade quality Iranian bauxites are suitable for alumina manufacturing by sintering process. The bench-scale test results can be found in the Attachment A2. The detailed general description of the sintering process is included in Interim Report 2.

The composition of the raw materials are shown in Chapter 2.2.

The process can be followed on the Process flow-sheet for Sintering Process, see Fig. 3-1 in Chapter 3.4.

## Bauxite and limestone receiving

Dump-trucks are envisaged to transport the bauxite and limestone from the mine into the plant area. The bauxite with an adhesive moisture content of about 5 % and maximum 250 mm lump size is discharged from the dump-trucks into bins (hoppers) where-from conveyor belts deliver it to the crushing. Jaw crusher and hammer mill both equipped with vibrating screens crush the bauxite until its size is less than 20 mm. Conveyor belts deliver the crushed bauxite to the covered bauxite storage facility. The storage and handling of the limestone is solved in the same manner as the ones of the bauxite.

Storage capacity has been calculated by 10-day-period for bauxite. The question of storage capacities has to be revised later in accordance with the final site selection and transport possibilities.

## Soda ash receiving and soda storage

The soda ash transported to the plant site by trucks is discharged and delivered the storage silos with a capacity of 2500 tons by a pneumatic system.

## Wet grinding, slurry adjustment and slurry storage

Moisture content of the composite should be of 38–40 % and the 0.088 mm sieve residue should not exceed 10 %. Sinter feed mixture is prepared in tube mills by common wet grinding. Adjusting of mixture composition takes place in the adjustment tanks.

Wet grinding of bauxite, limestone, soda and recovered products are carried out in multichamber tube mill, its size is Ø 2.6x13 m. Number of mills is 2, equipment are set up outdoors. Required site is 30x66 m.

In order to keep compound for two days (48 hours) twelve tanks 1000 $m^3$ each is built in. Required area for building is 54x54 m.

## Sintering

Sinter feed mixture is composited from bauxite, limestone, digestion liquor, soda ash, and white mud from desilication aimed at following molar ratios:

$$\frac{Na_2O}{Al_2O_3+Fe_2O_3+SO_3} = 1.0 \qquad \frac{CaO}{SiO_2} = 2.0$$

with the purpose to form water-soluble sodium-aluminates and sodium-ferrites and insoluble dicalcium-silicates in sinter.

The fuel oil - due to its high S-content - does not meet the requirements of the sintering, therefore natural gas has been taken into consideration for sintering.

Sintering is envisaged in rotary kilns fired by fuel oil (with an S-content of max. 1 %), or natural gas. Slurry feed is done through a slurry pulverizer into the kilns. Slurry pressure before nozzle should be 2.3-2.5 MPa. Specific heat consumption of sintering is 1450 kcal/kg. Cooling of sinter is solved in grill-type cooler, the amount of cooling air is 25-30000 $Nm^3/h$. Suction of air through the cooler is solved by exhaust fans behind the kilns (with 5-7 mm water-head suction at hot end of kiln). Electrofilters are used to clean the flue gases.

Sintering of the composite is solved in rotary kilns of size ⌀ 5x120 m, its capacity is 65 t/hour for sinter. Mixture composite is fed pulverized into the kiln through nozzle. Equipment is set up in open air. Required area for 3 kilns along with electric filters and scrubbers considering joint gas purification for gas exhauster is about 62x260 m.

Crushing and leaching of sinter

The cooled sinter is delivered for two stage crushing by conveyors for jaw crusher and then for short-conic Simons crusher with a diameter of 2200 mm. Sinter is screened by a double vibrating screen for two fractions.

Upper product is transferred to the conic crusher from the first screen (+6 mm), then transferred on the screen along with fresh sinter. Upper product of second screen (-6+2mm) as coarse fraction of sinter is transferred to the leaching unit. The coarse fraction amounts to about

80 % of the sinter. Smaller fraction of second screen (-2 mm) is transferred for the agitated tanks and settler-filter line.

Equipment to be prevented from rain and wind has to be set up and installed in building. Each transfer action of sinter must be provided with gas exhaustion. Building size of crushing unit is 30x66 m its height is about 40 m. The maximum angle of conveyors is 12 %.

Leaching unit (belt percolator) means a conveyor-like equipment that continuously transports the assembled containers on the conveyor filled with sinter in one end and pours out the washed mud itself on the other end. Leaching liquor (originally hot water) is passed through longitudinally but in countercurrent direction. Leaching water dissolves sodium-aluminate and aluminate liquor forms as approaching the sinter loading end. Its caustic molar ratio is adjusted by spent liquor originating from precipitation. Leaching time in percolating equipment is 6 hours, temperature of hot water is 98°C,moisture content of mud leaving the leaching unit including the water loss is 50 %.

Belt percolator is used for leaching of coarse fraction, its capacity for sinter is 70 t/hour, number of built-in equipment is 2.

Fine fraction of sinter is leached in agitated tanks than it is screened and washed in settler-filters, fitter-area of the latter is 41.5 $m^2$. Settler-filter line consists of 6 equipment. Aluminate liquor and wash-water introduced into the corresponding zone of the leaching unit. Washed mud is pumped to the mud disposal area together with the mud from the leaching unit. Leaching time in this agitated tanks is 35 minutes.

Equipment are set up in open air, required area is about 54x72 m.

Composition of the aluminate liquor is: $Al_2O_3$ =135 g/l, caustic $Na_2O/Al_2O_3$ molar ratio is 1.55. Ratio of liquid to solid phase in settler-washer is 2.5:1 with respect to mud.

The weighted average yield from sinter, that is the sum of the leaching and agitating system recovery is : 85 % for $Al_2O_3$ and 91 % for $Na_2O$. The leached mud is transferred to settler-washer system where it is separated from solution and mud is washed off.
The aluminate liquor obtained is pumped into a two-stage desilication system.

## Aluminate liquor desilication

In the first stage the silica transforms into almost insoluble sodium-alumo-hydrosilicate: $Na_2O.Al_2O_3.(1.7-1.75)SiO_2.nH_2O$, which separates from solution as precipitate.

The autoclave desilication takes place at a temperature of 150°C and the holding time is one hour. Desired temperature is attained by contact heating of 0.5 MPa steam. The final silicon modulus is 240-250 units.

Empty autoclaves of Ø 2.5x14 m are used for desilication, their volume is 50 $m^3$ each. 14 autoclaves are set up. Autoclaves form two series. Equipment are set up in open air, site area is 24x60 m.

In the second stage silica gets in a less soluble compound, namely in calcium-alumo-silicate (hydrogarnet $3CaO.Al_2O_3.nSiO_2.(6-2n)H_2O$). Its solubility is less than that of sodium-alumo-hydrosilicate. This compound is formed by the chemical reaction of lime and the aluminate liquor, contaminated with silicon.

Solution enters the deep desilication after control filtration. Filtration rate is 0.3 $m^3/m^2/h$. Lime feed is calculated by taking the weight proportion of CaO to $SiO_2$ equal to 5:40. Retention time of desilication in mixing vessels is 2 hours. Temperature is 88-90°C.
Composition of the secondary mud formed:
Moisture content= 40 %, CaO= 44 %, $Na_2O$= 0.6 %, weight proportion of CaO to $Al_2O_3$ is 1.8:1.

Secondary mud is separated in settlers. Velocity of overflow is 0.8 m/h. Liquid to solid ratio in settler underflow is 2:1. Solution of overflow after control filtration gets into the carbonisation step. Velocity of filtration is 0.3 $m^3/m^2/h$, moisture content of the mud is 40 %.

## Regeneration of secondary mud

Secondary mud is regenerated in order to recover the aluminium-oxide content of the white mud before sintering process. This process is carried out by a two-stage treatment with soda solution. Soda decompose hydrogarnets according to the following reaction:

$$3CaO.Al_2O_3.mSiO_2(6-2m)H_2O+3Na_2CO_3-(m+x)H_2O \longrightarrow$$
$$(m-x)/2\ (Na_2O.Al_2O_3.2SiO_2.2H_2O)+(2-m+x)AlO_2^- +$$
$$+\ xSiO_2(OH)_2^{2-}+(6-m+x)Na^+ +\ (4-2x)OH^-$$

The $Al_2O_3$ yield from white mud is 60 % after first soda treatment and 85 % after the second one.

Units are close to each other from process engineers' point of wiew, therefore equipment are grouped in the following blocks:

- white mud No.1. and white mud No.2 settling
- white mud No.1. and white mud No.2 filtering
- control filtration of solution
- lime desilication (deep desilication)
- regeneration of white mud of desilication No.2.

All equipment but filters are placed in open air, roof is provided over filters to prevent them from rain. Approximate required area is 60x96 m, closed area of it is 18x60 m.

Separation of aluminium hydroxide

In order to separate aluminium hydroxide the vast majority of aluminate liquor is delivered for carbonisation, the rest for precipitation, to obtain caustic soda which is important in the leaching of the sinter.

The continuous carbonisation process is carried out in agitated carbonisation tanks, where flue gas is entered from downwards. Carbonisation takes place at 85°C when cleaned flue gas developed during sintering is passed through the solution. Carbonisation lasts for 6 hours. Residual $Al_2O_3$ in solution is 5 g/dm . $CO_2$ content in gas used for carbonisation is 10-12 %.

Agitated tanks of Ø 6x9 m are used as carbonizers, 10 equipment form a line. Equipment are set up in open air, required area is 10x62 m.

Solution for precipitation is cooled to 62-65°C in vacuum-flash tanks. Precipitation process takes place in air-agitated precipitators. Seed ratio is 2.5. Process lasts for 45 hours. Final molar ratio of aluminate liquor solution is 3.5.

A line of vacuum-coolers is designed for cooling aluminate liquor, with a capacity of 150 $m^3$/hour. Precipitation is carried out in a line of 10 agitated tanks, 1000 $m^3$ each. Site area is 24x60 m.

## Alumina hydrate processing

The aluminium-hydroxide is filtered in disc filters, washed twice in agitating tanks and vacuum drum filters.

Disc vacuum filter is used for filtration of seed hydrate, its surface area is 100 $m^2$, 3 of them are used for the carbonized and the precipitated slurry.

Washing of hydrate is done in vacuum drum filters with a surface area of 20 $m^2$. Number of built-in filters is 6. Equipment are set up in building closed by one hydrate storage. Area of building is 48x78 m, area of hydrate storage from it is 48x24 m.

Calcination of alumina takes place in fluid-bed kilns, afterwards product alumina is taken for storage and for shipping to purchasers. Storage capacity have been calculated for 20 days.

Evaporation

The soda spent liquor solution is evaporated in a five-effect evaporator in order to eliminate excess water in the process. Five-effect evaporation station is designed for carbonised liquor evaporation with a heating surface of 1000 $m^2$ each body. Two evaporators are provided. Equipment are located in open air, area is 24x78 m.

Evaporated soda-solution is taken to the composite to be sintered, thus closing the process cycle.

Lime burning and slaking

Shaft furnace is used for lime burning, its capacity is 70 t per day for burnt lime. Individual design is necessary for gas purfication of shaft furnaces.

Slaking of calcined lime is envisaged in drum-type device of size Ø 1.8x10 m and is furnished by spiral classifier in order to remove uncalcined parts.

## 3.3 Description of the Bayer process variants by units

The general description of the Bayer process can be found in the Attachment 1. The process variants can be followed on the Process flow-sheets for Bayer Process Autoclave Digestion, Fig. 3-2 and Process flow-sheets for Bayer process Tube Digestion Fig. 3-3 in Chapter 3.4 respectively. The differences between the Autoclave Digestion and Tube Digestion variant of the Bayer process have been mentioned in the present description.

As a result of the cost-benefit analysis, instead of the liquid NaOH, as it is used in the international practice, a causticized soda make-up has been selected. From gas and fuel oil the fuel oil proved to be more economical.

### Bauxite receiving, crushing and storage

Dump-trucks are envisaged to transport the bauxite from the mine into the plant area. The bauxite with an adhesive moisture content of about 5 % and maximum 250 mm lump size is discharged from the dump-trucks into bins (hoppers) where-from conveyor belts deliver it to the crushing. Jaw-crusher and hammer mill both equipped with vibrating screens crush the bauxite until its size is less than 20 mm. Conveyor belts deliver the crushed bauxite to the covered bauxite storage facility.

The jaw-crusher and the hammer mill are located indoors. The size of the bauxite receiving and crushing building is 20 x 36 m. The covered bauxite storage is 42 x 100 m. The bauxite storage makes it possible to store a quantity of bauxite corresponding to maximum 10 days bauxite to the process in the case of some bauxite transportation difficulty. The chosen bauxite storage design allows to homogenize the bauxite delivered from various parts of the mine or transported at different times.

### Wet grinding

The bauxite is recovered from the storage area by front end loaders and belt conveyor. The belt conveyor feed the bauxite into the transfer bins of the rubber belt conveyors with weighing belts which transfer the bauxite into the wet grinding ball mills. The size of the ball mill is Ø 3.3 x 14 m. Out of the 3 mills two are operating and 1 is spare. The equipment are located outdoors. The required site is 46 x 75 m.

Multi-chamber wet grinding mills (with different ball sizes in each chamber) have been envisaged. In order to ensure an effective operation of the mills, closed-cycle mills using vibrating screens are designed.

The flow-rate of the bauxite fed into the mills is continuously measured and the grinding liquor is added in proportional quantity so that the solids content of the slurry leaving the grinding section should be about 500 g/l. In the case of tube digestion spent liquor, while in case of autoclave digestion digestion liquor is used as grinding liquor.

Minimum 95 % of the bauxite should be ground to sizes less than 90 micron. Temperature of the slurry after grinding is about 75 °C.

## Lime handling

At different points of the process, namely predesilication, red mud causticization, sodium carbonate causticization CaO is dosaged into the system in the form of slaked lime. The lime demand is covered by limestone burning followed by slaking the burnt lime.

The limestone transportation, receiving, crushing and storage is quite similar to those of bauxite.

The size of the limestone receiving and crushing is 18 x 18 m and the covered limestone storage area is 30 x 100 m.

From the storage area crushed limestone is reclaimed and fed into fuel oil fired shaft kilns. Burnt lime is transported into a silo by elevators. From the silos vibrating feeders transport the burnt lime to weighing belts and finally it gets into the lime slaking facility.

Lime slaking is done with water with a temperature of about 80 °C. Lime milk containing 200 g/1 active CaO is pumped into a storage tank. The required flow-rate of the lime milk is delivered by pumps into the individual plant units.

The unslaked residue of the limestone is pumped with the red mud to the red mud disposal area.

Predesilication, digestion and dilution

Digestion represents one of the two main chemical reactions in the Bayer process, i.e. the dissolution of alumina hydrates (in the Iranian bauxites first of all diaspore) as sodium aluminate. Digestion of boehmite and diaspore requires a reaction temperature above 220 °C, favourably above 250 °C CaO dosage promotes the digestion of diaspore.

In case of the tube digestion a reaction temperature of 280 °C has been taken into consideration. This is the highest digestion temperature realized up to now in a commercial size alumina plant. Some 15-20 minutes retention time is envisaged for completion of the digestion. In case of autoclave digestion 1 hour retention time and 260 °C digestion temperature have been selected, the latter as the highest one realized up to now in similar plants.

A multi-stage counter-current heat recovery system utilises the heat content of the digested slurry and only the final 45-50 °C temperature range has to be heated by molten salt in case of tube digestion and by high pressure steam from the power plant in case of autoclave digestion.

Two molten salt heating units with a capacity of 65 GJ/each are considered for the two tube digestion lines. Two units are located near the tube digestion lines in the area provided for the tube digestion.

A 7 % CaO dosage relative to the dry bauxite is added into the predesilication stage to form a hydrogarnet catalyst that promotes the digestion of diaspore.

Two digestion lines have been envisaged for both the tube digestion and the autoclave digestion.

In case of low-quality bauxite, the caustic concentration of the digestion liqour is 170 g/l, while in case of high quality bauxite 160 g/l.

Predesilication is located outdoors, site requirement: 28 x 50 m. Digestion is located outdors, site requirement of the autoclave digestion is 28 x 202 m and of tube digestion is 70 x 120 m.

High-pressure diaphragm pumps feed the digestion facilities with predesilicated slurry and digestion liquor.

In case of autoclave digestion two diaphragm pumps are operating with adjusted slurry and one is spare. In case of tube digestion two pumps are operating with predesilicated slurry and two with digestion liquor. One pump is kept as spare for slurry and one for liquor services. The pumps are installed indoors, the required area is 15 x 50 m for autoclave digestion and 15 x 80 m for tube digestion.

The slurry leaving the reaction zone of the digester system flows through a series of flash tanks where its pressure gradually decreases and the temperature falls to about 115 °C. Vapours released from the flash stages are utilized for preheating the slurry, as previously mentioned.

The slightly alcaline condensate originating from flash vapours is utilized as red mud wash water.

The slurry effluent leaving the flashing series is diluted by the overflow of the first red mud washing stage to the designed 140 gpl caustic $Na_2O$ concentration. The designed molar ratio of the liquid phase is 1.6. The diluted slurry is pumped to the red mud settlers by centifugal pumps at a temperature of 100-102 °C.

## Red mud settling, washing and causticization

The red mud is separated from the diluted slurry in Ø 30 m dia single tray settlers. In order to form well-sedimenting flocs a starch solution and a synthetic flocculant solution are dosaged to the diluted slurry as settling aids. The hot aluminate liquor that overflows the settlers contain some 15-25 mg/l floating fine red mud particles. It is pumped into the control filtration unit through an intermediate storage tank.

The slurry of about 400 g/l solids content is discharged as underflow from the settlers in case of processing high quality bauxite. The useful components of the liquid phase i.e. the caustic and dissolved alumina contents are recovered in a counter-current washing system. The red mud washers are of the same size and construction as the settlers. The solids content of the underflow slurry is 450 g/l in case of processing high quality bauxite. When processing low-quality bauxite, the solids content are 300 g/l in the settlers and 350 g/l in the washers respectively.

In order to minimize the make-up caustic consumption about 45 % of the $Na_2O$ bound in the red mud is recovered by slaked lime dosage. This caustic recovery process is called as mud causticization. It is carried out at a temperature of 95-100 °C in a series of agitated tanks. 4 hours reaction time is ensured for this reaction.

After the causticization the mud is filtered and washed on vacuum drum filters.

Red mud settling and washing is located outdoors, the required site is 120 x 176 m. Along one side of the area the building of the mud causticization and red mud filtration (the required area for processing low quality bauxite is 27 x 70 m, while for high quality bauxite is 27 x 42 m) is located and near this unit the building of the flocculant additive preparation (area: 18 x 18 m) and of the control filtration (area: 18 x 60 m) can be found.

In order to protect the filters and increase the service time of the filter cloth the coarse particles are separated by vibrating screens. The oversize fraction is washed in rake-classifiers and added to the filtered mud.

The filtered red mud is delivered by diaphragm piston pumps to the disposal area, where it consolidates. Being well isolated from the soil its sodium content does not contaminate the environment and the mud can be piled up to a height of about 30 m.

For the processing of low-quality bauxite an extra filter stage is envisaged between the last washer and the causticization stage, otherwise the dissolved alumina losses (as tricalcium-aluminate) would be extremely high.

## Control filtration, heat interchange

In order to keep the contamination of the alumina with iron and silica at the minimum, the hot aluminate liquor is filtered on pressure filters using fine calcium carbonate precipitate from the soda ash causticization as filter aid.

The filtered aluminate liquor practically free from suspended mud particles is pumped from the storage tank to parallelly operated plate heat exchanger units. Cold spent liquor is fed in counter-current to the aluminate liquor. As a result of the heat exchange the temperature of the cooled aluminate liquor is 63 °C and that of the hot spent liquor is about 84 °C.

The cold aluminate liquor is transferred to the precipitation whereas the hot spent liquor is pumped to various points of the process, including the evaporation.

## Precipitation, hydrate classification and filtration

The cold aluminate liqour supersaturated with respect to dissolved alumina is seeded by previously crystallized alumina hydrate. The seeding increases the rate of crystallization of the dissolved alumina as alumina hydrate and is favourable with respect of the grain size distribution of the hydrate leaving the precipitation stage.

When processing diasporic type bauxites it can not be reached such $Al_2O_3$ supersaturation in the aluminate liquor as in case of gibbsitic bauxites and at certain digestion parameters in case of boehmitic bauxites. Therefore in the precipitation the so-called agglomeration technology, which is a precondition of producing very coarse and strong typical sandy alumina, can not be applied. The chosen crystal growth precipitation technology results in an alumina hydrate of slightly finer grain size.

15 operating 2000 $m^3$ volume air-agitated tanks are designed for the precipitation process. An interstage cooling step between the 2nd and 3rd precipitation stages increases the precipitation efficiency and is useful for the control of the grain size distribution of the hydrate.

A classification stage is envisaged to separate the coarser fraction of the hydrate as product hydrate. The remaining finer fraction is used as seed in the next precipitation cycle after filtering it on disc filters.

The coarser fraction is injected with hydrate wash water and is pumped to the pan filters close to the calciners.

The equipment of the precipitation and hydrate classification are located outdoors while that of the hydrate filtration and heat interchange indoors. The required site for precipitation and hydrate classification is 36 x 138 m and for the hydrate filtration and heat interchange building is 42 x 78 m. The vacuum and compressor station (14 x 78 m) is attached to this building.

Evaporation, salt removal, test tank liquor preparation

The water-balance of the plant is maintained by five-effect counter-current evaporator units. Only a part of the spent liquor preheated in the heat interchange is directed into the feed tank of the evaporators, from where it is pumped through the evaporator bodies. The strong liquor containing about 250 gpl caustic $Na_2O$ is supersaturated with respect to sodium carbonate in a crystallizer evaporator (superconcentrator).

The two five-effect counter-current evaporators are located outdoor in an area of 26 x 84 mm. The superconcentrator is placed close to the evaporators in the same plant unit area.

The tanks belonging to salt removal and soda ash handling included the silos and causticization units as well are placed in a common area of 40 x 50 m.

The filters of the soda ash handling and that of the salt removal are installed in a building (required area: 18 x 40 m) located close to the outdoor equipment. The test tanks are placed in the slurry storage and predesilication unit which is near to the salt separation unit.

The slightly alcaline condensate from the evaporation is utilized partly as hydrate and partly as red mud wash water. The pure condensate originating from the back-pressure steam used in the evaporator returns to the power plant.

After completion the crystallization the salt mainly sodium carbonate salt is removed from the strong liquor in filters. The filtered salt is repulped by hot wash water and pumped into the causticization to recover its caustic soda content. The strong liquor is pumped to the test tanks.

The strong liquor free from crystalline sodium carbonate salt is mixed in the test tanks with the make up caustic solution and with a part of the spent liquor. The test tank liquor is pumped to the digestion and in case of autoclave digestion to the bauxite grinding as well.

## Calcination

The product hydrate slurry is pumped to pan filters close to the calciners. The hydrate is washed by hot wash water in 2 counter-current stages on the pan filters. The filtered and washed product hydrate is transported to the feeding hopper of the calcining kilns by conveyor belts. Rotary kiln construction for calcination has been selected that enables milder calcination circumstances than the latest fluid bed and gas suspension calciner developments.

Two rotary kilns of capacities 350 tons per day calcined alumina each have been designed. The hydrate passes from the feeding hoppers of the kilns over a weighing belt and a mixing screw - where precipitated alumina dust is mixed with the hydrate - into the cyclone system and subsequently into the calciner. The calcination temperature in the kiln is about 1050 °C. The hot alumina leaving the calcining zone is cooled at first by combustion air and finally by water in a countercurrent heat recovery system. The cooled alumina is transported to silos by elevators. 20 days production can be stored in the product alumina silos.

The two rotary kilns are located outdoors. The required site is 54 x 125 m.

Soda ash handling and causticization

The soda ash transported to the plant site by trucks is discharged and delivered the storage silos by a pneumatic system. 15 days soda ash consumption of the plant can be stored in the silos. From the silos the soda ash is delivered to the causticization unit by another pneumatic system.

The hot water used for slurrying the soda ash, the lime milk and the steam are dosaged so that the caustic $Na_2O$ concentration of the slurry should be 90-100 g/l. 95 °C temperature and 3 hours retention time are designed for completion of the causticization reaction. A continuously operating pressure belt filter is envisaged for separating the $CaCO_3$ precipitate from the make-up solution.
The make-up caustic is pumped to the test tanks. The $CaCO_3$ precipitate is partly used as a filter aid in the control filtration, and the excess is added to the red mud to be disposed of.

The soda ash handling and causticization is placed at a common area with the salt separation and causticization close to the evaporation.

Description of caustic soda regeneration processes

The caustic soda losses are proportional with the silica content of the bauxite in the Bayer process. The CaO+MgO content of the bauxite also influences the caustic soda losses. The so called caustic soda regeneration processes have a great importance in processing low grade, high silica bauxite to reduce the fresh caustic soda consumption. We have to consider such type of bauxite in the Jajarm region, consequently the caustic soda regeneration processes are characteristic for the selected variant of the Bayer technology. In this study theree different causticization processes have been studied and considered in the Bayer technology.

a) Soda ($Na_2CO_3$) causticization

For the compensation of the caustic soda ($Na_2C$) losses at the Bayer process in general liquoid or solid NaOH is used in the industrial practice. There are, however, special conditions, where the use of soda ash ($Na_2CO_3$) should be preferred to substitute the caustic soda losses. In this case the soda ash should be converted into NaOH in a special causticization unit before making-up caustic. Under the conditions existing in the Islamic Reppublic of Iran the causticization of the soda ash is much more profitable than purchasing NaOH. The related calculation is shown at the end of this chapter.

The soda ash by means of pneumatic system will be transported from the silo into the tanks of causticization. This causticization system is consisting of stirred tanks in series. The soda ash, lime milk and water in proper ratios will be added into the first tank. The amount of the water is determined by the final concentration of the $Na_2O$ caustic after the causticization which should reach a concentration of 90-100 gpl. To achieve a high yield of causticization a temperature of min. 95 °C and a retention time of 4 hours is necessary. The lime requirement should be considered according to the following ratio: 1.1 mole active CaO/1.0 mole $Na_2CO_3$ (10 % excess to stochiometry).

At the end of the causticization the liquid phase containing NaOH should be separated from the solid phase containing $CaCO_3$ by means of continuous filter. The solid phase should be washed out on the filter until it becomes caustic-free. The filter cake $CaCO_3$ can be used partially as filtering aid at the control filtration of the aluminate liquor, the excess can be burnt together with the limestone into lime or eventually can be stored in the red mud disposal area.

b) Soda salt causticization

The $CaCO_3$ (calcite) and $CaMg(CO_3)_2$ (dolomite) content of the bauxite will be dissolved in the caustic liquor at the digestion temperature and will be converted into $Na_2CO_3$. In consequence, the soda ($Na_2CO_2$) will be enriched in the Bayer cycle. The harmful effect of this soda, above a given level, becomes more and more significant reduction of the precipitation yield, soda salt formation and scaling in the evaporation station and in the flash tanks, etc., therefore it should be removed from the cycle. At a given (higher) caustic soda concentration the soda salt ($Na_2CO_3$) and from other sodium-containing salts can be crystallized and removed, from the evaporated liquor by filtration (or centrifuging). To reduce the caustic soda losses the $Na_2CO_3$ content of the "soda salt" can be (and should be) converted into NaOH by means of causticization in a similar way as was mentioned before the soda ash causticization.

### c) Red mud causticization

During the bauxite digestion the silica content of the bauxite will be transformed into sodium-aluminium-hydrosilicates in which each kg $SiO_2$ bounds about 0.7 kg $Na_2O$. These sodium-aluminium-hydrosilicates are the main phases of the red mud and without further treatment would be perfectly lost in the red mud disposal area. About 50 % of the $Na_2O$ losses bound to $SiO_2$ can be recovered by means of the causticization of the red mud.

The last washer's underflow (red mud slurry) will be causticized. For processing the lower grade bauxite this underflow red mud slurry should be filtered before causticization to avoid the extremely high dissolved losses of alumina. The causticization system (agitated tanks in series), the temperature (95 °C) and retention time (4 hours) are similar to the causticization of the $Na_2CO_3$, the only significant difference is the lime requirement which is much higher here: 3 mole active CaO/1 mole $Na_2O$ (bound in the red mud).

All the three causticization units are plotted in the process flow-sheets in Fig. 3-2 and 3.3.

For better overview of the significant effects of caustic soda regeneration processes the caustic soda balance (in kg per t of alumina) can be seen below.

Caustic soda balance ($Na_2CO_3$ 99 %) kg/t alumina (200 kt/year alumina)

| | Autoclave | | Tube dig. | |
|---|---|---|---|---|
| | HQB | LQB | HQB | LQB |
| Out: Losses: | | | | |
| Bound to SiO2 in red mud | 161.2 | 327.7 | 154.6 | 358.8 |
| Bound to salt at digestion | 68.9 | 91.0 | 68.9 | 91.0 |
| With alumina | 6.9 | 6.9 | 6.9 | 6.9 |
| Physical losses | 5.2 | 5.0 | 4.3 | 5.2 |
| Filtered red mud liquor phase | 27.5 | 71.9 | 27.0 | 67.7 |
| Total | 269.7 | 547.5 | 261.7 | 529.6 |
| Recovery (regeneration) | | | | |
| At salt causticization | -68.1 | -89.8 | -68.1 | -89.8 |
| At red mud causticization | -72.6 | -167.7 | -69.6 | -161.8 |
| Total | -140.7 | -257.5 | -137.7 | -251.6 |
| In: Na2CO3 consumption (Substitution by make-up caustic) | 129.0 | 290.0 | 124.0 | 278.0 |

## Substitution of caustic soda (NaOH) with sodium carbonate ($Na_2CO_3$)

When the Study was prepared, the economic consequences of substituting caustic soda (NaOH) with sodium carbonate ($Na_2CO_3$) as a source of caustic was thoroughly investigated.

It can be stated (investigating the possibilities of the supply) that during the last years and according to the forcasting in the next future as well, the market of the NaOH was uncertain enough with highly fluctuating prices. The reason is included in that fact that the production of NaOH is in a close connection with the demand for chlorine, which is decreasing in the last time due to the environmental requirements. In contrary, the price of sodium carbonate was relatively stable without similar uncertainities.

The fluctuation of the prices of alumina, NaOH and $Na_2CO_3$ between 1982 and 1988 is summarized in the Table below.

| Year | Price in USD/t | | |
|---|---|---|---|
| | Alumina | NaOH | Na2CO3 |
| 1982. | 206 | 325 | 125 |
| 1983. | 212.5 | 262 | 111 |
| 1984. | 204 | 186 | 99 |
| 1985. | 180 | 158 | 126 |
| 1986. | 158 | 169 | 142 |
| 1987. | 156 | 180 | 130 |
| 1988. | 280 | 360 | 150 |

Furthermore, it should be considered, that one of the most important preconditions of the caustic soda (NaOH) production is the industrial processing of the chlorine gas formed. Similar problems do not arise in the case of $Na_2CO_3$ production, therefore, for domestic caustic supply in the Islamic Republic of Iran the erection of a $Na_2CO_3$ plant can be recommended.

The economic aspect of the question was investigated for the processing of high quality bauxite by tube digestion which process requires the less caustic. For other variants the economy of sodium carbonate causticization would be rather better. The results of the calculations can be seen in the next Table.

| Item | Substitution of the caustic soda losses by | | | |
|---|---|---|---|---|
| | NaOH | | Na2CO3 (with causticization) | |
| Market price Rls/t | 28510 | | 11880 | |
| Costs, Rls/t alumina | 92.84 kg | 2647 | 124.2 kg | 1475 |
| Excess limestone | | | 129.0 kg | 120 |
| Excess fuel oil | | | 27.0 kg | 35 |
| Saving in electrical power | | | -36 kWh | -94 |
| Total costs Rls/t | | 2647 | | 1536 |
| Saving using Na2CO3, Rls/t | | | | -1111 |
| Total yearly saving, (200 kt alumina/year) | $10^6$ Rls/year | | | -222.2 |
| Investment costs, $10^6$ Rls | | | | 104 |
| Excess investment costs for Na2CO3 caust. | $10^6$ Rls (104-67) | | | +37 |

It can be seen that the rate of return of the excess investment costs of the sodium carbonate treatment (causticisation plant) is about 2 months only.

Consequently, the use of $Na_2CO_3$ should be preferred.

## 3.4. Process flow-sheets

The process flow-sheets of the Sintering Process, the Bayer Process Autoclave Digestion and the Bayer Process Tube Digestion are shown on Figure 3-1, Fig. 3-2 and Fig. 3-3 respectively. All the three process flow-sheets refer to the low-quality bauxite processing. In case of the higher quality bauxite because of the lower quantity of the red mud there is no red mud filtering envisaged between the last washer and the red mud causticization.

## 3.5. Preparation of the conceptional plant lay-out, main equipment list and price list of the main equipment

The conceptional plant lay-out for sintering process is shown in drawing No. CPL-1, in case of Bayer process variants in drawings CPL-2, CPL-3, CPL-4, CPL-5.

For the arrangement of plant units the following were considered:

- the technological connection of the plant units
- the material transportation among the units
- the possible separation of welfare and management buildings
- the transportation of raw and auxiliary materials, as well as of alumina
- water supply system
- electrical connection to the national grid
- the way of personnel traffic.

The lay-outs were elaborated taking into consideration presumed infrastructural connections. Space for future expansion was not considered inside the boundary.

The main equipment list for sintering as well as for the Bayer process variants is given in Attachment 4. In the equipment list the main equipment are listed with outline of their technical specifications (capacity, total weight, characteristic dimensions).

Most of the main equipment are considered as imported items. Atmospheric tanks, pumps for water services and some other items are considered as domestic items. These items are marked with asterisk in the main equipment list.

Some other parts of the incvestment costs are also envisaged as domestic supply. These are discussed and detailed in Chapter 14.

A price list for the main equipment are given in the Attachment 5.

## 3.6. Alumina quality

Concerning the desirable properties of alumina for Hall-Héroult cells the opinion of Prof. G. Winkhaus can be considered (Aluminium, Vol. 64. 1988. No.6. pp.593-602.), as follows:

Since the industrial production of aluminium began, the question as to what constitutes the optimum alumina quality for smelting has been topic of continuous discussion.

Until the end of the sixties, the opinions expressed were somewhat confused and the results of published laboratory work were often contradictory, especially regarding the dissolution behaviour of th alumina in the electrolyte.

In the seventies, however, it became necessary to quantify the essential properties of alumina in electrolysis due to

- the need for tighter control in the smelters following the drastic increase in energy costs,

- the introduction of new technologies in the alumina plant (fluid bed calcination) and in the smelter (automatic cell feeding),

- the stricter requirements of environmental control (dry scrubbing, dust removal),

- the increasing need for smelters to cope with the processing of spot alumina deliveries from a variety of sources.

Consequently, basic investigations were commenced in many laboratoryes and although useful results were obtained it was clear that simulating the industrial process on the laboratory scale was difficult.

World-wide, modern smelters nowadays prefer "sandy" to "fluory" type aluminas.

The modern smelter requires

- constancy of properties of the alumina to be processed,

- optimum dissolution behaviour of the alumina in the electrolyte,

- optimum crust formation, due to heat transfer considerations among others,

- good and constant flow properties of the alumina with minimum tendency to dust formation,

- high adsorption capacity for hydrogen fluoride in the dry scrubbing process,

- guaranteed alumina purity, particularly concerning elements which reduce current efficiency, phosphorus above all.

The present state of knowledge can be summarized as follows

- the question of optimum alumina quality cannot be generalized, but can only be answered in terms of a specific smelter operation,

- for modern, automated, high-capacity cells, it is possible to define a wide range of measurable alumina properties. However, detailed predictions of the likely behaviour of an alumina during electrolytic reduction cannot yet be made satisfactorily. Furhter investigations, including plant level studies, are necessary to study, amongst others, the various transitional crystalline phases present in the alumina.

The typical physical data and the typical analysis of the impurities for Bayer aluminas are given below.

Physical data for Bayer aluminas
(typcal values)

| Aluminium-oxide type | | Fluory | Sandy |
|---|---|---|---|
| Specific surface area (B.E.T.), | m2/g | 5 | 50-100 |
| alfa - $Al_2O_3$, | % | 90 | 20-10 |
| Grains - 45 micron, | % | 45 | 10 |
| Angle of repose | degree | 45 | 30 |
| Bulk density, | g/cm3 | 0.8 | 0.95 |

## Impurities in Bayer alumina
(typical analysis); data in mass %

| Contaminant | Content |
|---|---|
| $Fe_2O_3$ | 0.015 % |
| $SiO_2$ | 0.015 % |
| $TiO_2$ | 0.003 % |
| $CaO$ | 0.015 % |
| $P_2O_5$ | 0.001 % |
| $V_2O_5$ | 0.002 % |
| $ZnO$ | 0.005 % |
| $Na_2O$ | 0.5 % |

The essential alumina requirements of a modern smelter are:

1. Priority: constant quality.

2. Most important is the degree of calcination, which affects dissolution behaviour as well as dry scrubbing performance.

3. The next most important factors are particle size and structure, and size distribution of the alumina.

4. The alumina should dissolve quickly. The formation of moderately hard crusts on the surface of the melt and around the edges of the cell is desirable.

5. Impurities in the alumina which affect metal purity and reduce current efficiency should be limited.

Typical measurable specifications for smelter alumina, corresponding to the above requirements, are given below.

### Alumina frame specifications for central-chammel systems with pre-baked anodes

| | | | |
|---|---|---|---|
| Specific surface area (B.E.T.) | m2/g | | 50-80 |
| alfa - Al2O3 | % | | 20-10 |
| Grains 45 micron | % | | 10-20 |
| 105 micron | % | max. | 10 |
| Bulk dansity | g/cm3 | | 0.95 |
| Angle of repose, | degree | | 35-30 |
| Loss on ignition | % | | 0.6-0.9 |
| P2O5 | % | | 0.001 |

In the following the expected alumina quality characteristic for the sintering variant (base on the information submitted by the experts of VAMI) and for the Bayer variant as well can be found only the later, meets the general requirtrements of the up-to-date smelters for metal grade alumina.

### 3.6.1. Product quality (sintering variant)

| Grade according to USSR Standards | G0 | G1 |
|---|---|---|
| Expected rate of annual alumina production | 20 % | 80 % |
| $Al_2O_3$-content, % at least | 98.6 | 98.5 |
| Contaminants, % maximum values | | |
| $SiO_2$ | 0.03 | 0.05 |
| $Fe_2O_3$ | 0.05 | 0.06 |
| $TiO_2+V_2O_5+MnO+Cr_2O_3$ | 0.02 | 0.03 |
| $P_2O_5$ | 0.003 | 0.003 |
| $Na_2O+K_2O$ | 0.5 | 0.6 |
| ZnO | 0.02 | 0.03 |
| Loss on ignition (300 °C), % | 0.9 | 0.7 |

Physical properties

| | | |
|---|---|---|
| Specific surface area B.E.T. $m^2/g$, less than | | 40 |
| Bulk density, | $t/m^3$ | 0.75-0.85 |
| Angle of repose, | degrees | 41 - 42 |

| Screen analysis indication, % | | Hydrate | Alumina |
|---|---|---|---|
| +100 | micron | 30 | 16 |
| -100/+80 | micron | 16 | 12 |
| - 80/+60 | micron | 18 | 16 |
| - 60/+45 | micron | 12 | 16 |
| - 45 | micron | 23 | 40 |

### 3.6.2. Product quality (Bayer process variant)

| CONTAMINANTS | TIPICAL wt% | MAXIMUM wt% |
|---|---|---|
| SiO2 | 0.020 | 0.030 |
| Fe2O3 | 0.020 | 0.030 |
| TiO2 | 0.004 | 0.007 |
| Na2O | 0.400 | 0.500 |
| ZnO | 0.010 | 0.015 |
| CaO | 0.040 | 0.060 |
| V2O5+MnO+Cr2O3 | 0.010 | 0.012 |
| P2O5 | 0.001 | 0.003 |

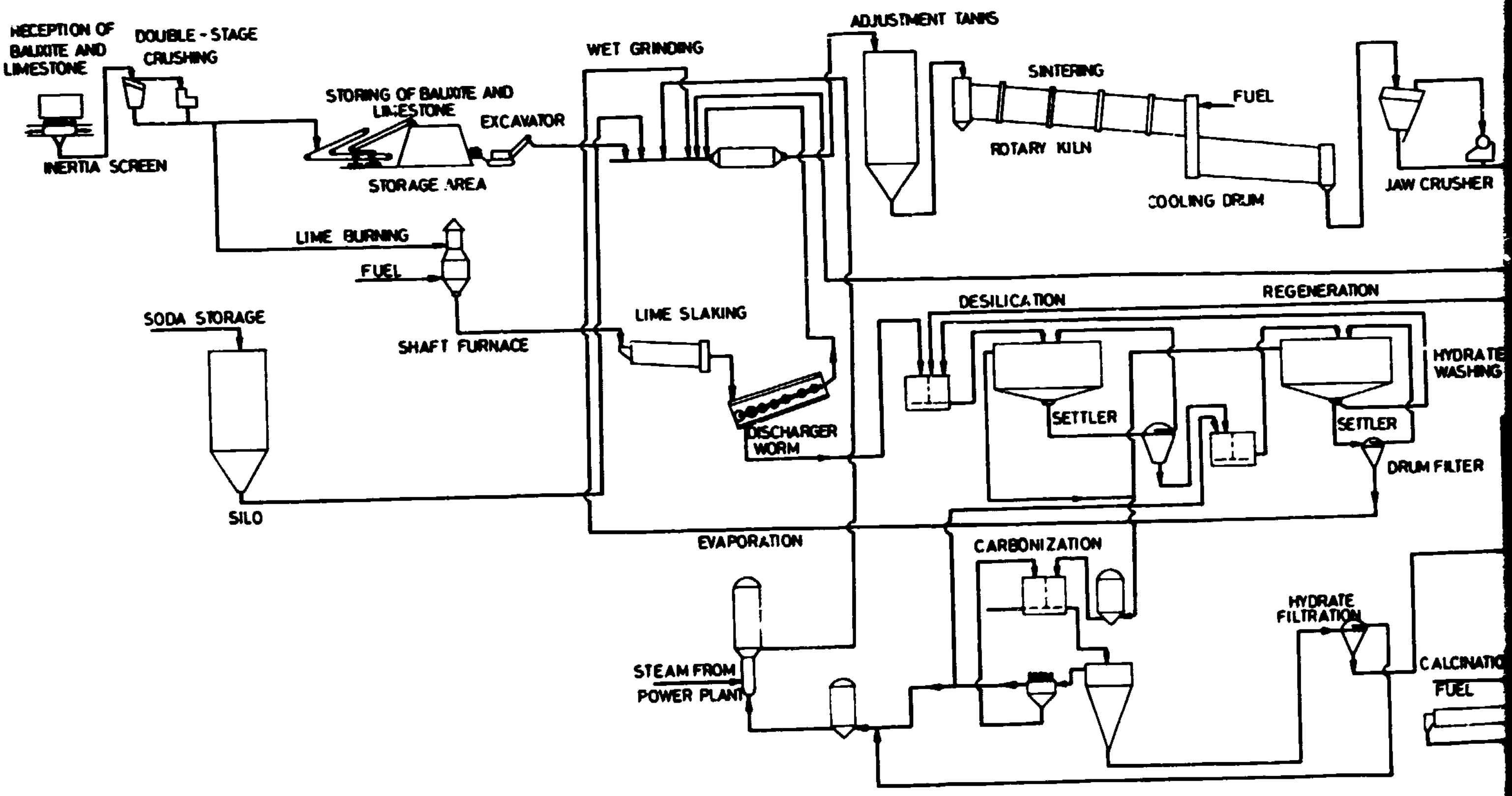
PHYSICAL PROPERTIES

| | | |
|---|---|---|
| Loss on ignition (300 °C-1.000 °C), | % | 0.6- 0.9 |
| Specific surface area B.E.T. | m2/g | 40 - 70 |
| Alpha alumina, | % | 10 - 20 |
| Bulk density, | t/m3 | 0.9-0.95 |
| Angle of repose, | degree | 30 - 35 |

SCREEN ANALYSIS, %

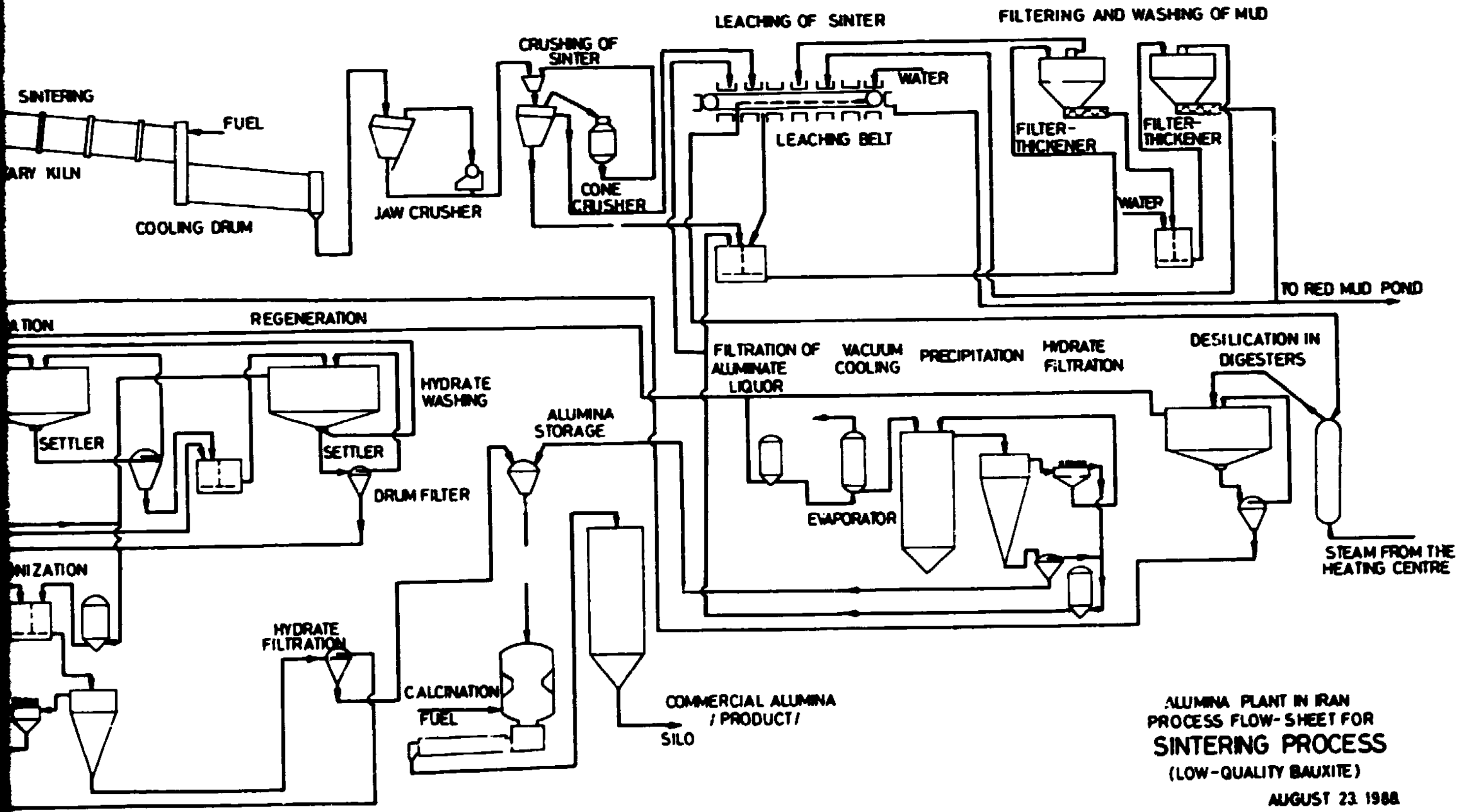
| | | |
|---|---|---|
| + 150 mesh | ( + 105 micron) | 5 - 10 |
| - 150/+ 325 mesh | (44-105 micron) | 70 - 85 |
| - 325 mesh | ( - 44 micron) | 10 - 20 |

The quality of the alumina produced by sintering process can meet the requirements of the IRALCO Smelter in Iran according to the information submitted by the experts of ARMP, considering that the aluminium produced there is used mainly for silicon-containing aluminium alloys. It should be stated, however, that the alumina containing higher amount of impurities (e.g., $SiO_2$ and $Fe_2O_3$) is not suitable for the production of aluminium with high electrical conductivity and that of some speciality aluminas, and can cause operational difficulties during feeding and dry scrubbing in an up-to-date smelter.


RECEPTION OF BAUXITE AND LIMESTONE
DOUBLE - STAGE CRUSHING
INERTIA SCREEN
STORING OF BAUXITE AND LIMESTONE
STORAGE AREA
EXCAVATOR
WET GRINDING
ADJUSTMENT TANKS
SINTERING
FUEL
ROTARY KILN
COOLING DRUM
JAW CRUSHER
LIME BURNING
FUEL
SHAFT FURNACE
SODA STORAGE
SILO
LIME SLAKING
DISCHARGER WORM
DESILICATION
REGENERATION
HYDRATE WASHING
SETTLER
SETTLER
DRUM FILTER
EVAPORATION
CARBONIZATION
HYDRATE FILTRATION
STEAM FROM POWER PLANT
CALCINATIO
FUEL

# SECTION 1

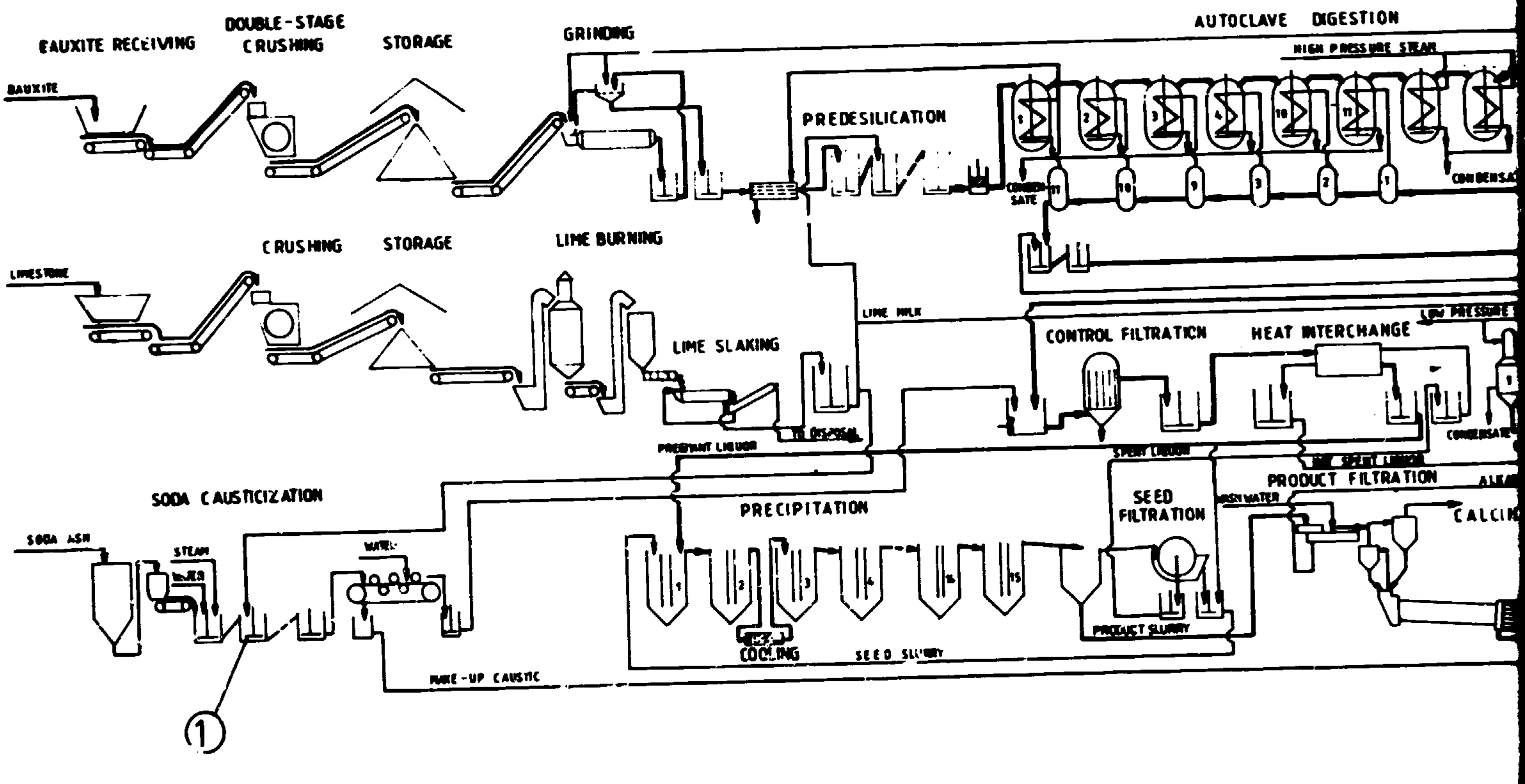
Fig. 3-1



ALUMINA PLANT IN IRAN
PROCESS FLOW-SHEET FOR
SINTERING PROCESS
(LOW-QUALITY BAUXITE)
AUGUST 23 1988

SECTION 2

# SECTION 1



CAUSTICIZATION UNITS FOR:

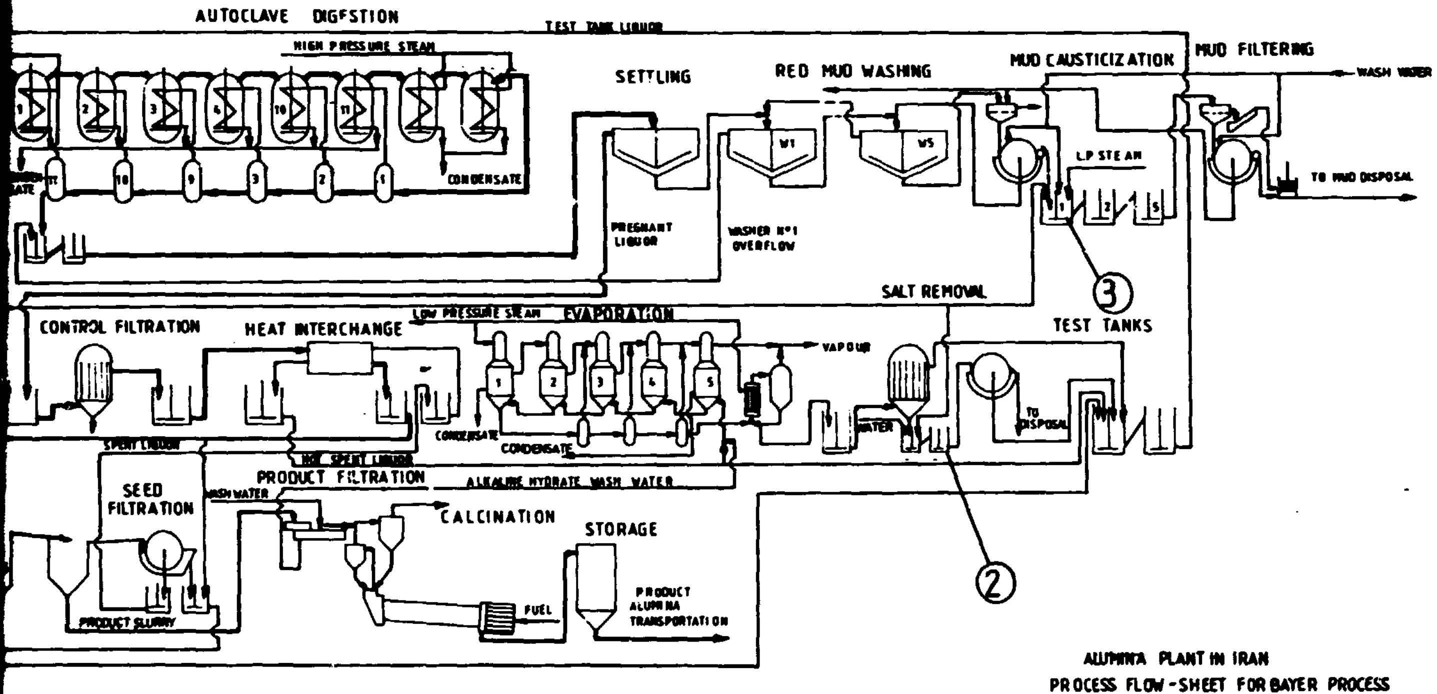
① SODA ASH

② SODA SALT

③ RED MUD

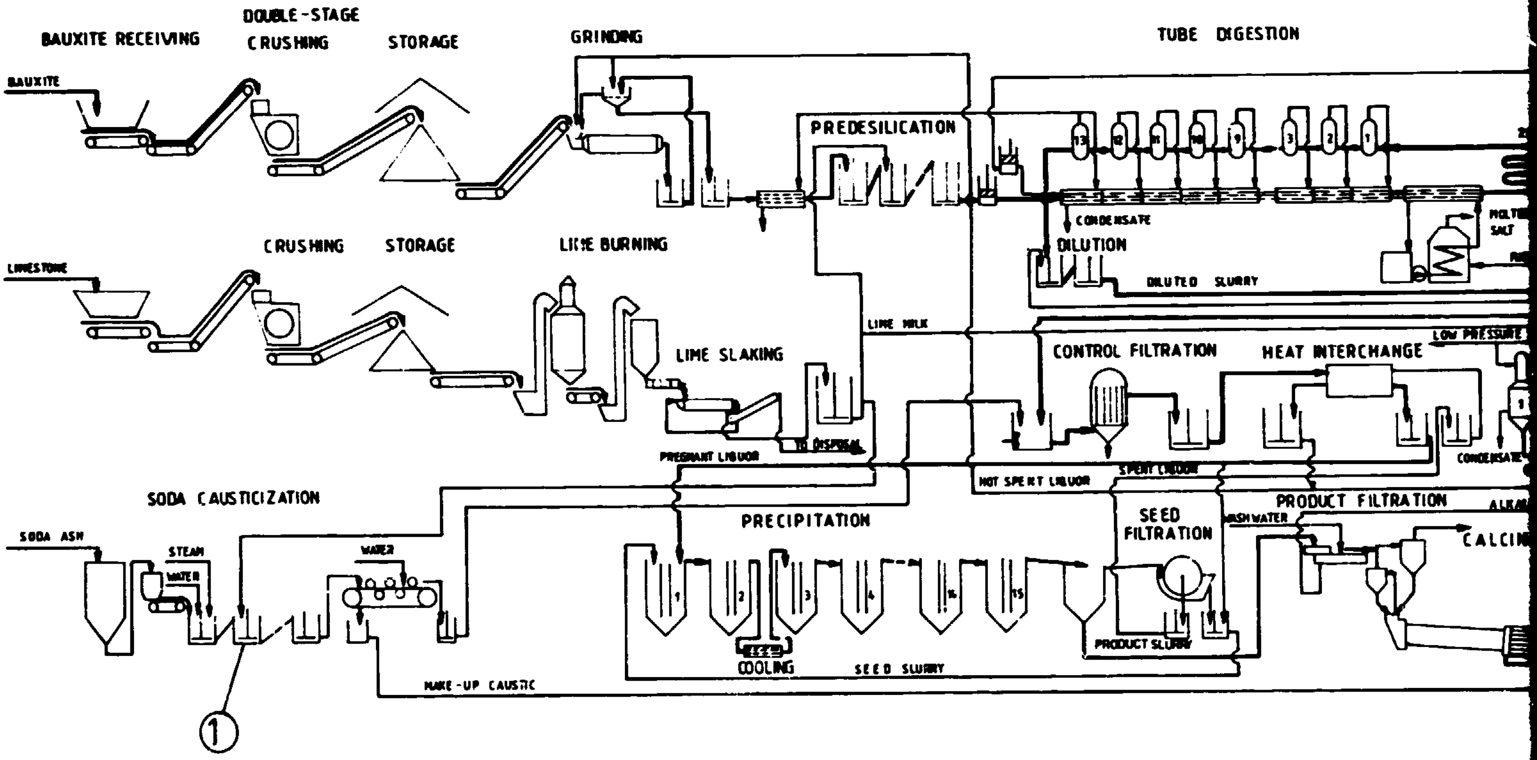
# SECTION 2

Fig. 3-2



ALUMINA PLANT IN IRAN
PROCESS FLOW-SHEET FOR BAYER PROCESS
AUTOCLAVE DIGESTION
(LOW-QUALITY BAUXITE)
August 23 1988

# SECTION 1



CAUSTICIZATION UNITS FOR:

① SODA ASH

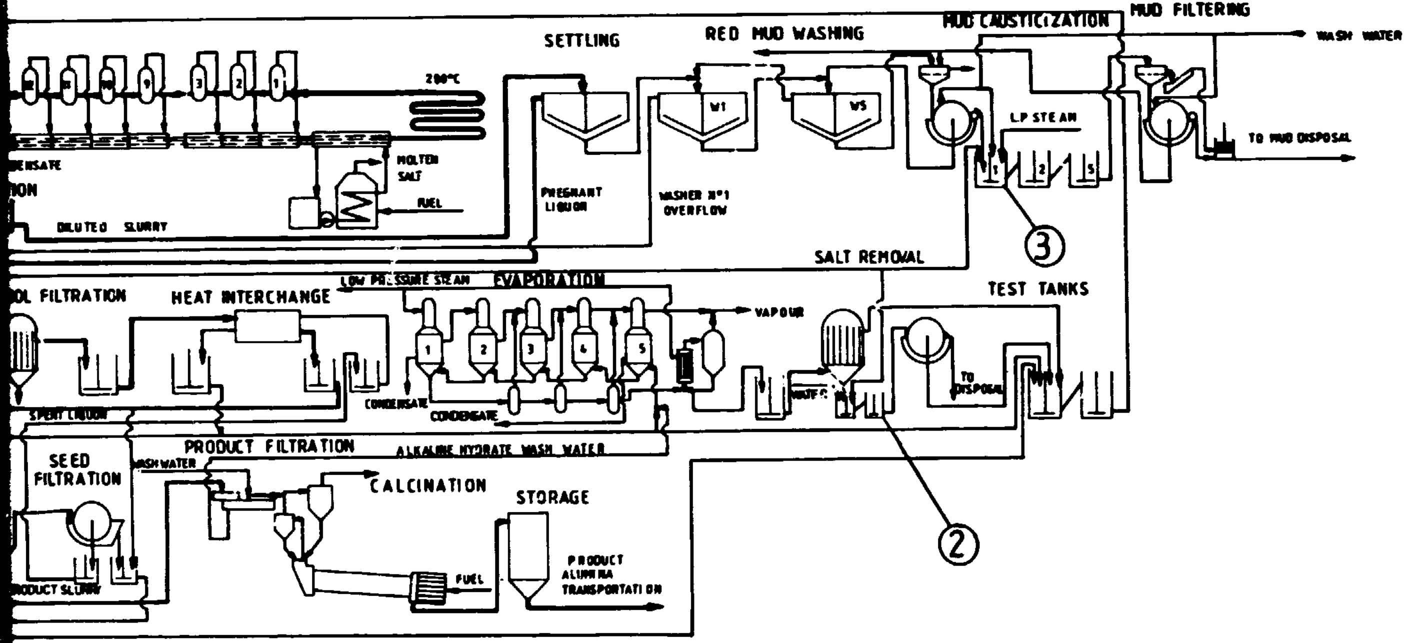
② SODA SALT

③ RED MUD

# SECTION 2

Fig. 3-3

TUBE DIGESTION



ALUMINA PLANT IN IRAN

PROCESS FLOW-SHEET FOR BAYER PROCESS

TUBE DIGESTION

(LOW-QUALITY BAUXITE)

August 23, 1980

# 4. NON-TECHNOLOGICAL UNITS

# 4. NON-TECHNOLOGICAL UNITS

## 4.1. POWER PLANT

### 4.1.1. Sintering process

A power plant is provided to supply electric and thermal energy for the plant.

Conception of the power plant is as it follows:
Existing national electric energy grid is assumed on the plant site. Power supply is provided in cooperation with the national grid. In order to maintain the continuous operation of the plant, for the case if national network fails an independent stand-by power supply will be set up.

To maintain the demand of the plant the following power and thermal capacities are provided:

Power demand of the plant: 23.5 MW max. 26 MW
Thermal capacity:

| | |
|---|---|
| steam 1.6 MPa pressure: | $p_k$=16 bar<br>$t_k$=220 °C<br>$G_k$=40 t/h<br>max.45 t/h |
| steam 0.8 MPa pressure: | $p_e$= 8 bar<br>$t_e$= 190 °C<br>$G_e$=55.3 t/h<br>max.60 t/h |

About 60 % of steam returns as condensate from the plant. Structure of energy demand enables to set up a coupled electric power and thermal energy power plant. Therefore the power plant is provided with the following main equipment:

3 oil fired boilers (2 operating, 1 spare)

$p_o$= 80 bar
$t_o$= 500 °C
$G_o$= 35 t/h

2 extraction back-pressure steam turbine-generator (2 operating)

$p_o$= 80 bar
$t_o$= 500 °C
$G_o$= 85 t/h steam inlet

extraction:

$p_k$= 16.5 bar
$G_k$= 15-25 t/h

back-pressure:

$p_e$= 8 bar
$G_e$= 60-70 t/h

Generator capacity: 20 MW

1 Condensation turbine-generator (stand-by)

$p_o$= 8 bar
$t_o$= 250-300 °C
$G_o$= 45-65 t/h

Generator capacity: 10 MW

Cooling tower plant (stand-by)
Cooling water : 3500 $m^3/h$
$\Delta t$ : 20 °C
Make-up water demand: 250 $m^3/h$

Normally the power plant cooperates with the national grid. In this case condensation turbine-generator unit is on stand-by.

At the characteristic process steam consumption the power plant generates 11.2 MW power. Taking the power plants own consumption into consideration, 14 MW power should be purchased. 23.5 MW is provided for the plant.

In case of grid failure missing power can be generated in the condensation turbine. In this mode of operation the extraction back-pressure turbine unit generates 18.2 MW. Condensation turbine unit generators 8.4 MW.
Power for the plant in this case is also 23.5 MW.
Fuel oil consumption of power plant is:

| | |
|---|---|
| in normal operation | 8.2 t/h |
| in grid failure mode | 12.8 t/h |

### 4.1.2 Bayer process, low quality bauxite autoclave digestion

A power plant is provided to supply electric and thermal energy for the plant.

Conception of the power plant is as it follows:
Existing national electric energy grid is assumed on the plant site. Power supply is provided in cooperation with

the national grid. In order to maintain the continuous operation of the plant, for the case if national network fails an independent stand-by power supply will be set up.

To maintain the demand of the plant the following thermal and power capacities are provided:

Thermal capacity:

steam 8.0 MPa pressure:
$p_n = 8.0$ MPa
$t_n = 300$ °C
$G_n = 73.5$ t/h
max.90 t/h

steam 0.5 MPa pressure:
$p_e = 0.5$ MPa
$t_e = 170$ °C
$G_e = 48.8$ t/h
max.60 t/h

About 70 % of the steam returns as condensate from the plant.

Power demand of the plant: 11.5 MW max. 14 MW

Structure of energy demand enables to set up a coupled electric power and thermal energy power plant.

Therefore the power plant is provided with the following main equipment:

3 oil fired boilers (2 operating, 1 spare)
$p_o = 8.6$ MPa
$t_o = 500$ °C
$G_o = 75$ t/h

2 back-pressure steam turbine-generator set
(2 operating)

$p_o$= 8.6 MPa
$t_o$= 500 °C
$G_o$= 40 t/h steam inlet

back-pressure:

$p_e$= 0.55 MPa
$G_e$= 30-40 t/h
Generator capacity: 5.5 MW

1 Condensation turbine-generator (stand-by)
$p_o$= 0.55 MPa
$t_o$= 250-300 °C
$G_o$= 15-25 t/h
Generator capacity: 3.5 MW

Cooling tower plant (stand-by)
Cooling water : 1400 $m^3/h$
$\Delta t$ : 20 °C
Make-up water: 100 $m^3/h$

Normally the power plant cooperates with the national grid. In this case condensation turbine-generator unit is on stand-by.

At the characteristic process steam consumption the power plant generates 7.93 MW power. Taking the power plants own consumption into consideration, 5.22 MW power should be purchased. So 11.5 MW is provided for the plant.

In case of grid failure missing power can be generated in the condensation turbine. In this mode of operation the extraction back-pressure turbine unit generates 10.72 MW. Condensation turbine unit generators 2.95 MW. Power for the plant in this case is also 11.5 MW.

Fuel oil consumption of power plant is:

| | |
|---|---|
| in normal operation | 9.54 t/h |
| in grid failure mode | 11.26 t/h |

### 4.1.3 Bayer process, low quality bauxite tube digestion

A power plant is provided to supply electric and thermal energy for the plant.

Conception of the power plant is as it follows:
Existing national electric energy grid is assumed on the plant site. Power supply is provided in cooperation with the national grid. In order to maintain the continuous operation of the plant, for the case if national network fails an independent stand-by power supply will be set up.

To maintain the demand of the plant the following thermal and power capacities are provided:

Thermal capacity:

steam 0.5 MPa pressure: $p_e$= 0.5 MPa
$t_e$= 170 °C
$G_e$= 73.3 t/h
max.90 t/h

About 60 % of the steam returns as condensate from the plant.

Power demand of the plant: 12.13 MW, max. 15 MW

Structure of energy demand enables to set up a coupled electric power and thermal energy power plant.

Therefore the power plant is provided with the following main equipment:

3 oil fired boilers (2 operating, 1 spare)

$p_o$= 8.6 MPa
$t_o$= 500 °C
$G_o$= 50 t/h

2 back-pressure steam turbine-generator set (2 operating)

$p_o$= 8.6 MPa
$t_o$= 500 °C
$G_o$= 50 t/h steam inlet

back-pressure:

$p_e$= 0.55 MPa
$G_e$= 40-50 t/h

Generator capacity: 6.5 MW

1 Condensation turbine-generator (stand-by)

$p_o$= 0.55 MPa
$t_o$= 250-300 °C
$G_o$= 10-14 t/h

Generator capacity: 2 MW

Cooling tower plant (stand-by)
Cooling water : 780 $m^3/h$
$\Delta t$ : 20 $^oC$
Make-up water: 55 $m^3/h$

Normally the power plant cooperates with the national grid. In this case condensation turbine-generator unit is on stand-by.

At the characteristic process steam consumption the power plant generates 10.4 MW power. Taking the power plants own consumption into consideration, 3.24 MW power should be purchased. So 12.13 MW is provided for the plant.

In case of grid failure missing power can be generated in the condensation turbine. In this mode of operation the extraction back-pressure turbine unit generates 12.14 MW. Condensation turbine unit generators 1.83 MW. Power for the plant in this case is also 12.13 MW.

Fuel oil consumption of power plant is:

| | |
|---|---|
| in normal operation | 6.41 t/h |
| in grid failure mode | 7.48 t/h |

### 4.1.4 Bayer process, high quality bauxite autoclave digestion

A power plant is provided to supply electric and thermal energy for the plant.

Conception of the power plant is as it follows:
Existing national electric energy grid is assumed on the plant site. Power supply is provided in cooperation with the national grid. In order to maintain the continuous operation of the plant, for the case if national network fails an independent stand-by power supply will be set up.

To maintain the demand of the plant the following thermal and power capacities are provided:

Thermal capacity:

steam 8.0 MPa pressure:

$p_n$= 8.0 MPa
$t_n$= 300 °C
$G_n$= 69.1 t/h
max.80 t/h

steam 0.5 MPa pressure:

$p_e$= 0.5 MPa
$t_e$= 170 °C
$G_e$= 31.8 t/h
max.38 t/h

About 70 % of the steam returns as condensate from the plant.

Power demand of the plant: 10 MW, max. 12 MW

Structure of energy demand enables to set up a coupled electric power and thermal energy power plant.

Therefore the power plant is provided with the following main equipment:

3 oil fired boilers (2 operating, 1 spare)

$p_o$= 8.6 MPa
$t_o$= 500 °C
$G_o$= 60 t/h

2 back-pressure steam turbine-generator set (2 operating)

$p_o$= 8.6 MPa
$t_o$= 500 °C
$G_o$= 30 t/h steam inlet

back-pressure:

$p_e$= 0.55 MPa
$G_e$= 20-30 t/h

Generator capacity: 5 MW

1 Condensation turbine-generator (stand-by)

$p_o$= 0.55 MPa
$t_o$= 250-300 °C
$G_o$= 15-25 t/h

Generator capacity: 3.5 MW

Cooling tower (stand-by):

Cooling water : 1400 $m^3/h$
$\Delta t$ : 20 °C
Make-up water: 1000 $m^3/h$

Normally the power plant cooperates with the national grid. In this case condensation turbine-generator unit is on stand-by.

At the characteristic process steam consumption the power plant generates 5.48 MW power. Taking the power plants own consumption into consideration, 5.8 MW power should be purchased. So 10 MW is provided for the plant.

In case of grid failure missing power can be generated in the condensation turbine. In this mode of operation the extraction back-pressure turbine unit generates 8.6 MW. Condensation turbine unit generators 3.25 MW. Power for the plant in this case is also 10 MW.

Fuel oil consumption of power plant is:

| | |
|---|---|
| in normal operation | 7.8 t/h |
| in grid failure mode | 9.7 t/h |

## 4.1.5. Bayer process, high quality bauxite tube digestion

A power plant is provided to supply electric and thermal energy for the plant.

Conception of the power plant is as it follows:
Existing national electric energy grid is assumed on the plant site. Power supply is provided in cooperation with the national grid. In order to maintain the continuous operation of the plant, for the case if national network fails an independent stand-by power supply will be set up.

To maintain the demand of the plant the following thermal and power capacities are provided:

Thermal capacity:

steam 0.5 MPa pressure:
$p_e$= 0.5 MPa
$t_e$= 170 °C
$G_e$= 53.5 t/h
max.65 t/h

About 60 % of the steam returns as condensate from the plant.

Power demand of the plant: 10.5 MW, max. 12.5 MW

Structure of energy demand enables to set up a coupled electric power and thermal energy power plant.

Therefore power plant is provided with the following main equipment:

3 oil fired boilers (2 operating, 1 spare)
$p_o$= 8.6 MPa
$t_o$= 500 °C
$G_o$= 50 t/h

2 back-pressure steam turbine-generator set (2 operating)
$p_o$= 8.6 MPa
$t_o$= 500 °C
$G_o$= 35 t/h steam inlet

back-pressure:
$p_e$= 0.55 MPa
$G_e$= 25-35 t/h

Generator capacity: 5 MW

1 Condensation turbine-generator (stand-by)

$p_o$= 0.55 MPa
$t_o$= 250-300 °C
$G_o$= 14-18 t/h

Generator capacity: 3 MW

Cooling tower plant (stand-by)

Cooling water : 1000 $m^3$/h
$\Delta t$ : 20 °C
Make-up water: 70 $m^3$/h

Normally the power plant cooperates with the national grid. In this case condensation turbine-generator unit is on stand-by.

At the characteristic process steam consumption the power plant generates 7.6 MW power. Taking the power plants own consumption into consideration, 4 MW power should be purchased. So 10.5 MW is provided for the plant.

In case of grid failure missing power can be generated in the condensation turbine. In this mode of operation the extraction back-pressure turbine unit generates 9.74 MW. Condensation turbine unit generators 2.26 MW. Power for the plant in this case is also 10.5 MW.

Fuel oil consumption of power plant is:

| | |
|---|---|
| in normal operation | 4.68 t/h |
| in grid failure mode | 6.00 t/h |

## 4.2 PROCESS CONTROL SYSTEM

A distributed control system is provided for the entire alumina plant. The control of the plant is normally automatic using different kinds of control loops (feedback, feed forward ratio etc.). Manual control and backup systems allow manual control of selected loops in case of central unit's failure. Primary measuring elements, field instrumentation and final control elements will be heavy duty industrial class devices.

The control system will be fully distributed and will consist controllers for process monitoring and control, and sequential controllers for motor and electrical system monitoring and control. The controllers will be electronic, receiving and outputting 4 to 20 mA dc analog signals, the sequential controllers will handle either 220 V ac or low voltage dc digital signals.

The control system is microprocessor based, using configurable controllers together with programmable logic controllers where it is necessary.

The system is provided with uninterruptible power supply units for continuous, automatic operation.

### 4.2.1. Control rooms

Control rooms will be located at the main points of plant units.
In case of sintering process Control Room No.1. will contain the instrumentation of the following plant units:

Bauxite Receiving and crushing (1)
Bauxite Storage (1a)
Limestone Receiving and crushing (2)
Limestone Storage (2a)
Lime Burning (3)
Lime Slaking (3a)
Soda Ash Receiving and Storage (4)

Control Room No.2. will contain the instrumentation of the following plant units:

Wet Grinding (5)
Adjustment Tanks (6)
H.P. Pump Station (6a)
Sintering (7)
Sinter Crushing (8)
Sinter Leaching (9)
Evaporation (19)

Control Room No.3. will be erected for the instruments of

Autoclave Desilication (10)
White Mud No.1.Settling (11)
Control Filtration (12)
Flash Cooling, Precipitation (13)
Deep Desilication (14)
Compressor Station (21)

Control Room No.4. will collect the instruments of

Carbonisation and Filtration (15)
Carbonised Hydrate Filtration (16)
Hydrate Storage (17)

Calcination, Alumina Storage (18)
Vacuum Station (20)
Oil Storage or Gas Receiving (28)

In case of the all Bayer process variants the control rooms will be located at the main points of plant units.

Control Room No.1. will contain the instrumentation of the following plant units:

Bauxite Receiving and crushing (1)
Bauxite Storage (1a)
Limestone receiving and crushing (2)
Limestone Storage (2a)
Lime Burning (3)
Lime Slaking (3a)
Soda Ash Receiving, Storage and Causticization (4)

Control Room No.2. will contain the instrumentation of the following plant units:

Wet Grinding (5)
Slurry storage and predesilication (6)
H.P. Pump Station (7)
Digestion and dilution (8)
Evaporation (17)
Salt removal (18)

Control Room No.3. will be erected for the instruments of

Red Mud settling and washing (9)
Additive preparation (10)
Mud causticization and red mud filtration (11)
Control filtration (12)

Control Room No.4. will collect the instruments of
- Heat interchange (13)
- Precipitation (14)
- Hydrate Filtration (15)
- Vacuum station (19)
- Compressor station (20)
- Calcination and alumina storage (16)
- Oil storage (21)

The control rooms will be air conditioned, with elevated floor to make cable routing easy. All the cables will be terminated using terminal panels. Equipment racks will be used for housing the auxiliary devices of control and measuring loops. The central cabinets of the distributed automation system will be placed here as well. The operational part of the control room will contain the operator-process interface elements such as color monitors, keyboards, floppy units, printers etc.

### 4.2.2. Telephone network

A telephon network system is considered with the following main features: 20 main lines and 300 extensions for plant service, 2 main lines for telefax and 3 main lines for telex system.

### 4.2.3. Fire signalling system

A fire signalling system will be provided with central units located into control rooms, smoke, heat, flame detectors and hand signalling units will be placed throughout the plant units at points where the probability of fire is real.

### 4.2.4. Loudspeaker network

A loudspeaker network will supplement the plant's communication system with central units located into the control rooms, and local loudspeakers at the technological points where the operators can receive messages from control rooms, or from where the operators can report to control room's personnel.

### 4.2.5. The origin of instruments

All the instrumentation will be supplied from Western instrument manufacturers. The devices choosen will have good references in alumina plant application.

### 4.2.6. Short description of system elements

#### 4.2.6.1. Field instrumentation

Flowmeters
For measuring liquors and slurries magnetic flow meters will be used with PTFE lining, switched dc magnetic field. Orifice plates will be used for measuring clean fluids such as steam, water, compressed air, etc.

Level
For measuring levels of different mediums, the following devices will be used: DP type level transmitters for clean fluids, nuclear radiation type transmitters for measuring solids or slurry levels.

Pressure

Normal pressure transmitters for pure fluids, diaphragm type transmitters with attached or remote seals for slurries.

Temperature

Thermocouples for higher, resistance thermometers (Pt 100) for lower temperatures. The fireing systems will be checked by infrared systems.

Position status

Angular rotation position transmitters will be used for checking rotating equipment. Limit position switches will check the position of moving parts.

Density

Nuclear density transmitters will measure the fluids density in pipelines.

Local gauges

Generally the transmitters are specified with local indicators, but at certain places temperature and pressure gauges will give information for the operators.

### 4.2.6.2. Final control elements

Control valves will be supplied for controlling the flow, pressure, or vacuum in pipeline or in equipment. The following valve types will be used throughout the plant: single seat, double seat globe body valves, angle body valves, butterfly valves, on/off control valves with tight shut-off, rotating eccentric plug valves. All the valve types will be equipped with pneumatic operation, electropneumatic positioner and manual operation.

At certain points (highly abrasive service, high dynamic loss etc.) instead of control valves, pump RPM regulation is considered to be very useful, because all the problems regarding control valve wear will be eliminated, the life expectancy of delivery will be more advantageous, and the power consumption of fluid delivery will be reduced.

#### 4.2.6.3. Cables, cable routing

Shielded type 1 mm$^2$ twisted pair, triad, twelve pair multiconductor cables will be used for transmitting signals from field to control room and vica versa. Cables will be provided with polyethylene insulation, the shield shall be copper-nylon for complete coverage. Overall jacket will be chrome vonyl. All the cables will have 0.8 mm$^2$ stranded copper drain wire.

Individual cables will be protected with galvanized steel conduits.Galvanized steel cable trays will be used for safety routing of group of cables. The trays will be fastened to the steel structures, to walls to other units. Solid covers will be provided for cable protection.

## 4.3 Electric energy supply

### 4.3.1. Sintering process

Alumina refining by sintering process requires process steam at pressure 0.5-1.6 MPa (5-16 bars), it is favourable to erect a power plant with extraction back-pressure turbine-generator(s) in cooperation with the national grid (see general description of the Power Plant, Chapter 4.1).

The characteristic electrical power demand of the plant is 23.5 MW. Taking into account an average power factor (cos φ ) of 0.92, this figure amounts to 25.5 MVA apparent power. At the characteristic power steam consumption the power plant generates 11.2 MW power. Taking the power plants own consumption into consideration, 14 MW power shoud be purchased.

Since can not be guaranteed a continuous and properly reliable power supply from the national grid at the plant site, for the national grid failure case a stand-by condensation turbine unit is provided in the power plant belonging to the alumina plant.

Electric network of the plant will be connected to the national grid through two 120/11 kV transformers and two independent 132 kV overhead lines.

In normal operation the power balance is:

| | |
|---|---|
| 2 back-pressure generators generate | 11.2 MW |
| self-consumption in the power plant | - 1.7 MW |
| remaining for the alumina plant | 9.5 MW |
| to be purchased from the national gri | 14.0 MW |
| alumina plant demand | 23.5 MW |

In case of a national grid failure the power balance:

| | |
|---|---|
| 2 back-pressure generators/generate | 18.2 MW |
| 1 condensation unit generates | 8.4 MW |
| for the power plant's consumption | - 3.1 MW |
| for the alumina plant | 23.5 MW |

Electric power distribution system

For receiving and distribution of the above mentioned electric power demand a 10 kV central switching station with a central room with permanent operating staff, and with a D.C and A.C auxiliary plant is provided.

The estimated quantity of the 10 kV cubicles of the central switching station is 70 pieces. Their short-circuit power will be 500 MVA. The busbar system will be doubled, devided into two sections each.

The 10 kV distribution system will be fed directly by the three generators and by the two 120/11 kV transformers. Between the transformer station and the 10 kV central distributor in order to limiting the short-circuit power of the transformers side a twin-reactor in both lines has been selected.

From the 10 kV central switching station 23 transformer stations and 5 h.v. motors will be fed directly. Among this 23 there are 2 transformer stations of 10/6.3 kV, the remainders are of 10/0,4 kV. A 10/6.3 kV and a 10/0.4 transformer stations with two tarnsformers each will be located at the power plant.

All transformer stations will be indoor and furnished with oilimmersed transformers, with an out of cubicles assembled 0.4 kV distributor system which will be devided into two sections with single busbar each. The 0.4 kV power factor correction capacitor equipment and the speed control equipment also will be located at the control rooms of the transformer stations.

The quantity of the r.p.m. controlled motors amounts to 70 units. The operation of the motors will be local and remote.

Power factor correction

A power factor correstion is provided on the 0.4 kV and on the middle voltage network. The 0.4 kV capacitors and their control equipment will be located into the 0.4 kV transformer stations the 10 kV capacitors outdoor at the 10 kV central switching station.

Lighting

For the illumination of the indoor areas will generally be used fluorescent, incandeseent and mercury vapor lamps.

For the illumination of the outdoor areas and traffic roads the sources of light will be of mercury vapor, sodium and halogen type with up to date fittings on steel posts where it will be necessary.

### Cabling and cable installation

All the power and control cables will be of plastic insulation and plastic sheeth type with copper counductors. The cabling generally will be overhead on steel constructions and cable racks.

### Shock protection

The shock protection on the electric network will be:

a) on the middle voltage system - earthing
b) on the A.C. low voltage system - neutral earthing
c) on the D.C. low voltage system - earthing

This study does not contain the followings:

a) the electrical equipment of the power plant
b) the 120/11 kV outdoor transformer stations transformers and the h.v. equipment
c) the 132 kV double overhead line.

## 4.3.2. Bayer process, low quality bauxite autoclave digestion

Alumina manufacturing by Bayer-process requires process steam at pressure 0.5 and 8 MPa (5-80 bars), it is favourable to erect a power plant with extraction back-pressure turbine-generator(s) in cooperation with the national grid (see general description of the Power Plant, Chapter 4.1).

The characteristic electric power demand of the plant is 11.5 MW. Taking into account an average power factor (cos φ) of 0.92, this figure amounts to 12.5 MVA apparent power. At the characteristic power steam consumption the power plant generates 7.93 MW power. Taking the power plants own consumption into consideration, 5.22 MW power shoud be purchased.

Since can not be guaranteed a continuous and properly reliable power supply from the national grid at the plant site, for the national grid failure case a stand-by condensation turbine unit is provided in the power plant belonging to the alumina plant.

Electric network of the plant will be connected to the national grid through two 120/11 kV transformers and two independent 132 kV overhead lines. The proposed rated power of the above transformers is 16 MW each.

In normal operation the power balance is:

| | | |
|---|---|---|
| 2 back-pressure generators generate | 7.93 | MW |
| self-consumption in the power plant | - 1.65 | MW |
| remaining for the alumina plant | 6.28 | MW |
| to be purchased from the national grid | 5.22 | MW |
| the alumina plant demand | 11.5 | MW |

In case of a national grid failure the power balance:

| | | |
|---|---|---|
| 2 back-pressure generators/generate | 10.72 | MW |
| 1 condensation unit generates | 2.95 | MW |
| for the power plant's consumption | - 2.18 | MW |
| remaining for the alumina plant | 11.50 | MW |

The electric power distribution system

For receiving and distribution of the above mentioned electric power demand a 10 kV central switching station with a central room with permanent operating staff, and with a D.C and A.C auxiliary plant is provided.

The estimated quantity of the 10 kV cubicles of the central switching station is 68 pieces. Their short-circuit power will be 500 MVA. The busbar system will be doubled, devided into two sections each.

The 10 kV distribution system will be fed directly by the three generators and by the two 120/11 kV transformers.

From the 10 kV central switching station 20 transformer stations and 5 h.v. motors will be fed directly. Among this 20 there are 1 transformer station of 10/6.3 kV, the remainders are of 10/0.4 kV. A 10/6.3 kV and a 10/0.4 transformer stations with two tarnsformers each will be located at the power plant.

All transformer stations will be indoor and furnished with oilimmersed transformers, with an out of cubicles assembled 0.4 kV distributor system which will be devided into two sections with single busbar each. The 0.4 kV power factor correction capacitor equipment and the speed control equipment also will be located at the control rooms of the transformer stations.

The quantity of the r.p.m. controlled motors amounts to 110 units.
The operation of the motors will be local and remote.
The power factor correction, the lighting, the cabling and the shock protection are the same as shortly described in the Chapter 4.3.1.

### 4.3.3. Bayer process, low quality bauxite tube digestion

Alumina manufacturing by Bayer-process from low quality bauxite using tube digestion requires process steam at pressure 0.5 MPa (5 bar), it is favourable to erect a power plant with back-pressure turbine-generator(s) in cooperation with the national grid (see the general description of the Power Plant, Chapter 4.1).

The characteristic electric power demand of the plant is 12.13 MW. Taking into account an average power factor (cos $\varphi$) of 0.92, this figure amounts to 13.2 MVA apparent power. At the characteristic power steam consumption the power plant generates 10.4 MW power. Taking the power plants own consumption into consideration, 3.24 MW power shoud be purchased.

Since can not be guaranteed a continuous and properly reliable power supply from the national grid at the plant site, for the national grid failure case a stand-by condensation turbine unit is provided in the power plant belonging to the alumina plant.

Electric network of the plant will be connected to the national grid through two 120/11 kV transformers and two independent 132 kV overhead lines. The proposed rated power of the transformers is 16 MW each.

In normal operation the power balance is:

| | |
|---|---|
| 2 back-pressure generators generate | 10.40 MW |
| self-consumption in the power plant | - 1.52 MW |
| remaining for the alumina plant | 8.88 MW |
| to be purchased from the national grid | 3.25 MW |
| the alumina plant demand | 12.13 MW |

In case of a national grid failure the power balance:

| | |
|---|---|
| 2 back-pressure generators/generate | 12.14 MW |
| 1 condensation unit generates | 1.83 MW |
| for the power plant's consumption | - 1.84 MW |
| remaining for the alumina plant | 12.13 MW |

The electric power distribution system, the power factor correction, the lighting, the cabling and the shock protection are the same as shortly described in the Capter 4.3.2.

### 4.3.4. Bayer process, high quality bauxite autoclave digestion

Alumina manufacturing by Bayer-process requires process steam at pressure 0.5 and 8 MPa (5-80 bars), it is favourable to erect a power plant with extraction back-pressure turbine-generator(s) in cooperation with the national grid (see general description of the Power Plant, Chapter 4.1).

The characteristic electric power demand of the plant is 10.0 MW. Taking into account an average power factor (cos φ) of 0.92, this figure amounts to 10.9 MVA apparent power. At the characteristic power steam consumption the power plant generates 5.48 MW power. Taking the power plants own consumption into consideration, 5.8 MW power shoud be purchased.

Since can not be guaranteed a continuous and properly reliable power supply from the national grid at the plant site, for the national grid failure case a stand-by condensation turbine unit is provided in the power plant belonging to the alumina plant.

Electric network of the plant will be connected to the national grid through two 120/11 kV transformers and two independent 132 kV overhead lines. The proposed rated power of the above transformers is 16 MW each.

In normal operation the power balance is:

| | | |
|---|---|---|
| 2 back-pressure generators generate | 5.48 | MW |
| self-consumption in the power plant | - 1.27 | MW |
| remaining for the alumina plant | 4.21 | MW |
| to be purchased from the national grid | 5.80 | MW |
| the alumina plant demand | 10.01 | MW |

In case of a national grid failure the power balance:

| | | |
|---|---|---|
| 2 back-pressure generators/generate | 8.60 | MW |
| 1 condensation unit generates | 3.25 | MW |
| for the power plant's consumption | - 1.85 | MW |
| remaining for the alumina plant | 10.00 | MW |

The electric power distribution system

For receiving and distribution of the above-mentioned electric power demand a 10 kV central switching station with a central room with permanent operating staff, and with a D.C and A.C auxiliary plant is provided.

The estimated quantity of the 10 kV cubicles of the central switching station is 66 pieces. Their short-circuit power will be 500 MVA. The busbar system will be doubled, devided into two sections each.

The 10 kV distribution system will be fed directly by the three geneators and by the two 120/11 kV transformers.

From the 10 kV central switching station 19 transformer stations and 5 h.v. motors will be fed directly.Among this 19 there are 1 transformer station of 10/6.3 kV, the remainders are of 10/0,4 kV. A 10/6.3 kV and a 10/0.4 transformer stations with two tarnsformers each will be located at the power plant.

All transformer stations will be indoor and furnished with oilimmersed transformers, with an out of cubicles assembled 0.4 kV distributor system which will be devided into two sections with single busbar each. The 0.4 kV power factor correction capacitor equipment and the speed control equipment also will be located at the control rooms of the transformer stations.

The quantity of the r.p.m. controlled motors amounts to 71 units. The operation of the motors will be local and remote.

The power factor correction, the lighting, the cabling and the shock protection are the same as shortly described in the Chapter 4.3.1.

### 4.3.5. Bayer process, high quality bauxite, tube digestion

Alumina manufacturing by Bayer-process from high quality bauxite using tube digestion requires process steam at pressure 0.5 MPa (5 bar), so it is favourable to erect a power plant with extraction back-pressure turbine generator(s) in cooperation with the national grid (see the general description of the Power Plant, Chapter 4.1).

The characteristic electric power demand of the plant is 10.5 MW. Taking into account an average power factor (cos $\varphi$) of 0.92, this figure amounts to 11.5 MVA apparent power. At the characteristic power steam consumption the power plant generates 7.6 MW power. Taking the power plants own consumption into consideration, 4 MW power shoud be purchased.

For the national grid failure case a stand-by condensation turbine unit is provided in the power plant belonging to the alumina plant.

Electric network of the plant will be connected to the national grid through two 120/11 kV transformers and two independent 132 kV overhead lines. The proposed rated power of the transformers is 10 MW each.

In normal operation the power balance is:

| | |
|---|---|
| 2 back-pressure generators generate | 7.6 MW |
| self-consumption in the power plant | -1.11 MW |
| remaining for the alumina plant | 6.5 MW |
| to be purchased from the national grid | 4.0 MW |
| the alumina plant demand | 10.5 MW |

In case of a national grid failure the power balance:

| | |
|---|---|
| 2 back-pressure generators/generate | 9.74 MW |
| 1 condensation unit generates | 2.26 MW |
| for the power plant's consumption | -1.5 MW |
| remaining for the alumina plant | 10.5 MW |

The electric power distribution system, the power factor correction, the lighting, the cabling and the shock protection are the same as shortly described in the Chapter 4.3.2.

# 5. PLANT LOCATION AND CIVIL ENGINEERING

# 5. PLANT LOCATION AND CIVIL ENGINEERING

## 5.1. Plant location

According to ARHP information the Alumina Plant will be located in Jajarm area, where the bauxite deposit was discovered.

The final plant site has not been determined yet, so infrastructural connections and transporting problems will not be detailed here. Consequently the plant inside the fence will be examined as a unit independent from the surroundings, but assumed at the same time that all the required connections are granted.

## 5.2. Civil engineering work

As generally it can be said that the plant, from civil engineering's point of view, consists of technological buildings, outdoor technological plant units and non technological buildings.

Technological buildings with high dynamical loads are of r.c.c. structure, while the others of steel structure. Central switch-house and central laboratory are of heat insulated r.c.c. structure.

In the outdoor plant units the platforms supporting smaller tanks and equipment are of steel structure, but supports under bigger tanks and the whole construction of alumina silos are of r.c.c. structure. The supporting columns and bridges for the yard pipe network are also made of steel structure.

Non technological buildings (change house, canteen management building) are of heat insulated r.c.c. structure.

## 5.3. Water supply

Industrial water supply of the Alumina Plant will be ensured by 3 systems:

- industrial and fire-fighting system
- recirculating cooling water system No 1 (alkali contaminated)
- recirculating cooling water system No 2 (not contaminated by alkali)

In the area of the water plant there can be found different buildings and civil structures as well as the machinery and equipment for water treatment and water recirculation, furthermore reservoirs and cooling equipment.

## 5.4. Red Mud Disposal

It is supposed that near the plant site, not further than 2-4 km, there is a valley suitable for disposal with the help of certain quer-dam system and terrace-art filling method.

In case of sintering process the red mud will be pumped from the plant through centrifugal pumps operating in series to the red mud disposal area. Pumping water returns gravitationally to the plant.

In case of the Bayer process variants the filtered red mud is delivered by diaphragm piston pumps to the disposal area, where it consolidates. Being well isolated from the soil its sodium content does not contaminate the environment and the mud can be piled up to a height of about 30 m.

# 6. ESTIMATED FIXED INVESTMENT COSTS OF THE SELECTED TECHNOLOGIES

# 6. ESTIMATED FIXED INVESTMENT COSTS OF THE SELECTED TECHNOLOGIES

The investment costs estimate covers the fixed assets of the alumina plant within the fence including the cost of the red mud disposal.

This is in accordance with the Minutes drawn up between the Iranian partner (ARMP) and Aluterv-FKI during Aluterv-FKI's visit in the Islamic Republic of Iran in November 1987. The relevant part of the Minutes reads as follows:

"In the evaluation, the technological and auxiliary plant units as well as the red mud disposal will be considered only within the fence."

On the basis of the above the fixed investment costs of infrastructure was not taken into consideration.

The fixed investment costs of the alumina plant for the selected technologies are divided into three major categories, namely

- Direct fixed investment costs of the selected technologies mechanical engineering,
- Direct fixed investment costs of the selected technologies civil engineering,
- Indirect fixed investment costs of the selected technologies.

Direct fixed investment costs of mechanical engineering work (Table 6-1) include the following:

- Costs of the production equipment including the technological piping, electrical, automation and instrumentation works.
- Costs of the equipment of auxiliary plant units (Limestone receiving and crushing, Limestone storage, Lime burning and slaking, Soda ash handling and causticization including the piping, electrical and instrumentation works).
- Costs of the service equipment (Vacuum and Compressor station, water supply system, Maintenance shop and Motor vehicles).
- Costs of mechanical engineering work of Power plant.
- Costs of spare parts.
- Costs of transportation.
- Costs of erection and mounting.

Direct fixed investment costs of civil engineering work (Table 6-2) include the following:

- Costs of site preparation and development.
- Costs of building work of technological units.
- Costs of outdoor work.
- Costs of fresh-water supply system.
- Costs of building work for non-technological units.
- Costs of power plant.
- Costs of red mud pond.

Indirect fixed investment costs of the selected technologies (Table 6-3) include the following:

- Costs of engineering work and know-how fee.
- Costs of construction and general management.
- Costs of site supervision.
- Costs of start up and complex trials.
- Costs of insurance.

Table 6-4 shows the summary of direct and indirect fixed investment costs.

The foreign exchange requirement is discussed in Chapter 14. Table 14-1 Shows a break up of the investment - costs for domestic and foreign supply.

Working capital requirements.

Working capital requirements of the selected technologies are given in Table 6-5/A-E.

Material stocks required for the continuous operation of the alumina plant were determined by considering the emergency stoks and the frequency of supply.

Table 6-1

### Estimated direct fixed investment costs of the selected technologies
### Mechanical engineering work
millions of Rls

| Item | Low quality bauxite | | | High quality bauxite | |
|---|---|---|---|---|---|
| | Sintering | Autoclave Digestion | Tube Digestion | Autoclave Digestion | Tube Digestion |
| Production equipment | 11380 | 7183 | 7545 | 6534 | 6734 |
| Auxiliary equipment | 626 | 688 | 688 | 688 | 688 |
| Service equipment | 1116 | 1003 | 1000 | 987 | 992 |
| Power plant | 2744 | 2159 | 1933 | 1895 | 1522 |
| Spare parts | 807 | 553 | 560 | 510 | 497 |
| Transportation | 604 | 446 | 448 | 409 | 397 |
| Erection and mounting | 3545 | 2588 | 2626 | 2382 | 2337 |
| Total direct costs, mechanical eng. works. | 20822 | 14620 | 14800 | 13405 | 13167 |

Table 6-2

### Estimated direct fixed investment costs of the selected technologies
Civil engineering work
millions of Rls

| Item | Low quality bauxite | | | High quality bauxite | |
|---|---|---|---|---|---|
| | Sintering | Autoclave Digestion | Tube Digestion | Autoclave Digestion | Tube Digestion |
| Site preparation and development | 360 | 360 | 360 | 358 | 358 |
| Technological buildings | 1785 | 1005 | 1020 | 952 | 969 |
| Outdoor work | 1585 | 1200 | 1290 | 1110 | 1196 |
| Fresh-water supply system | 335 | 335 | 335 | 335 | 335 |
| Non-technological building | 225 | 225 | 225 | 225 | 225 |
| Power plant | 687 | 586 | 525 | 515 | 423 |
| Red mud pond | 1080 | 1175 | 1175 | 790 | 790 |
| Total direct costs, civil eng. works | 6057 | 4886 | 4930 | 4285 | 4296 |

Table 6-3

Estimated indirect fixed investment costs of the selected technologies
millions of Rls

| Item | Low quality bauxite | | | High quality bauxite | |
|---|---|---|---|---|---|
| | Sintering | Autoclave Digestion | Tube Digestion | Autoclave Digestion | Tube Digestion |
| Engineering and know-how fee | 1970 | 1250 | 1300 | 1200 | 1250 |
| Construction management cost | 420 | 310 | 320 | 280 | 280 |
| General management cost | 140 | 100 | 100 | 90 | 90 |
| Cost of site supervision | 130 | 95 | 95 | 87 | 87 |
| Cost of start up, complex trials | 170 | 125 | 125 | 120 | 120 |
| Insurance | 130 | 95 | 95 | 87 | 87 |
| Total indirect costs | 2960 | 1975 | 2035 | 1864 | 1914 |

Table 6-4

Estimated direct and indirect fixed investment costs of the selected technologies
millions of Rls

| Item | Low quality bauxite | | | High quality bauxite | |
|---|---|---|---|---|---|
| | Sintering | Autoclave Digestion | Tube Digestion | Autoclave Digestion | Tube Digestion |
| Estimated direct costs mech. eng. works | 20822 | 14620 | 14800 | 13405 | 13167 |
| Estimated direct costs civil eng. works | 6057 | 4886 | 4930 | 4285 | 4296 |
| Estimated indirect costs | 2960 | 1975 | 2035 | 1864 | 1914 |
| Estimated direct and indirect costs | 29839 | 21481 | 21765 | 19554 | 19377 |
| Contingency ( 10 %) | 2984 | 2149 | 2177 | 1955 | 1938 |
| Total costs of the selected technologies | 32823 | 23630 | 23942 | 21509 | 21315 |

Table 6-5/A

Working Capital Requirement
Low quality bauxite sintering process million of RIs

| Year | Days | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| I.Current assets | | | | | |
| A.Account receivable | 15 | | | 82 | 164 |
| B.Inventory | | | | | |
| Raw material | | | | | |
| Bauxit | 10 | | | 39 | 72 |
| Sodium carbonate | 20 | | | 18 | 30 |
| Other materials | 10 | | | 13 | 32 |
| Spare parts 5% | | | | 917 | 917 |
| Work-in-progress | 35 | | | 336 | 583 |
| Finished products | 10 | | | 96 | 167 |
| C.Cash in hand | 5 | | | 27 | 55 |
| D.Current assets | | 0 | 0 | 1528 | 2020 |
| E.Increase in current assets | | 0 | 0 | 1528 | 492 |
| II.Current liabilities | | | | | |
| A.Accounts payable | 15 | 0 | 0 | -107 | -203 |
| III.Working capital | | | | | |
| A.Net working capital | | 0 | 0 | 1421 | 1817 |
| B.Increase in working capital | | 0 | 0 | 1421 | 396 |

Table 6-5/B

Working Capital Requirement

Low quality bauxite autoclave digestion million of Rls

| Year | Days | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| I.Current assets | | | | | |
| A.Account receivable | 15 | | | 82 | 164 |
| B.Inventory | | | | | |
| Raw material | | | | | |
| Bauxit | 10 | | | 49 | 89 |
| Sodium carbonate | 20 | | | 23 | 38 |
| Other materials | 10 | | | 13 | 31 |
| Spare parts 5% | | | | 637 | 637 |
| Work-in-progress | 35 | | | 344 | 599 |
| Finished products | 10 | | | 98 | 171 |
| C.Cash in hand | 5 | | | 27 | 55 |
| D.Current assets | | 0 | 0 | 1273 | 1784 |
| E.Increase in current assets | | 0 | 0 | 1273 | 511 |
| II.Current liabilities | | | | | |
| A.Accounts payable | 15 | 0 | 0 | -110 | -208 |
| III.Working capital | | | | | |
| A.Net working capital | | 0 | 0 | 1163 | 1576 |
| B.Increase in working capital | | 0 | 0 | 1163 | 413 |

Table 6-5/C

### Working Capital Requirement

Low quality bauxite tube digestion million of Rls

| Year | Days | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| I.Current assets | | | | | |
| A.Account receivable | 15 | | | 82 | 164 |
| B.Inventory | | | | | |
| Raw material | | | | | |
| Bauxit | 10 | | | 49 | 89 |
| Sodium carbonate | 20 | | | 22 | 36 |
| Other materials | 10 | | | 13 | 31 |
| Spare parts 5% | | | | 645 | 645 |
| Work-in-progress | 35 | | | 339 | 592 |
| Finished products | 10 | | | 97 | 169 |
| C.Cash in hand | 5 | | | 27 | 55 |
| D.Current assets | | 0 | 0 | 1274 | 1781 |
| E.Increase in current assets | | 0 | 0 | 1274 | 507 |
| II.Current liabilities | | | | | |
| A.Accounts payable | 15 | 0 | 0 | -109 | -206 |
| III.Working capital | | | | | |
| A.Net working capital | | 0 | 0 | 1165 | 1575 |
| B.Increase in working capital | | 0 | 0 | 1165 | 410 |

Table 6-5/D

Working Capital Requirement

High quality bauxite autoclave digestion million of Rls

| Year | Days | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| I.Current assets | | | | | |
| A.Account receivable | 15 | | | 82 | 164 |
| B.Inventory | | | | | |
| Raw material | | | | | |
| Bauxit | 10 | | | 34 | 62 |
| Sodium carbonate | 20 | | | 10 | 17 |
| Other materials | 10 | | | 9 | 22 |
| Spare parts 5% | | | | 584 | 584 |
| Work-in-progress | 35 | | | 255 | 437 |
| Finished products | 10 | | | 73 | 125 |
| C.Cash in hand | 5 | | | 27 | 55 |
| D.Current assets | | 0 | 0 | 1074 | 1466 |
| E.Increase in current assets | | 0 | 0 | 1074 | 392 |
| II.Current liabilities | | | | | |
| A.Accounts payable | 15 | 0 | 0 | -72 | -138 |
| III.Working capital | | | | | |
| A.Net working capital | | 0 | 0 | 1002 | 1328 |
| B.Increase in working capital | | 0 | 0 | 1002 | 326 |

Table 6-5/E

## Working Capital Requirement

High quality bauxite tube digestion million of Rls

| Year | Days | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| I.Current assets | | | | | |
| A.Account receivable | 15 | | | 82 | 164 |
| B.Inventory | | | | | |
| Raw material | | | | | |
| Bauxit | 10 | | | 34 | 61 |
| Sodium carbonate | 20 | | | 10 | 16 |
| Other materials | 10 | | | 9 | 22 |
| Spare parts 5% | | | | 574 | 574 |
| Work-in-progress | 35 | | | 251 | 432 |
| Finished products | 10 | | | 72 | 123 |
| C.Cash in hand | 5 | | | 27 | 55 |
| D.Current assets | | 0 | 0 | 1059 | 1447 |
| E.Increase in current assets | | 0 | 0 | 1059 | 388 |
| II.Current liabilities | | | | | |
| A.Accounts payable | 15 | 0 | 0 | -72 | -137 |
| III.Working capital | | | | | |
| A.Net working capital | | 0 | 0 | 987 | 1310 |
| B.Increase in working capital | | 0 | 0 | 987 | 323 |

# 7. MAJOR INPUT REQUIREMENTS

## 7. MAJOR INPUT REQUIREMENTS

### SPECIFIC CONSUMPTIONS (Comparative table)

| | Low quality bauxite | | | High quality bx | |
|---|---|---|---|---|---|
| | sinter | autocl. digest. | tube digest. | autocl. digest. | tube digest. |
| Bauxite (moisture 5%),t | | | | | |
| $Al_2O_3$ 44.2 %, $SiO_2$ 11.7 % | 2.90 | 3.588 | 3.588 | - | - |
| $Al_2O_3$ 52.4 %, $SiO_2$ 7.6 % | - | - | - | 2.487 | 2.480 |
| Limestone,t | | | | | |
| CaO 54.6 % | 1.46 | 2.093 | 2.036 | 0.983 | 0.959 |
| Sodium carbonate (soda ash),t | | | | | |
| $Na_2CO_3$ 99 % | 0.227 | 0.290 | 0.278 | 0.129 | 0.124 |
| Power,MWh | | | | | |
| for the process | 0.76 | 0.41 | 0.435 | 0.35 | 0.37 |
| for other requirements | 0.18 | 0.05 | 0.05 | 0.05 | 0.05 |
| total (excluded power plant) | 0.94 | 0.46 | 0.485 | 0.40 | 0.42 |
| self-generation (included power plant) | 0.45 | 0.32 | 0.42 | 0.22 | 0.30 |
| to be purchased | 0.56 | 0.21 | 0.13 | 0.23 | 0.16 |
| Fuel oil (39 GJ/ton net heating value),t | | | | | |
| for tube digestion | - | - | 0.123 | - | 0.117 |
| for power plant | 0.33 | 0.382 | 0.256 | 0.312 | 0.187 |
| for calcining | 0.08 | 0.090 | 0.090 | 0.090 | 0.090 |
| for lime burning | 0.06 | 0.086 | 0.084 | 0.040 | 0.039 |
| total | 0.47 | 0.558 | 0.553 | 0.442 | 0.433 |

SPECIFIC CONSUMPTIONS (Comparative table, cont.)

| | Low quality bauxite | | | High quality bx | |
|---|---|---|---|---|---|
| | sinter | autocl. digest. | tube digest. | autocl. digest. | tube digest. |
| Natural gas (30.76 MJ/m3),m3 | | | | | |
| for sintering | 767 | - | - | - | - |
| Make up water, m3 | 10 | 7 | 7 | 6 | 6 |
| Flocculant - natural,t | 0.003 | 0.004 | 0.004 | 0.002 | 0.002 |
| - synthetic,kg | - | 0.23 | 0.23 | 0.12 | 0.12 |
| Filter cloth, m2 | 0.45 | 0.40 | 0.40 | 0.30 | 0.30 |
| Grinding material,t | 0.005 | 0.005 | 0.005 | 0.004 | 0.004 |
| Total primary energy,GJ (Fuel oil + Natural gas) | 42.92 | 21.76 | 21.57 | 17.24 | 16.89 |

Table 7-1

## Specific and annual consumptions
## Low quality bauxite sintering process

| | Specific consumption (per 1 ton of alumina) | | Annual consumptions |
|---|---|---|---|
| Bauxite (5 % moisture) | | | |
| Al2O3 44.2 %, SiO2 11.7 % | 2.90 | t | 580,000 t |
| Limestone (moisture 5 %) | | | |
| CaO 54.6 % | 1.46 | t | 292,000 t |
| Sodium carbonate (soda ash) | | | |
| (as 99 % Na2CO3) | 0.227 | t | 45,400 t |
| Purchased power | 0.56 | MWh | 112,000 MWh |
| Fuel oil (39 GJ/t net heating value) | 0.47 | t | 94,000 t |
| Natural gas (30.76 MJ/m3) | 767 | m3 | 153,400 th.m3 |
| Make up water | 10 | m3 | 2,000,000 m3 |
| Flocculant - natural | 0.003 | t | 600 t |
| Filter cloth | 0.45 | m2 | 90,000 m2 |
| Grinding material | 0.005 | t | 1,000 t |

Table 7-2

## Specific and annual consumptions
## Low quality bauxite, Bayer process, autoclave digestion

| | Specific consumption (per 1 ton of alumina) | | Annual consumption | |
|---|---|---|---|---|
| Bauxite (5 % moisture) | | | | |
| $Al_2O_3$ 44.2 %, $SiO_2$ 11.7 % | 3.588 | t | 717,600 | t |
| Limestone (moisture 5 %) | | | | |
| CaO 54.6 % | 2.093 | t | 418,600 | t |
| Sodium carbonate (soda ash) | | | | |
| (as 99 % $Na_2CO_3$) | 0.290 | t | 58,000 | t |
| Purchased power | 0.210 | MWh | 42,000 | MWh |
| Fuel oil (39 GJ/t net heating value) | | | | |
| | 0.558 | t | 111,600 | t |
| Make up water | 7 | m3 | 1,400,000 | m3 |
| Flocculant - natural | 0.004 | t | 800 | t |
| - synthetic | 0.23 | kg | 46 | t |
| Filter cloth | 0.45 | m2 | 90,000 | m2 |
| Grinding material | 0.005 | t | 1,000 | t |

Table 7-3

## Specific and annual consumptions
## Low quality bauxite, Bayer process, tube digestion

| | Specific consumption (per 1 ton of alumina) | | Annual consumption | |
|---|---|---|---|---|
| Bauxite (5 % moisture) | | | | |
| $Al_2O_3$ 44.2 %, $SiO_2$ 11.7 % | 3.588 | t | 717,600 | t |
| Limestone (moisture 5 %) | | | | |
| CaO 54.6 % | 2.036 | t | [illegible]07,200 | t |
| Sodium carbonate (soda ash) | | | | |
| (as 99 % $Na_2CO_3$) | 0.278 | t | 55,600 | t |
| Purchased power | 0.130 | MWh | 26,000 | MWh |
| Fuel oil (39 GJ/t net heating value) | | | | |
| | 0.553 | t | 110,600 | t |
| Make up water | 7 | m3 | 1,400,000 | m3 |
| Flocculant - natural | 0.004 | t | 800 | t |
| - synthetic | 0.23 | kg | 46 | t |
| Filter cloth | 0.45 | m2 | 90,000 | m2 |
| Grinding material | 0.005 | t | 1,000 | t |

Table 7-4

### Specific and annual consumptions
### High quality bauxite, Bayer process, autoclave digestion

| | Specific consumption (per 1 ton of alumina) | | Annual consumption | |
|---|---|---|---|---|
| Bauxite (5 % moisture) | | | | |
| $Al_2O_3$ 52.4 %, $SiO_2$ 7.6 % | 2.487 | t | 497,400 | t |
| Limestone (moisture 5 %) | | | | |
| CaO 54.6 % | 0.983 | t | 196.600 | t |
| Sodium carbonate (soda ash) | | | | |
| (as 99 % $Na_2CO_3$) | 0.129 | t | 25,800 | t |
| Purchased power | 0.230 | MWh | 46,000 | MWh |
| Fuel oil (39 GJ/t net heating value) | | | | |
| | 0.442 | t | 88,400 | t |
| Make up water | 6 | m3 | 1,200,000 | m3 |
| Flocculant - natural | 0.002 | t | 400 | t |
| - synthetic | 0.12 | kg | 24 | t |
| Filter cloth | 0.30 | m2 | 60,000 | m2 |
| Grinding material | 0.004 | t | 800 | t |

Table 7-5

### Specific and annual consumptions
### High quality bauxite, Bayer process, tube digestion

| | Specific consumption (per 1 ton of alumina) | | Annual consumption | |
|---|---|---|---|---|
| Bauxite (5 % moisture) | | | | |
| $Al_2O_3$ 52.4 %, $SiO_2$ 7.6 % | 2.480 | t | 496,000 | t |
| Limestone (moisture 5 %) | | | | |
| CaO 54.6 % | 0.959 | t | 191,800 | t |
| Sodium carbonate (soda ash) | | | | |
| (as 99 % $Na_2CO_3$) | 0.124 | t | 24,800 | t |
| Purchased power | 0.160 | MWh | 32,000 | MWh |
| Fuel oil (39 GJ/t net heating value) | | | | |
| | 0.433 | t | 86,600 | t |
| Make up water | 6 | m3 | 1,200,000 | m3 |
| Flocculant - natural | 0.002 | t | 400 | t |
| - synthetic | 0.12 | kg | 24 | t |
| Filter cloth | 0.30 | m2 | 60,000 | m2 |
| Grinding material | 0.004 | t | 800 | t |

# 8. PRODUCTION COST ESTIMATE

## 8. PRODUCTION COST ESTIMATE

The material costs were computed from the specific consumptions given in Chapter 7. Transportation costs are included in the prices. (Tables 8-1/A-E)

The bauxite and sodium carbonate prices were calculated as follows:

Bauxite

| | | |
|---|---|---|
| Underground bauxite | 60 % | RLS 6330 |
| Overground bauxite | 40 % | RLS 1800 |
| Average | | RLS 4518 |

Sodium carbonate

| | |
|---|---|
| World market CIF price in US dollars | 150 |
| by official exchange rate 66 RLS/USD | 9900 |
| + 20 % | 1980 |
| Total price in RLS | 11880 |

Manpower requirements are shown in Tables 8-2/A-E

Other operating costs were developed from experiences gained in other plants and projects.
An interest rate of 10 percent/annum was assumed for credit.

The depreciation of the investment was calculated in Table 8-3.
The plant operating period was assumed for 20 years according to the financial evaluation. The production cost estimate is shown in Tables 8-4/A-E. The production cost in the 5th year is summarized as follows:

| Variants | Production cost in 5th year | |
|---|---|---|
| | million of Rls | Rls per t |
| Low quality bx.sintering process | 8422 | 42110 |
| Low quality bx.autoclave digestion | 8023 | 40115 |
| Low quality bx.tube digestion | 7964 | 39820 |
| High quality bx.autoclave dig. | 6206 | 31030 |
| High quality bx.tube digestion | 6114 | 30570 |

Raw materials Table 8-1/A

Low quality bauxite sintering process

| Item | Unit | Unit price<br>Rls/unit | 4-th year<br>Consumption | 100000<br>Consumption<br>(total) | tpy<br>Costs<br>million of Rls | 5-th year<br>Consumption | 200000<br>Consumption<br>(total) | tpy<br>Costs<br>million of Rls |
|---|---|---|---|---|---|---|---|---|
| Bauxit | t | 4518.00 | 3.190 | 319000 | 1441.2 | 2.900 | 580000 | 2620.4 |
| Sodium carbonate | t | 11880.00 | .272 | 27200 | 323.1 | .227 | 45400 | 539.4 |
| Limestone | t | 931.00 | 1.606 | 160600 | 149.5 | 1.460 | 292000 | 271.9 |
| Fuel oil | t | 1300.00 | .611 | 61100 | 79.4 | .470 | 94000 | 122.2 |
| Natural gas | Mill.m3 | 2060.00 | .997 | 99700 | 205.4 | .767 | 153400 | 316.0 |
| Purchased power | Mwh | 2600.00 | .728 | 72800 | 189.3 | .560 | 112000 | 291.2 |
| Other materials | | | | | 76.0 | | | 136.0 |
| Maintenance material | | | | | 150.0 | | | 635.0 |
| Total | | | | | 2614.0 | | | 4932.0 |

Raw materials Table 8-1/B

Low quality bauxite autoclave digestion

| Item | Unit | Unit price<br>Rls/unit | 4-th year<br>Consumption | 100000<br>Consumption<br>(total) | tpy<br>Costs<br>million of Rls | 5-th year<br>Consumption | 200000<br>Consumption<br>(total) | tpy<br>Costs<br>million of Rls |
|---|---|---|---|---|---|---|---|---|
| Bauxit | t | 4518.00 | 3.947 | 394700 | 1783.3 | 3.588 | 717600 | 3242.1 |
| Sodium carbonate | t | 11880.00 | .348 | 34800 | 413.4 | .290 | 58000 | 689.0 |
| Limestone | t | 931.00 | 2.302 | 230200 | 214.3 | 2.093 | 418600 | 389.7 |
| Fuel oil | t | 1300.00 | .725 | 72500 | 94.3 | .558 | 111600 | 145.1 |
| Natural gas | Mill.m3 | 2060.00 | .000 | 0 | .0 | .000 | 0 | .0 |
| Purchased power | Mwh | 2600.00 | .273 | 27300 | 71.0 | .210 | 42000 | 109.2 |
| Other materials | | | | | 31.0 | | | 148.0 |
| Maintenance material | | | | | 130.0 | | | 441.0 |
| Total | | | | | 2737.2 | | | 5164.2 |

Raw materials

Table 8-1/C

Low quality bauxite tube digestion

| Item | Unit | Unit price Rls/unit | 4-th year Consumption | 100000 tpy Consumption (total) | Costs million of Rls | 5-th year Consumption | 200000 tpy Consumption (total) | Costs million of Rls |
|---|---|---|---|---|---|---|---|---|
| Bauxit | t | 4518.00 | 3.947 | 394700 | 1783.3 | 3.588 | 717600 | 3242.1 |
| Sodium carbonate | t | 11860.00 | .334 | 33400 | 396.1 | .278 | 53600 | 660.5 |
| Limestone | t | 931.00 | 2.240 | 224000 | 208.5 | 2.036 | 407200 | 379.1 |
| Fuel oil | t | 1300.00 | .719 | 71900 | 93.5 | .553 | 110600 | 143.8 |
| Natural gas | Mill.m3 | 2050.00 | .000 | 0 | 0 | .000 | 0 | .0 |
| Purchased power | Mwh | 2600.00 | .169 | 16900 | 43.9 | .130 | 26000 | 67.6 |
| Other materials | | | | | 81.0 | | | 148.0 |
| Maintenance material | | | | | 100.0 | | | 447.0 |
| Total | | | | | 2707.0 | | | 5088.1 |

Raw materials

Table 8-1/D

High quality bauxite autoclave digestion

| Item | Unit | Unit price Rls/unit | 4-th year Consumption | 100000 tpy Consumption (total) | Costs million of Rls | 5-th year Consumption | 200000 tpy Consumption (total) | Costs million of Rls |
|---|---|---|---|---|---|---|---|---|
| Bauxit | t | 4518.00 | 2.736 | 273600 | 1236.1 | 2.487 | 497400 | 2247.3 |
| Sodium carbonate | t | 11930.00 | .155 | 15500 | 184.1 | .129 | 25600 | 306.5 |
| Limestone | t | 931.00 | 1.081 | 108100 | 100.6 | .983 | 196600 | 183.0 |
| Fuel oil | t | 1300.00 | .575 | 57500 | 74.8 | .442 | 88400 | 114.9 |
| Natural gas | Mill.m3 | 2050.00 | .000 | 0 | 0 | .000 | 0 | .0 |
| Purchased power | Mwh | 2600.00 | .300 | 30000 | 78 | .230 | 46000 | 119.6 |
| Other materials | | | | | 59.0 | | | 107.0 |
| Maintenance material | | | | | 100.0 | | | 404.0 |
| Total | | | | | 1832.7 | | | 3482.3 |

Raw materials

Table 8-1/E

High quality bauxite tube digestion

| Item | Unit | Unit price<br>Rls/unit | 4-th year<br>Consumption | 100000 tpy<br>Consumption<br>(total) | Costs<br>million of Rls | 5-th year<br>Consumption | 200000 tpy<br>Consumption<br>(total) | Costs<br>million of Rls |
|---|---|---|---|---|---|---|---|---|
| Bauxit | t | 4518.00 | 2.728 | 272800 | 1232.5 | 2.480 | 496000 | 2240.9 |
| Sodium carbonate | t | 11880.00 | .149 | 14900 | 177.0 | .124 | 24800 | 294.6 |
| Limestone | t | 931.00 | 1.055 | 105500 | 98.2 | .959 | 191800 | 178.6 |
| Fuel oil | t | 1300.00 | .563 | 56300 | 73.2 | .433 | 86600 | 112.6 |
| Natural gas | Mill.m3 | 2060.00 | .000 | 0 | 0 | .000 | 0 | .0 |
| Purchased power | Mwh | 2600.00 | .208 | 20800 | 54.1 | .160 | 32000 | 83.2 |
| Other materials | | | | | 59.0 | | | 107.0 |
| Maintenance material | | | | | 100.0 | | | 397.0 |
| Total | | | | | 1794.0 | | | 3413.9 |

Wages and Salaries

Table 8-2/A

Low quality bauxite sintering process

| Item | Average Wages<br>thRls/year | 4-th year<br>Head | <br>Costs | 5-th year<br>Head | <br>Costs |
|---|---|---|---|---|---|
| Management | 4780 | 7 | 33.5 | 7 | 33.5 |
| Engineers | 3470 | 45 | 156.2 | 45 | 156.2 |
| Clarks | 1215 | 55 | 66.8 | 55 | 66.8 |
| Foremen | 2090 | 90 | 188.1 | 90 | 188.1 |
| Skilled Workers | 1450 | 70 | 101.5 | 110 | 159.5 |
| Semi-skilled Workers | 910 | 200 | 182.0 | 320 | 291.2 |
| Plain | 725 | 120 | 87.0 | 200 | 145.0 |
| Total | | 587 | 815.0 | 827 | 1040.2 |

Wages and Salaries Table 8-2/B

Low quality bauxite autoclave digestion

| Item | Average Wages thRls/year | 4-th year | | 5-th year | |
|---|---|---|---|---|---|
| | | Head | Costs | Head | Costs |
| Management | 4780 | 7 | 33.5 | 7 | 33.5 |
| Engineers | 3470 | 43 | 149.2 | 43 | 149.2 |
| Clarks | 1215 | 53 | 64.4 | 53 | 64.4 |
| Foremen | 2090 | 86 | 179.7 | 86 | 179.7 |
| Skilled Workers | 1450 | 60 | 87.0 | 96 | 139.2 |
| Semi-skilled Workers | 910 | 180 | 163.8 | 296 | 269.4 |
| Plain | 725 | 120 | 87.0 | 200 | 145.0 |
| Total | | 549 | 764.6 | 781 | 980.4 |

Wages and Salaries Table 8-2/C

Low quality bauxite tube digestion

| Item | Average Wages thRls/year | 4-th year | | 5-th year | |
|---|---|---|---|---|---|
| | | Head | Costs | Head | Costs |
| Management | 4780 | 7 | 33.5 | 7 | 33.5 |
| Engineers | 3470 | 43 | 149.2 | 43 | 149.2 |
| Clarks | 1215 | 53 | 64.4 | 53 | 64.4 |
| Foremen | 2090 | 86 | 179.7 | 86 | 179.7 |
| Skilled Workers | 1450 | 60 | 87.0 | 100 | 145.0 |
| Semi-skilled Workers | 910 | 180 | 163.8 | 300 | 273 |
| Plain | 725 | 120 | 87.0 | 200 | 145.0 |
| Total | | 549 | 764.6 | 789 | 989.8 |

Wages and Salaries Table 8-2/D

High quality bauxite autoclave digestion

| Item | Average Wages thRls/year | 4-th year | | 5-th year | |
|---|---|---|---|---|---|
| | | Head | Costs | Head | Costs |
| Management | 4780 | 7 | 33.5 | 7 | 33.5 |
| Engineers | 3470 | 43 | 149.2 | 43 | 149.2 |
| Clarks | 1215 | 53 | 64.4 | 53 | 64.4 |
| Foremen | 2090 | 86 | 179.7 | 86 | 179.7 |
| Skilled Workers | 1450 | 60 | 87.0 | 96 | 139.2 |
| Semi-skilled Workers | 910 | 180 | 163.8 | 296 | 269.4 |
| Plain | 725 | 120 | 87.0 | 200 | 145.0 |
| Total | | 549 | 764.6 | 781 | 980.4 |

Wages and Salaries Table 8-2/E

High quality bauxite tube digestion

| Item | Average Wages thRls/year | 4-th year | | 5-th year | |
|---|---|---|---|---|---|
| | | Head | Costs | Head | Costs |
| Management | 4780 | 7 | 33.5 | 7 | 33.5 |
| Engineers | 3470 | 43 | 149.2 | 43 | 149.2 |
| Clarks | 1215 | 53 | 64.4 | 53 | 64.4 |
| Foremen | 2090 | 86 | 179.7 | 86 | 179.7 |
| Skilled Workers | 1450 | 60 | 87.0 | 100 | 145.0 |
| Semi-skilled Workers | 910 | 180 | 163.8 | 300 | 273 |
| Plain | 725 | 120 | 87.0 | 200 | 145.0 |
| Total | | 549 | 764.6 | 789 | 989.8 |

Table 8-3

## Depreciation Estimate

million of RLS

| Item | % per year | LQBSP Invest-ment | LQBSP Depre-ciation | LQBAD Invest-ment | LQBAD Depre-ciation | LQBTD Invest-ment | LQBTD Depre-ciation | HQBAD Invest-ment | HQBAD Depre-ciation | HQBTD Invest-ment | HQBTD Depre-ciation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Civil Works | 5 | 6663 | 333 | 5375 | 269 | 5423 | 271 | 4714 | 236 | 4726 | 236 |
| Chemical Ins. | 6 | 17880 | 1073 | 12092 | 725 | 12582 | 755 | 11197 | 672 | 11462 | 688 |
| Power Plant | 10 | 3472 | 347 | 2891 | 289 | 2589 | 259 | 2538 | 254 | 2038 | 204 |
| Other | 6 | 4808 | 288 | 3272 | 196 | 3348 | 201 | 3060 | 184 | 3089 | 185 |
| Total | | 32823 | 2041 | 23630 | 1479 | 23942 | 1486 | 21509 | 1346 | 21315 | 1313 |

Annual production-cost estimate

Table 8-4/A

Low quality bauxite sintering process

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production<br>programme tpy | | | | 100000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 |
| Raw materials | | | | | | | | | | | | | |
| Bauxite | | | | 1441 | 2621 | 2621 | 2621 | 2621 | 2621 | 2621 | 2621 | 2621 | 2621 |
| Sodium carbonate | | | | 323 | 539 | 539 | 539 | 539 | 539 | 539 | 539 | 539 | 539 |
| Limestone | | | | 150 | 272 | 272 | 272 | 272 | 272 | 272 | 272 | 272 | 272 |
| Fuel oil | | | | 79 | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 122 |
| Natural gas | | | | 205 | 316 | 316 | 316 | 316 | 316 | 316 | 316 | 316 | 316 |
| Purchased power | | | | 189 | 291 | 291 | 291 | 291 | 291 | 291 | 291 | 291 | 291 |
| Other materials | | | | 76 | 136 | 136 | 136 | 136 | 136 | 136 | 136 | 136 | 136 |
| Maintenance | | | | 150 | 635 | 635 | 635 | 635 | 635 | 635 | 635 | 635 | 635 |
| Material costs | 0 | 0 | 0 | 2614 | 4932 | 4932 | 4932 | 4932 | 4932 | 4932 | 4932 | 4932 | 4932 |
| Labour | | | | 559 | 784 | 784 | 784 | 784 | 784 | 784 | 784 | 784 | 784 |
| Direct costs | 0 | 0 | 0 | 3173 | 5716 | 5716 | 5716 | 5716 | 5716 | 5716 | 5716 | 5716 | 5716 |
| Salaries & wages | | | | 256 | 256 | 256 | 256 | 256 | 256 | 256 | 256 | 256 | 256 |
| Administration | | | | 38 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 |
| Insurance | | | | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| Operating cost | 0 | 0 | 0 | 3500 | 6081 | 6081 | 6081 | 6081 | 6081 | 6081 | 6081 | 6081 | 6081 |
| Bank charges | 0 | 0 | 0 | 0 | 300 | 285 | 270 | 255 | 240 | 225 | 210 | 195 | 180 |
| Depreciation | 0 | 0 | 0 | 1000 | 2041 | 2041 | 2041 | 2041 | 2041 | 2041 | 2041 | 2041 | 2041 |
| Production cost | 0 | 0 | 0 | 4500 | 8422 | 8407 | 8392 | 8377 | 8362 | 8347 | 8332 | 8317 | 8302 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production<br>programme tpy | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 4100000 |
| Raw materials | | | | | | | | | | | | |
| Bauxite | 2621 | 2621 | 2621 | 2621 | 2621 | 2621 | 2621 | 2621 | 2621 | 2621 | 2621 | 53861 |
| Sodium carbonate | 539 | 539 | 539 | 539 | 539 | 539 | 539 | 539 | 539 | 539 | 539 | 11103 |
| Limestone | 272 | 272 | 272 | 272 | 272 | 272 | 272 | 272 | 272 | 272 | 272 | 5590 |
| Fuel oil | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 122 | 2519 |
| Natural gas | 316 | 316 | 316 | 316 | 316 | 316 | 316 | 316 | 316 | 316 | 316 | 6526 |
| Purchased power | 291 | 291 | 291 | 291 | 291 | 291 | 291 | 291 | 291 | 291 | 291 | 6009 |
| Other materials | 136 | 136 | 136 | 136 | 136 | 136 | 136 | 136 | 136 | 136 | 136 | 2796 |
| Maintenance | 635 | 635 | 635 | 635 | 635 | 635 | 635 | 635 | 635 | 635 | 635 | 12850 |
| Material costs | 4932 | 4932 | 4932 | 4932 | 4932 | 4932 | 4932 | 4932 | 4932 | 4932 | 4932 | 101254 |
| Labour | 784 | 784 | 784 | 784 | 784 | 784 | 784 | 784 | 784 | 784 | 784 | 16239 |
| Direct costs | 5716 | 5716 | 5716 | 5716 | 5716 | 5716 | 5716 | 5716 | 5716 | 5716 | 5716 | 117493 |
| Salaries & wages | 256 | 256 | 256 | 256 | 256 | 256 | 256 | 256 | 256 | 256 | 256 | 5376 |
| Administration | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 1558 |
| Insurance | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 693 |
| Operating cost | 6081 | 6081 | 6081 | 6081 | 6081 | 6081 | 6081 | 6081 | 6081 | 6081 | 6081 | 125120 |
| Bank charges | 165 | 150 | 135 | 120 | 105 | 90 | 75 | 60 | 45 | 30 | 15 | 3150 |
| Depreciation | 2041 | 2041 | 2041 | 2041 | 2041 | 2041 | 2041 | 2041 | 2041 | 2041 | 2041 | 41820 |
| Production cost | 8287 | 8272 | 8257 | 8242 | 8227 | 8212 | 8197 | 8182 | 8167 | 8152 | 8137 | 170090 |

Annual production-cost estimate

Table 8-4/3

Low quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production programme tpy | | | | 100000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 |
| Raw materials | | | | | | | | | | | | | |
| Bauxite | | | | 1763 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 |
| Sodium carbonate | | | | 414 | 689 | 689 | 689 | 689 | 689 | 689 | 689 | 689 | 689 |
| Limestone | | | | 214 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 |
| Fuel oil | | | | 94 | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 145 |
| Natural gas | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Purchased power | | | | 71 | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 109 |
| Other materials | | | | 81 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 |
| Maintenance | | | | 100 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 |
| Material costs | 0 | 0 | 0 | 2757 | 5164 | 5164 | 5164 | 5164 | 5164 | 5164 | 5164 | 5164 | 5164 |
| Labour | | | | 518 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 |
| Direct costs | 0 | 0 | 0 | 3275 | 5897 | 5897 | 5897 | 5897 | 5897 | 5897 | 5897 | 5897 | 5897 |
| Salaries & wages | | | | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 |
| Administration | | | | 38 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 |
| Insurance | | | | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| Operating cost | 0 | 0 | 0 | 3584 | 6244 | 6244 | 6244 | 6244 | 6244 | 6244 | 6244 | 6244 | 6244 |
| Bank charges | 0 | 0 | 0 | 0 | 300 | 285 | 270 | 255 | 240 | 225 | 210 | 195 | 180 |
| Depreciation | 0 | 0 | 0 | 830 | 1479 | 1479 | 1479 | 1479 | 1479 | 1479 | 1479 | 1479 | 1479 |
| Production cost | 0 | 0 | 0 | 4414 | 8023 | 8008 | 7993 | 7978 | 7963 | 7948 | 7933 | 7918 | 7903 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production programme tpy | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 4100000 |
| Raw materials | | | | | | | | | | | | |
| Bauxite | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 66623 |
| Sodium carbonate | 689 | 689 | 689 | 689 | 689 | 689 | 689 | 689 | 689 | 689 | 689 | 14194 |
| Limestone | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 8014 |
| Fuel oil | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 2994 |
| Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Purchased power | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 109 | 2251 |
| Other materials | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 3041 |
| Maintenance | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 441 | 8920 |
| Material costs | 5164 | 5164 | 5164 | 5164 | 5164 | 5164 | 5164 | 5164 | 5164 | 5164 | 5164 | 106037 |
| Labour | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 15178 |
| Direct costs | 5897 | 5897 | 5897 | 5897 | 5897 | 5897 | 5897 | 5897 | 5897 | 5897 | 5897 | 121215 |
| Salaries & wages | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 5187 |
| Administration | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 1558 |
| Insurance | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 504 |
| Operating cost | 6244 | 6244 | 6244 | 6244 | 6244 | 6244 | 6244 | 6244 | 6244 | 6244 | 6244 | 128464 |
| Bank charges | 165 | 150 | 135 | 120 | 105 | 90 | 75 | 60 | 45 | 30 | 15 | 3150 |
| Depreciation | 1479 | 1479 | 1479 | 1479 | 1479 | 1479 | 1479 | 1479 | 1479 | 1479 | 1479 | 30410 |
| Production cost | 7888 | 7873 | 7858 | 7843 | 7828 | 7813 | 7798 | 7783 | 7768 | 7753 | 7738 | 162024 |

Annual production-cost estimate

Table 5-4.C

Low quality bauxite tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production programme tpy | | | | 100000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 |
| Raw materials | | | | | | | | | | | | | |
| Bauxite | | | | 1783 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 |
| Sodium carbonate | | | | 397 | 661 | 661 | 661 | 661 | 661 | 661 | 661 | 661 | 661 |
| Limestone | | | | 208 | 379 | 379 | 379 | 379 | 379 | 379 | 379 | 379 | 379 |
| Fuel oil | | | | 94 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 |
| Natural gas | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Purchased power | | | | 44 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 |
| Other materials | | | | 81 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 |
| Maintenance | | | | 100 | 447 | 447 | 447 | 447 | 447 | 447 | 447 | 447 | 447 |
| Material costs | 0 | 0 | 0 | 2707 | 5088 | 5088 | 5088 | 5088 | 5088 | 5088 | 5088 | 5088 | 5088 |
| Labour | | | | 518 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 |
| Direct costs | 0 | 0 | 0 | 3225 | 5831 | 5831 | 5831 | 5831 | 5831 | 5831 | 5831 | 5831 | 5831 |
| Salaries & wages | | | | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 |
| Administration | | | | 38 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 |
| Insurance | | | | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| Operating cost | 0 | 0 | 0 | 3534 | 6178 | 6178 | 6178 | 6178 | 6178 | 6178 | 6178 | 6178 | 6178 |
| Bank charges | 0 | 0 | 0 | 0 | 300 | 285 | 270 | 255 | 240 | 225 | 210 | 195 | 180 |
| Depreciation | 0 | 0 | 0 | 900 | 1486 | 1486 | 1486 | 1486 | 1486 | 1486 | 1486 | 1486 | 1486 |
| Production cost | 0 | 0 | 0 | 4434 | 7964 | 7949 | 7934 | 7919 | 7904 | 7889 | 7874 | 7859 | 7844 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production programme tpy | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 4100000 |
| Raw materials | | | | | | | | | | | | |
| Bauxite | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 3242 | 66623 |
| Sodium carbonate | 661 | 661 | 661 | 661 | 661 | 661 | 661 | 661 | 661 | 661 | 661 | 13617 |
| Limestone | 379 | 379 | 379 | 379 | 379 | 379 | 379 | 379 | 379 | 379 | 379 | 7788 |
| Fuel oil | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 2974 |
| Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Purchased power | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 1394 |
| Other materials | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 148 | 3041 |
| Maintenance | 447 | 447 | 447 | 447 | 447 | 447 | 447 | 447 | 447 | 447 | 447 | 9040 |
| Material costs | 5088 | 5088 | 5088 | 5088 | 5088 | 5088 | 5088 | 5088 | 5088 | 5088 | 5088 | 104467 |
| Labour | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 15378 |
| Direct costs | 5831 | 5831 | 5831 | 5831 | 5831 | 5831 | 5831 | 5831 | 5831 | 5831 | 5831 | 119845 |
| Salaries & wages | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 5187 |
| Administration | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 1558 |
| Insurance | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 504 |
| Operating cost | 6178 | 6178 | 6178 | 6178 | 6178 | 6178 | 6178 | 6178 | 6178 | 6178 | 6178 | 127094 |
| Bank charges | 165 | 150 | 135 | 120 | 105 | 90 | 75 | 60 | 45 | 30 | 15 | 3150 |
| Depreciation | 1486 | 1486 | 1486 | 1486 | 1486 | 1486 | 1486 | 1486 | 1486 | 1486 | 1486 | 30620 |
| Production cost | 7829 | 7814 | 7799 | 7784 | 7769 | 7754 | 7739 | 7724 | 7709 | 7694 | 7679 | 160864 |

Annual production-cost estimate

Table 8-8.3

High quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production programme tpy | | | | 100000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 |
| Raw materials | | | | | | | | | | | | | |
| Bauxite | | | | 1236 | 2247 | 2247 | 2247 | 2247 | 2247 | 2247 | 2247 | 2247 | 2247 |
| Sodium carbonate | | | | 184 | 306 | 306 | 306 | 306 | 306 | 306 | 306 | 306 | 306 |
| Limestone | | | | 101 | 183 | 183 | 183 | 183 | 183 | 183 | 183 | 183 | 183 |
| Fuel oil | | | | 75 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 |
| Natural gas | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Purchased power | | | | 78 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 |
| Other materials | | | | 59 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 |
| Maintenance | | | | 100 | 404 | 404 | 404 | 404 | 404 | 404 | 404 | 404 | 404 |
| Material costs | 0 | 0 | 0 | 1833 | 3482 | 3482 | 3482 | 3482 | 3482 | 3482 | 3482 | 3482 | 3482 |
| Labour | | | | 518 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 |
| Direct costs | 0 | 0 | 0 | 2351 | 4215 | 4215 | 4215 | 4215 | 4215 | 4215 | 4215 | 4215 | 4215 |
| Salaries & wages | | | | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 |
| Administration | | | | 38 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 |
| Insurance | | | | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| Operating cost | 0 | 0 | 0 | 2658 | 4560 | 4560 | 4560 | 4560 | 4560 | 4560 | 4560 | 4560 | 4560 |
| Bank charges | 0 | 0 | 0 | 0 | 300 | 285 | 270 | 255 | 240 | 225 | 210 | 195 | 180 |
| Depreciation | 0 | 0 | 0 | 808 | 1346 | 1346 | 1346 | 1346 | 1346 | 1346 | 1346 | 1346 | 1346 |
| Production cost | 0 | 0 | 0 | 3466 | 6206 | 6191 | 6176 | 6161 | 6146 | 6131 | 6116 | 6101 | 6086 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production programme tpy | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 4100000 |
| Raw materials | | | | | | | | | | | | |
| Bauxite | 2247 | 2247 | 2247 | 2247 | 2247 | 2247 | 2247 | 2247 | 2247 | 2247 | 2247 | 46176 |
| Sodium carbonate | 306 | 306 | 306 | 306 | 306 | 306 | 306 | 306 | 306 | 306 | 306 | 6304 |
| Limestone | 183 | 183 | 183 | 183 | 183 | 183 | 183 | 183 | 183 | 183 | 183 | 3761 |
| Fuel oil | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 115 | 2375 |
| Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Purchased power | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 2478 |
| Other materials | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 2199 |
| Maintenance | 404 | 404 | 404 | 404 | 404 | 404 | 404 | 404 | 404 | 404 | 404 | 8180 |
| Material costs | 3482 | 3482 | 3482 | 3482 | 3482 | 3482 | 3482 | 3482 | 3482 | 3482 | 3482 | 71473 |
| Labour | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 733 | 15178 |
| Direct costs | 4215 | 4215 | 4215 | 4215 | 4215 | 4215 | 4215 | 4215 | 4215 | 4215 | 4215 | 86651 |
| Salaries & wages | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 5187 |
| Administration | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 1558 |
| Insurance | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 462 |
| Operating cost | 4560 | 4560 | 4560 | 4560 | 4560 | 4560 | 4560 | 4560 | 4560 | 4560 | 4560 | 93858 |
| Bank charges | 165 | 150 | 135 | 120 | 105 | 90 | 75 | 60 | 45 | 30 | 15 | 3150 |
| Depreciation | 1346 | 1346 | 1346 | 1346 | 1346 | 1346 | 1346 | 1346 | 1346 | 1346 | 1346 | 27728 |
| Production cost | 6071 | 6056 | 6041 | 6026 | 6011 | 5996 | 5981 | 5966 | 5951 | 5936 | 5921 | 124736 |

Annual production-cost estimate

Table 8-4/E

High quality bauxite tube digestion

million of Fts

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production programme tpy | | | | 100000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 |
| Raw materials | | | | | | | | | | | | | |
| Bauxite | | | | 1232 | 2241 | 2241 | 2241 | 2241 | 2241 | 2241 | 2241 | 2241 | 2241 |
| Sodium carbonate | | | | 177 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 |
| Limestone | | | | 99 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 |
| Fuel oil | | | | 73 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 |
| Natural gas | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Purchased power | | | | 54 | 83 | 83 | 83 | 83 | 83 | 83 | 83 | 83 | 83 |
| Other materials | | | | 59 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 |
| Maintenance | | | | 100 | 397 | 397 | 397 | 397 | 397 | 397 | 397 | 397 | 397 |
| Material costs | 0 | 0 | 0 | 1794 | 3414 | 3414 | 3414 | 3414 | 3414 | 3414 | 3414 | 3414 | 3414 |
| Labour | | | | 518 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 |
| Direct costs | 0 | 0 | 0 | 2312 | 4157 | 4157 | 4157 | 4157 | 4157 | 4157 | 4157 | 4157 | 4157 |
| Salaries & wages | | | | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 |
| Administration | | | | 38 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 |
| Insurance | | | | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| Operating cost | 0 | 0 | 0 | 2618 | 4501 | 4501 | 4501 | 4501 | 4501 | 4501 | 4501 | 4501 | 4501 |
| Bank charges | 0 | 0 | 0 | 0 | 300 | 285 | 270 | 255 | 240 | 225 | 210 | 195 | 180 |
| Depreciation | 0 | 0 | 0 | 788 | 1313 | 1313 | 1313 | 1313 | 1313 | 1313 | 1313 | 1313 | 1313 |
| Production cost | 0 | 0 | 0 | 3406 | 6114 | 6099 | 6084 | 6069 | 6054 | 6039 | 6024 | 6009 | 5994 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Production programme tpy | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 200000 | 4100000 |
| Raw materials | | | | | | | | | | | | |
| Bauxite | 2241 | 2241 | 2241 | 2241 | 2241 | 2241 | 2241 | 2241 | 2241 | 2241 | 2241 | 46053 |
| Sodium carbonate | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 6077 |
| Limestone | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 178 | 3658 |
| Fuel oil | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 113 | 2333 |
| Natural gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Purchased power | 83 | 83 | 83 | 83 | 83 | 83 | 83 | 83 | 83 | 83 | 83 | 1714 |
| Other materials | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 2199 |
| Maintenance | 397 | 397 | 397 | 397 | 397 | 397 | 397 | 397 | 397 | 397 | 397 | 8040 |
| Material costs | 3414 | 3414 | 3414 | 3414 | 3414 | 3414 | 3414 | 3414 | 3414 | 3414 | 3414 | 70074 |
| Labour | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 743 | 15378 |
| Direct costs | 4157 | 4157 | 4157 | 4157 | 4157 | 4157 | 4157 | 4157 | 4157 | 4157 | 4157 | 85452 |
| Salaries & wages | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 247 | 5187 |
| Administration | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 1558 |
| Insurance | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 441 |
| Operating cost | 4501 | 4501 | 4501 | 4501 | 4501 | 4501 | 4501 | 4501 | 4501 | 4501 | 4501 | 92638 |
| Bank charges | 165 | 150 | 135 | 120 | 105 | 90 | 75 | 60 | 45 | 30 | 15 | 3150 |
| Depreciation | 1313 | 1313 | 1313 | 1313 | 1313 | 1313 | 1313 | 1313 | 1313 | 1313 | 1313 | 27048 |
| Production cost | 5979 | 5964 | 5949 | 5934 | 5919 | 5904 | 5889 | 5874 | 5859 | 5844 | 5829 | 122836 |

# 9. ESTIMATED ANNUAL SALES REVENUE

## 9. ESTIMATED ANNUAL SALES REVENUE

According to the information of ARMP the sales price of the alumina was determined in Rls. 20,000 per ton.

Sales revenues are

| | | |
|---|---|---|
| in the 4th year | 100,000 tpy | million of Rls. 2000 |
| in the 5th year | 200,000 tpy | million of Rls. 4000 |

from the starting.

# 10. ORGANIZATIONAL AND MANAGEMENT ASPECTS OF THE PROJECT

# 10. ORGANIZATIONAL AND MANAGEMENT ASPECTS OF THE PROJECT

The other chapters are dealing with technical and economic calculations, evaluations and logical conclusions, the finding of this chapter are more or less depending on the outside conditions such as the content of the contract to be settled later and the real financing possibilities available at that time.

For this reason the organization and management of the project can be defined only in the conceptual and preliminary engineering design period.

# 11. AN INDICATIVE TIME SCHEDULE FOR IMPLEMENTATION

## 11. AN INDICATIVE TIME SCHEDULE FOR IMPLEMENTATION

The most important activities necessary to establish the 200,000 mtpy capacity alumina plant are summarized in the implementation schedule Fig.11-1.

Most of the activities of the investment work are concluded by the deadline to start producing alumina between the 38th and 39th month.

To meet the above schedule the conceptual and preliminary engineering design work starts in the 4th month and will be completed within 12 months.

On the basis of the design activities the civil work can start in the 6th month with the site preparation and development.

The civil work will be completed in the 34th month. Delivery of machinery is planned to start in the 10th month and should be completed within 24 months.

The erection work can start in the 12th month with the machinary mounting. The erection work (mechanical, electrical and instrumentation) should be completed in the 36th month.

Filling up of the process can be started in the 30th month and completed in the 32nd month. After this the complex trials will be carried out between the 32nd and 36th month.

From the 36th month there will be the start up period of the alumina plant.

The 200,000 mtpy full capacity of the alumina plant can be achieved in the 44th month.

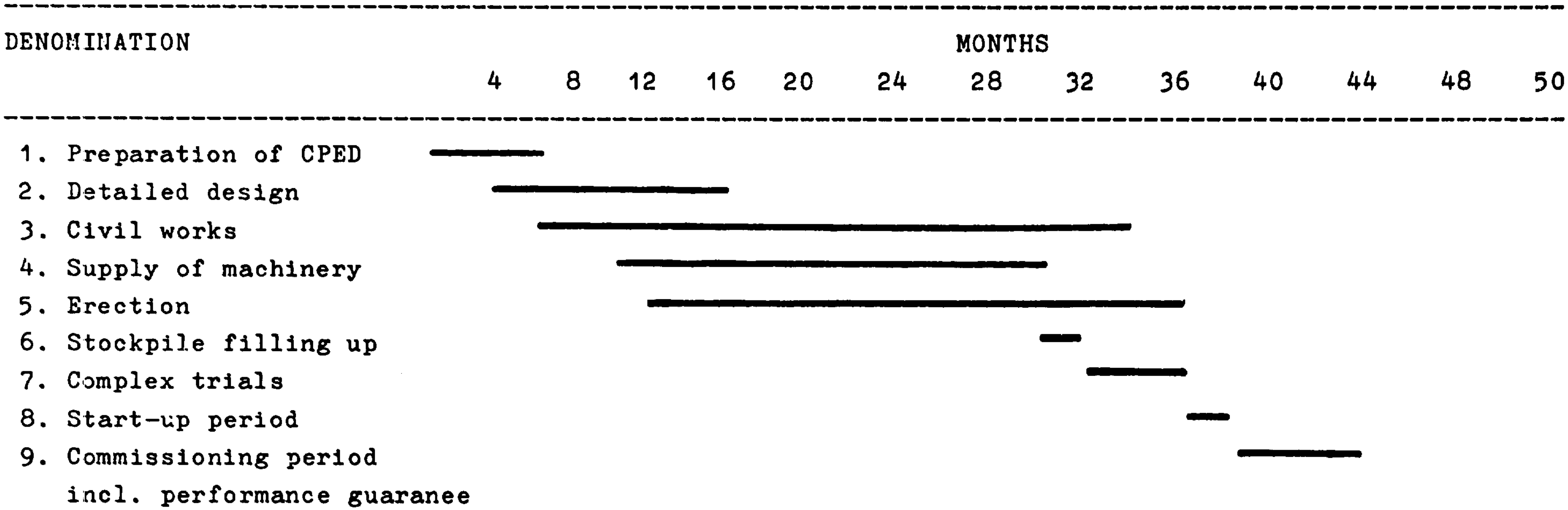
Within the 6 months of the commissioning period a test period of 30 days will also be completed for the performance guarantee.

The guarantees obtained should refer to the quantity and quality of the alumina produced as well as to the specific consumption of the most important basic and auxiliary materials.

The guarantee conditions should be fixed in the Engineering Contract.

Fig.11-1

## IMPLEMENTATION SCHEDULE



# 12. TOTAL INVESTMENT COST

## 12. TOTAL INVESTMENT COST

The investment period is planned for 4 years. The Tables 12-1/A-E show the phasing of Investment cost over the 4 years investment period. This schedule allows an alumina production of 100,000 t in the 4th year.

Cost of infrastructure was not planned because the location of the alumina plant has not been finalized, so there was no possibility to estimate the required infrastructural demand.

The total investment cost is the sum of the initial fixed investment cost and the working capital. Tables 12-2/A-E show the distribution of the total investment cost over 4 years.

## Phasing of Investment Cost

Table 12-1/A

Low quality bauxite sintering process

million of Rls

| Activities / Months | 0-6 | 7-12 | 13-18 | 19-24 | 25-30 | 31-36 | 37-42 | 43-48 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1.Civil Works | 500 | 850 | 1700 | 1700 | 850 | 457 | | | 6057 |
| 2.Machinery and Equipment | 1670 | 1670 | 5850 | 5850 | 1633 | | | | 16673 |
| 3.Erection and Mounting | | | 210 | 710 | 1250 | 1250 | 125 | | 3545 |
| 4.Transportation | | | 134 | 235 | 235 | | | | 604 |
| 5.Engineering and know-how fee | 250 | 500 | 500 | 250 | 200 | 140 | 85 | 45 | 1970 |
| 6.Construction management cost | 35 | 45 | 80 | 100 | 100 | 75 | 65 | 60 | 560 |
| 7.Site Supervision cost | | 9 | 17 | 26 | 26 | 26 | 17 | 9 | 130 |
| 8.Cost of start-up, complex trials | | | | | 43 | 43 | 43 | 41 | 170 |
| 9.Insurance | 12 | 12 | 43 | 43 | 20 | | | | 130 |
| 10.Contingency | 247 | 309 | 854 | 892 | 436 | 199 | 33 | 14 | 2984 |
| Total | 2714 | 3395 | 9388 | 9806 | 4793 | 2190 | 368 | 169 | 32823 |

Phasing of Investment Cost

Table 12-1/B

Low quality bauxite autoclave digestion

million of Rls

| Activities / Months | 0-6 | 7-12 | 13-18 | 19-24 | 25-30 | 31-36 | 37-42 | 43-48 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1.Civil Works | 400 | 684 | 1368 | 1368 | 684 | 382 | | | 4886 |
| 2.Machinery and Equipment | 1160 | 1160 | 4055 | 4055 | 1156 | | | | 11586 |
| 3.Erection and Mounting | | | 150 | 518 | 906 | 906 | 108 | | 2588 |
| 4.Transportation | | | 90 | 178 | 178 | | | | 446 |
| 5.Engineering and know-how fee | 156 | 312 | 312 | 156 | 125 | 94 | 63 | 32 | 1250 |
| 6.Construction management cost | 25 | 34 | 59 | 75 | 75 | 56 | 50 | 36 | 410 |
| 7.Site Supervision cost | | 6 | 12 | 20 | 20 | 20 | 11 | 6 | 95 |
| 8.Cost of start-up, complex trials | | | | | 31 | 31 | 31 | 32 | 125 |
| 9.Insurance | 10 | 10 | 32 | 32 | 11 | | | | 95 |
| 10.Contingency | 176 | 228 | 623 | 645 | 307 | 135 | 24 | 11 | 2149 |
| Total | 1927 | 2434 | 6701 | 7047 | 3493 | 1624 | 287 | 117 | 23630 |

Table 12-1/C

## Phasing of Investment Cost

Low quality bauxite tube digestion million of Rls

| Activities / Months | 0-6 | 7-12 | 13-18 | 19-24 | 25-30 | 31-36 | 37-42 | 43-48 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1.Civil Works | 404 | 690 | 1380 | 1380 | 690 | 386 | | | 4930 |
| 2.Machinery and Equipment | 1172 | 1172 | 4104 | 4104 | 1174 | | | | 11726 |
| 3.Erection and Mounting | | | 152 | 525 | 920 | 920 | 109 | | 2626 |
| 4.Transportation | | | 88 | 180 | 180 | | | | 448 |
| 5.Engineering and know-how fee | 163 | 326 | 326 | 163 | 130 | 97 | 65 | 30 | 1300 |
| 6.Construction management cost | 26 | 35 | 60 | 76 | 76 | 57 | 50 | 40 | 420 |
| 7.Site Supervision cost | | 6 | 12 | 20 | 20 | 20 | 11 | 6 | 95 |
| 8.Cost of start-up, complex trials | | | | | 31 | 31 | 31 | 32 | 125 |
| 9.Insurance | 10 | 10 | 32 | 32 | 11 | | | | 95 |
| 10.Contingency | 179 | 231 | 631 | 653 | 311 | 137 | 24 | 11 | 2177 |
| Total | 1954 | 2470 | 6785 | 7133 | 3543 | 1648 | 290 | 119 | 23942 |

Table 12-1/D

## Phasing of Investment Cost

High quality bauxite autoclave digestion — million of Rls

| Months<br>Activities | 0-6 | 7-12 | 13-18 | 19-24 | 25-30 | 31-36 | 37-42 | 43-48 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1.Civil Works | 351 | 600 | 1200 | 1200 | 600 | 334 | | | 4285 |
| 2.Machinery and Equipment | 1060 | 1060 | 3715 | 3715 | 1064 | | | | 10614 |
| 3.Erection and Mounting | | | 138 | 476 | 834 | 834 | 100 | | 2382 |
| 4.Transportation | | | 81 | 164 | 164 | | | | 409 |
| 5.Engineering and know how fee | 150 | 300 | 300 | 150 | 120 | 90 | 60 | 30 | 1200 |
| 6.Construction management cost | 23 | 31 | 53 | 67 | 67 | 50 | 45 | 34 | 370 |
| 7.Site Supervision cost | | 6 | 12 | 17 | 17 | 17 | 12 | 6 | 87 |
| 8.Cost of start-up, complex trials | | | | | 30 | 30 | 30 | 30 | 120 |
| 9.Insurance | 9 | 9 | 30 | 30 | 9 | | | | 87 |
| 10.Contingency | 160 | 207 | 567 | 587 | 280 | 123 | 21 | 10 | 1955 |
| Total | 1753 | 2213 | 6096 | 6406 | 3185 | 1478 | 268 | 110 | 21509 |

Table 12-1/E

## Phasing of Investment Cost

High quality bauxite tube digestion

million of Rls

| Months<br>Activities | 0-6 | 7-12 | 13-18 | 19-24 | 25-30 | 31-36 | 37-42 | 43-48 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1.Civil Works | 352 | 600 | 1200 | 1200 | 600 | 344 |  |  | 4296 |
| 2.Machinery and Equipment | 1043 | 1043 | 3652 | 3652 | 1043 |  |  |  | 10433 |
| 3.Erection and Mounting |  |  | 136 | 467 | 818 | 818 | 98 |  | 2337 |
| 4.Transportation |  |  | 77 | 160 | 160 |  |  |  | 397 |
| 5.Engineering and know-how fee | 156 | 312 | 312 | 156 | 125 | 94 | 63 | 32 | 1250 |
| 6.Construction management cost | 23 | 31 | 53 | 67 | 67 | 50 | 45 | 34 | 370 |
| 7.Site Supervision cost |  | 6 | 12 | 17 | 17 | 17 | 12 | 6 | 87 |
| 8.Cost of start-up, complex trials |  |  |  |  | 30 | 30 | 30 | 30 | 120 |
| 9.Insurance | 9 | 9 | 30 | 30 | 9 |  |  |  | 87 |
| 10.Contingency | 159 | 205 | 562 | 581 | 277 | 122 | 21 | 11 | 1938 |
| Total | 1742 | 2206 | 6034 | 6330 | 3146 | 1475 | 269 | 113 | 21315 |

Total investment cost

Table 12-2/A

Low quality bauxite sintering process

mill of Rls

| Year | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Fixed investment costs | 6109 | 19194 | 6983 | 537 | 32823 |
| Initial fixed investment costs | 6109 | 19194 | 6983 | 537 | 32823 |
| Replacement | 0 | 0 | 0 | 0 | 0 |
| Pre-production capital costs | 0 | 0 | 0 | 0 | 0 |
| Working capital increase | 0 | 0 | 1421 | 396 | 1817 |
| Total investment costs | 6109 | 19194 | 8404 | 933 | 34640 |

Total investment cost Table 12-2/B

Low quality bauxite autoclave digestion mill of Rls

| Year | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Fixed investment costs | 4361 | 13748 | 5117 | 404 | 23630 |
| Initial fixed investment costs | 4361 | 13748 | 5117 | 404 | 23630 |
| Replacement | 0 | 0 | 0 | 0 | 0 |
| Pre-production capital costs | 0 | 0 | 0 | 0 | 0 |
| Working capital increase | 0 | 0 | 1163 | 413 | 1576 |
| Total investment costs | 4361 | 13748 | 6280 | 817 | 25206 |

Total investment cost

Table 12-2/C

Low quality bauxite tube digestion

mill of Rls

| Year | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Fixed investment costs | 4424 | 13918 | 5191 | 409 | 23942 |
| Initial fixed investment costs | 4424 | 13918 | 5191 | 409 | 23942 |
| Replacement | 0 | 0 | 0 | 0 | 0 |
| Pre-production capital costs | 0 | 0 | 0 | 0 | 0 |
| Working capital increase | 0 | 0 | 1165 | 410 | 1575 |
| Total investment costs | 4424 | 13918 | 6356 | 819 | 25517 |

Total investment cost Table 12-2/D

High quality bauxite autoclave digestion mill of Rls

| Year | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Fixed investment costs | 3966 | 12502 | 4663 | 378 | 21509 |
| Initial fixed investment costs | 3966 | 12502 | 4663 | 378 | 21509 |
| Replacement | 0 | 0 | 0 | 0 | 0 |
| Pre-production capital costs | 0 | 0 | 0 | 0 | 0 |
| Working capital increase | 0 | 0 | 1002 | 326 | 1328 |
| Total investment costs | 3966 | 12502 | 5665 | 704 | 22837 |

## Total investment cost

Table 12-2/E

High quality bauxite tube digestion

mill of Rls

| Year | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Fixed investment costs | 3948 | 12364 | 4621 | 382 | 21315 |
| Initial fixed investment costs | 3948 | 12364 | 4621 | 382 | 21315 |
| Replacement | 0 | 0 | 0 | 0 | 0 |
| Pre-production capital costs | 0 | 0 | 0 | 0 | 0 |
| Working capital increase | 0 | 0 | 987 | 323 | 1310 |
| Total investment costs | 3948 | 12364 | 5608 | 705 | 22625 |

# 13. FINANCING DESCRIPTION

## 13. FINANCING DESCRIPTION

According to the information of ARMP financing of initial capital investment for the alumina plant is as follows:

- sources of budget for alumina plant are private and commercial banks which undertake to provide necessary funds to 60 %; credit ceiling is million of Rls 3000.
- Iranian Government shall provide up to 60 % or up to million of Rls 3000 of the projected total capital costs, in the form of Government subsidy.

Arrangement for payment installment shall be made one year after the implementation with a rate of interest of 10 %.

Financing of working capital can be carried out by Iranian Government.

The total capital cost, and the distribution based on the financing sources are projected in Tables 13-1/A-E.

Sources of initial funds Table 13-1/A

Low quality bauxite sintering process mill of Rls

| Year | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Equity capital | 5580 | 17531 | 7676 | 853 | 31640 |
| Preference capital | | | | | 0 |
| Loans | 529 | 1663 | 728 | 80 | 3000 |
| Supplier's credit | 0 | 0 | 0 | 0 | 0 |
| Current liabilitie | 0 | 0 | 107 | 96 | 203 |
| Subsidies | | | | | 0 |
| Total | 6109 | 19194 | 8511 | 1029 | 34843 |

Sources of initial funds Table 13-1/B

Low quality bauxite autoclave digestion mill of Rls

| Year | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Equity capital | 3842 | 12112 | 5533 | 719 | 22206 |
| Preference capital | | | | | 0 |
| Loans | 519 | 1636 | 747 | 98 | 3000 |
| Supplier's credit | 0 | 0 | 0 | 0 | 0 |
| Current liabilitie | 0 | 0 | 110 | 98 | 208 |
| Subsidies | | | | | 0 |
| Total | 4361 | 13748 | 6390 | 915 | 25414 |

Sources of initial funds Table 13-1/C

Low quality bauxite tube digestion mill of Rls

| Year | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Equity capital | 3904 | 12282 | 5609 | 722 | 22517 |
| Preference capital | | | | | 0 |
| Loans | 520 | 1636 | 747 | 97 | 3000 |
| Supplier's credit | 0 | 0 | 0 | 0 | 0 |
| Current liabilitie | 0 | 0 | 109 | 97 | 206 |
| Subsidies | | | | | 0 |
| Total | 4424 | 13918 | 6465 | 916 | 25723 |

Sources of initial funds Table 13-1/D

High quality bauxite autoclave digestion mill of Rls

| Year | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Equity capital | 3445 | 10860 | 4921 | 611 | 19837 |
| Preference capital | | | | | 0 |
| Loans | 521 | 1642 | 744 | 93 | 3000 |
| Supplier's credit | 0 | 0 | 0 | 0 | 0 |
| Current liabilitie | 0 | 0 | 72 | 66 | 138 |
| Subsidies | | | | | 0 |
| Total | 3966 | 12502 | 5737 | 770 | 22975 |

Sources of initial funds Table 13-1/E

High quality bauxite tube digestion mill of Rls

| Year | 1 | 2 | 3 | 4 | Total |
|---|---|---|---|---|---|
| Equity capital | 3425 | 10725 | 4864 | 611 | 19625 |
| Preference capital |  |  |  |  | 0 |
| Loans | 523 | 1639 | 744 | 94 | 3000 |
| Supplier's credit | 0 | 0 | 0 | 0 | 0 |
| Current liabilitie | 0 | 0 | 72 | 65 | 137 |
| Subsidies |  |  |  |  | 0 |
| Total | 3948 | 12364 | 5680 | 770 | 22762 |

# 14.ESTIMATED FOREIGN EXCHANGE REQUIREMENTS

## 14. ESTIMATED FOREIGN EXCHANGE REQUIREMENTS

Table 6-4 shows the summary of the estimated investment costs. In order to find out the foreign exchange requirements of the investment costs we have to go through all the basic investment details of the project to estimate the possibility and the scope of the domestic supply.

The estimation is based on the recommendation handed over to Aluterv-FKI (Calculation of local supply of materials, fabricated equipment and services: Unido project). In this recommendation only static equipment are suggested to be considered from domestic scope of supply. As boyler quality plates are also not available in the local markets, so all pressure vessels are considered as imported items.

In accordance with the recommendation the supply of dinamic elements like electromotors, pumps, gear boxes etc. are mostly considered as imported items. Only pumps of smaller capacity for water services are included in the scope of the domestic supply.

The domestic scope of supply for mechanical engineering includes:

- the equipment marked with an asterix in the equipment list,
- about 45 % of the piping work,
- it is presumed that some kind of manufacturing distribution can be achieved with the foreign suppliers and some part of the imported equipment can be manufactured in Iran on the basis of the detailed engineering drawings supplied by the foreign contractors, we presume that about 18 to 35 % of the production and auxialiary equipment can be supplied in this way,

- all painting and insulation work,
- about 80 % of the erection and mounting work
- about 80 % of the transportation costs.

In case of the civil engineering we presume that about 90 % of the civil engineering work can be covered from domestic supply. Only about 10 % (one part of the steel structure material and of the reinforcing steel) is envisaged as foreign supply.

In case of the indirect investment costs the following percentages are considered as domestic supply:

- about 50 % of the construction management costs,
- about 75-80 % of the general management costs,
- about 50 % of the site supervision costs,
- about 40 % of the costs of startup, complex trials,
- about 40 % of the insurance costs.

Table 14-1

## Estimated domestic and foreign supply
## million of Rls

| | Low quality bauxite | | | High quality bauxite | |
|---|---|---|---|---|---|
| | Sintering | Autoclave digestion | Tube digestion | Autoclave digestion | Tube digestion |
| Costs of estimated domestic supply | | | | | |
| Mechanical engineering | 5830 | 5130 | 5683 | 4660 | 5046 |
| Civil engineering | 5451 | 4397 | 4437 | 3857 | 3866 |
| Indirect costs | 515 | 401 | 406 | 365 | 365 |
| Total | 11796 | 9928 | 10526 | 8882 | 9277 |
| Contingency ( ~ 10%) | 1180 | 993 | 1053 | 888 | 928 |
| Total costs of domestic supply | 12976 | 10921 | 11579 | 9770 | 10205 |
| Costs of estimated foreign supply | | | | | |
| Mechanical engineering | 14992 | 9490 | 9117 | 8745 | 8121 |
| Civil engineering | 606 | 489 | 493 | 428 | 430 |
| Indirect costs | 2445 | 1574 | 1629 | 1499 | 1549 |
| Total | 18043 | 11553 | 11239 | 10672 | 10100 |
| Contigency ( ~10 %) | 1804 | 1156 | 1124 | 1067 | 1010 |
| Total costs of foreign supply | 19847 | 12709 | 12363 | 11739 | 11110 |
| Total fixed investment costs | 32823 | 23630 | 23942 | 21509 | 21315 |

# 15. FINANCIAL EVALUATION

# 15.FINANCIAL EVALUATION

## 15.1 Economic analysis

Economic analysis is shown in the following Tables:

15 - 1/A-E Total assets
15 - 2/A-E Net income statement
15 - 3/A-E Cash flow tables for financing planning
15 - 4/A-E Projected balance sheets
15 - 5/A-E Cash flow tables for the project
15 - 6/A-E Cash flow tables for equity

The economic analysis was prepared under the following conditions:

- The prices and other economic parameters (average saleries, depreciation, rate of interest, etc.) are corresponding to the 1988 year's level.

-The financing conditions were applied according to the data submitted in Chapter 13.

-Income taxes and dividens have not been calculated.

-The actual exchange rate in the Islamic Republic of Iran is 66 Rials per USD ( according to the information delivered by the ARMP experts). Although any change in this exchange rate is depending on the decision of the government, however, the international comparison ( Chapter 15.3 ) and the economic estimation of the Jajarm project confirm the reality of the use of a higher exchange rate to evaluate more exactly and adequately the erection of industrial facilities. Therefore, the economic analysis has been prepared with the following, different exchange rates:

Rls 66 per USD (official)
Rls 160 per USD
Rls 200 per USD
Rls 400 per USD

The results of these calculations are summarized below.

-The cummulated cash balance in the 20th year of production , billions of Rials ( See Tables 15-3 ) :

| Variant | Exchange rate Rls/USD | | | |
|---|---|---|---|---|
| | 66 | 160 | 200 | 400 |
| LQBSP | - 57.6 | 28.3 | 67.4 | 263.4 |
| LQBAD | - 58.4 | 23.2 | 60.4 | 247.0 |
| LQBTD | - 57.1 | 25.2 | 62.9 | 251.2 |
| HQBAD | - 23.3 | 69.4 | 111.5 | 322.0 |
| HQBTD | - 22.1 | 71.0 | 113.2 | 324.3 |

It can be seen from the data that the cash balance very sensitively reacts and steeply increases with the increasing of the exchange rate.

It can be recognised, furthermore, that the for low quality bauxites however, all three variants give results of the same order of magnitude for the low quality bauxite. The cumulated cash balance increases only with the improvement of the bauxite quality significantly.

The net income statement below shows the accumulated profits in billions of Rials:

| Variant | Exchange rate Rials/USD 66 | 160 | 200 | 400 |
|---|---|---|---|---|
| LQBSP | -88.1 | - 38.1 | -14.4 | +105.0 |
| LQBAD | -80.0 | - 21.8 | + 5.5 | +142.6 |
| LQBTD | -78.9 | - 19.0 | + 9.0 | +146.1 |
| HQBAD | -42.7 | + 28.4 | +61.4 | +226.0 |
| HQBTD | -40.8 | + 32.1 | +65.8 | +234.6 |

The sum of the accummulated profit at an exchange rate of 66 Rls/USD is negative for all variants.At an exchange rate of 160 Rls/USD the processing of high quality bauxite is already profitable.At an exchange rate of 200 Rls/USD the sinter process is the only non-profitable variant,while at the exchange rate of 400 Rls/USD all variants become very attractive.When looking from the point of view of the accumulated profit the advantages of the Bayer process become clearly visible in contrast to the sintering process. Both digestion variants are significanthy more profitable than the sintering process.Among the two digestion variants the tube digestion is more profitable.

- The ratio of the net profit to the equity after reaching the whole production capacity (in %):

| Variant | Exchange rate Rials/USD | | | |
|---|---|---|---|---|
| | 66 | 160 | 200 | 400 |
| LQBSP | - 14 | - 3 | - 7 | 4 |
| LQBAD | - 18 | - 3 | 0 | 8 |
| LQBTD | - 18 | - 3 | 1 | 8 |
| HQBAD | - 11 | 3 | 6 | 13 |
| HQBTD | - 11 | 4 | 7 | 14 |

The ratio of the net profit to the equity is at lower Rials/USD exchange rates quite modest at the processing of high quality bauxite as well, however, at the exchange rate of 400 Rials/USD - with the exception of the sinter process - attains values expected from big industrial facilities.

- The internal rate of return (causidering the total investment costs) is the following (in%):

| Variant | Exchange rate, Rials/USD | | | |
|---|---|---|---|---|
| | 66 | 160 | 200 | 400 |
| LQBSP | - | - | - | 6.01 |
| LQBAD | - | - | 1.92 | 9.87 |
| LQBTD | - | - | 2.33 | 10.28 |
| HQBAD | - | 5.45 | 8.49 | 14.49 |
| HQBTD | - | 6.05 | 9.11 | 15.22 |

The index of the internal rate of return is also highly increasing in the function of the exchange rate.

The values of the internal rate of return around or above 10 % can be evaluated as advantageous ones for the bigger industrial facilities. For comparison the calculations made with the exchange rate of 200 Rls/USD are also presented in Tables 15-7 through 15-12.

## 15.2 Foreign exchange savings

The alumina demand of the existing smelter (IRALCO) (which will be expanded) will be covered by imported material in want of a domestic one.The saving of the foreign exchange required for the import of this alumina should be taken into consideration when deciding the establishing of the projected alumina plant.

We are supposing that the total amount of the 200 kt alumina will substitute imported alumina or the excess can be exported, in such a way the Net Foreign exchange savings can be calculated as follows ( in million of USD ):

| Variant | LQBSP | LQBAD | LQBTD | HQBAD | LQBTD |
|---|---|---|---|---|---|
| Income: | | | | | |
| Substitution of importal alumina | 56.0 | 56.0 | 56.0 | 56.0 | 56.0 |
| Costs: | | | | | |
| Imported sodium carbonate | - 6.8 | - 8.7 | - 8.3 | - 3.9 | - 3.7 |
| Fuel oil which could be exported but consumed | - 9.3 | - 11.7 | - 11.6 | - 9.3 | - 9.1 |
| Net foreign Ex-change gain | 39.3 | 35.6 | 36.1 | 42.8 | 43.2 |
| Investment costs of foreign supplies for the alumina plant | 300.7 | 192.6 | 187.3 | 177.9 | 168.3 |
| Pay-back period ( year ) | 7.6 | 5.4 | 5.2 | 4.2 | 3.9 |

## 15.3 Break - even point

The Break - even point analysis was prepared for determining that alumina selling price at which the alumina refinery can just run without losses.

These balanced prices of alumina for irternal use are the following:

| Variant | Selling price at wich the project breaks even ( in Rls/ton's) | Exchange rate at the alumina price of 280 USD/t |
|---|---|---|
| LQBSP | 42110 | 150 |
| LQBAD | 40115 | 143 |
| LQBTD | 38470 | 137 |
| HQBAD | 31030 | 111 |
| HQBTD | 30570 | 109 |

According to the calculations the selling prices at alumina at wich the project breaks even are changing between 30570 and 42110 Rials/ton in the function of bauxite quality and selected technology.

These prices are corresponding at the alumina market price of 280 USD/t to exchange rates between 150 and 109 Rls per USD.

## 15.4 International comparison

The alumina produced in the frame of the Jajarm project will substitute imported material and occasionally one part of it can be exported for a shorter pericd.

Therefore it is reasonable to make an international comparison, evaluating the advantages and disadvantages in competition compared with alumina produced in other alumina refineries.

Based on the published technical literature the following data can be compared (in USD per tonne).

| Item | Alumina refinery | | | |
|---|---|---|---|---|
| | Pinjarra Australia | Friguia Guinea | Stade FRG | Korba India |
| Capacity, $10^3$ t/y | 2600 | 700 | 640 | 200 |
| Costs USD/t | | | | |
| Bauxite | 18.0 | 21.1 | 81.0 | 50.6 |
| Caustic Soda | 6.9 | 8.1 | 5.3 | 35.6 |
| Energy | 32.4 | 42.2 | 35.0 | 73.0 |
| Labour and other | 16.3 | 23.0 | 37.3 | 13.3 |
| Direct operating costs | 73.6 | 94.7 | 158.6 | 172.5 |

The main tendencies are evident from this table. No alumina plant can be competitive with the high capacity Australian refineries based on local bauxites. The processing of the very high grade African bauxite cost is also very attractive, however it is raised by the price of the imported energy. Both the bauxite and the energy should be imported to the European alumina plants, therefore significant surplus expenses. The higher costs being the consequence of the relatively low capacity and expensive materials and energy in India can not be compensated by the lower labour costs.

Supposing the processing of low grade bauxite the Jajarm project can be characterized by the following data at different exchange rates for comparison (Cost in USD/tonne of alumina):

| Exchange rate Rls/USD | 66 | 160 | 200 | 400 |
|---|---|---|---|---|
| Costs USD/t: | | | | |
| Bauxite | 246 | 101 | 81 | 40 |
| Caustic Soda | 50 | 50 | 50 | 50 |
| Energy | 16 | 7 | 5 | 3 |
| Labour and other | 130 | 54 | 43 | 22 |
| Direct operating cost | 442 | 212 | 179 | 115 |

The comparison confirms the supposition that the real exchange rate for the industrial facilities should be around Rls 200 per USD. Under this condition the Jajarm project can be compared with other (foreign) alumina plants and this comparison is acceptable for the Iranian project.

The Jajarm project has a significant advantage compared with other alumina refineries related to the energy costs. Though it is burdened by the costs due to the inevitably higher investment costs of newly erected facilities, it can be competitive, especially considering the general policy and aims of the government of the Islamic Republic of Iran.

Fig.15-1

CUMULATED CASH BALANCE

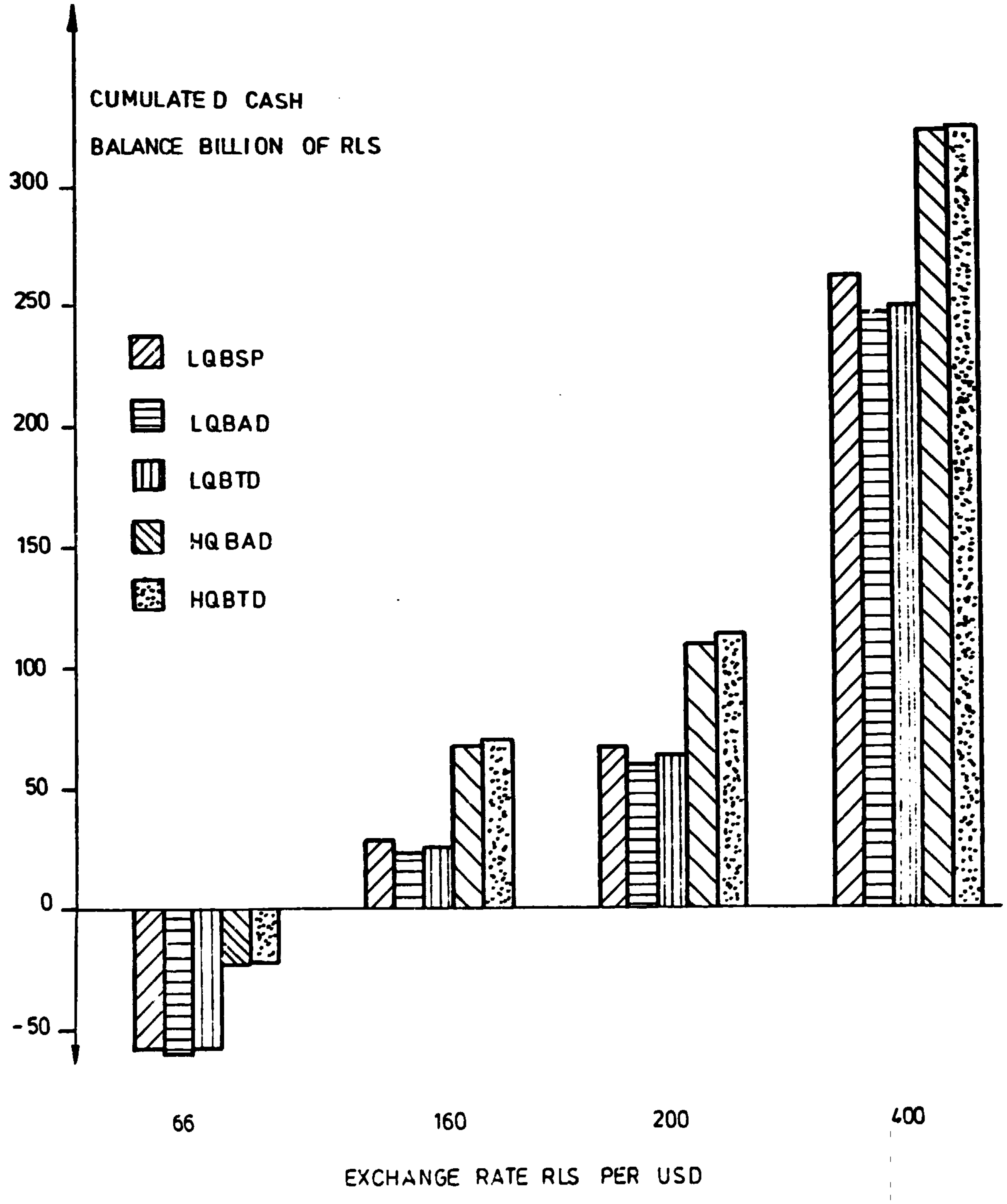
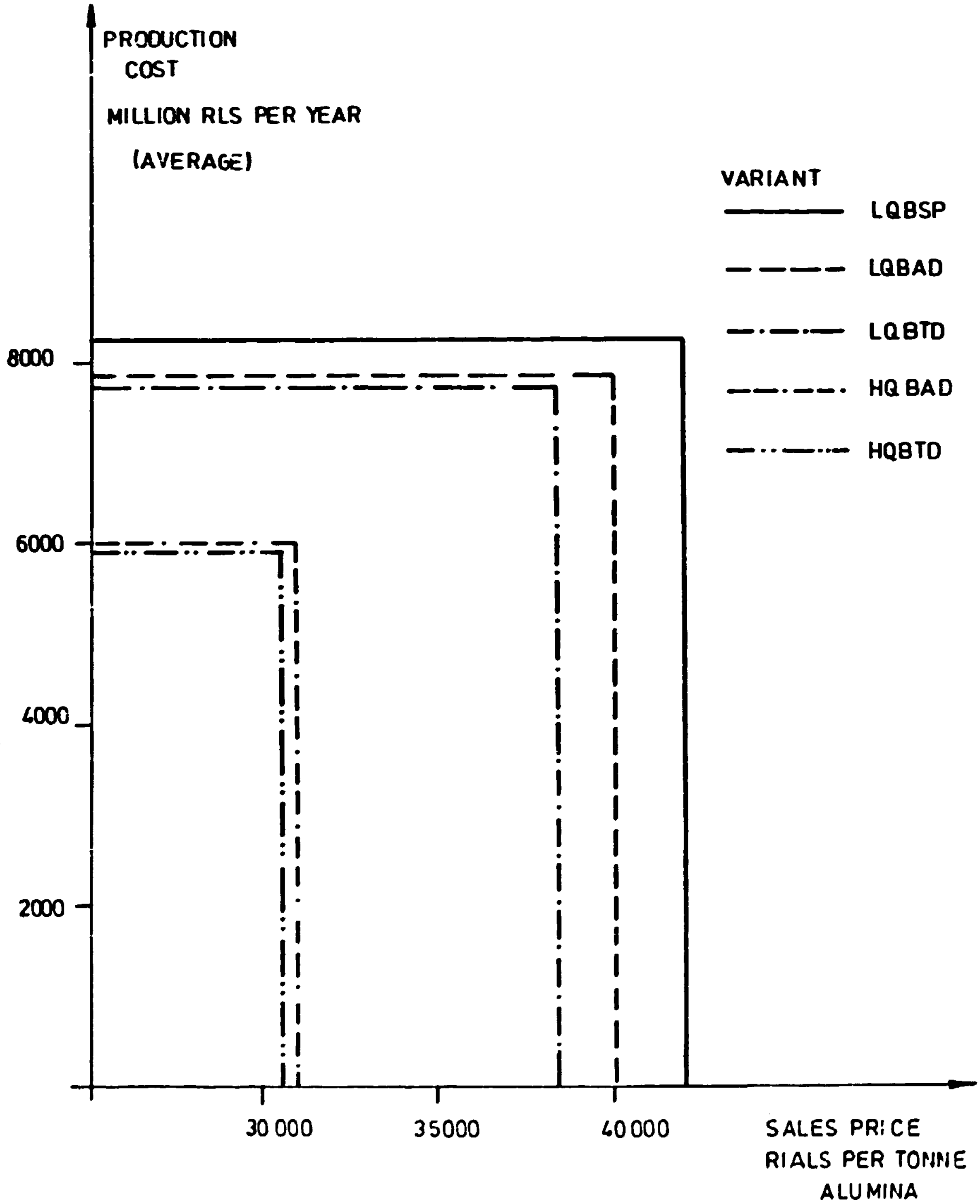


Fig.15-2

# BREAK-EVEN POINT AS SELLING PRICE



Total assets

Table 15-1/A

Low quality bauxite sintering process

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 6109 | 19194 | 6983 | 537 | 0 | 0 | 0 | 985 | 985 | 985 | 985 | 985 | 985 |
| a.Initial fixed investm. cost | 6109 | 19194 | 6983 | 537 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 985 | 985 | 985 | 985 | 985 | 985 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 1528 | 492 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total assets | 6109 | 19194 | 8511 | 1029 | 0 | 0 | 0 | 985 | 985 | 985 | 985 | 985 | 985 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 49568 |
| a.Initial fixed investm. cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32823 |
| b.Replacement | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 16745 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2020 |
| Total assets | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 51588 |

Total assets

Table 15-1/8

Low quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 4361 | 13748 | 5117 | 404 | 0 | 0 | 0 | 710 | 710 | 710 | 710 | 710 | 710 |
| a.Initial fixed investm. cost | 4361 | 13748 | 5117 | 404 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 710 | 710 | 710 | 710 | 710 | 710 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 1273 | 511 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total assets | 4361 | 13748 | 6390 | 915 | 0 | 0 | 0 | 710 | 710 | 710 | 710 | 710 | 710 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 35700 |
| a.Initial fixed investm. cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23630 |
| b.Replacement | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 12070 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1784 |
| Total assets | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 37484 |

Total assets

Table 15-1/C

Low quality bauxite tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 4424 | 13918 | 5191 | 409 | 0 | 0 | 0 | 718 | 718 | 718 | 718 | 718 | 718 |
| a.Initial fixed investm. cost | 4424 | 13918 | 5191 | 409 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 718 | 718 | 718 | 718 | 718 | 718 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 1274 | 507 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total assets | 4424 | 13918 | 6465 | 916 | 0 | 0 | 0 | 718 | 718 | 718 | 718 | 718 | 718 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 36148 |
| a.Initial fixed investm. cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23942 |
| b.Replacement | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 12206 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1781 |
| Total assets | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 37929 |

Total assets

Table 15-1/9

High quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 3966 | 12502 | 4663 | 378 | 0 | 0 | 0 | 645 | 645 | 645 | 645 | 645 | 645 |
| a.Initial fixed investm. cost | 3966 | 12502 | 4663 | 378 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 645 | 645 | 645 | 645 | 645 | 645 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 1074 | 392 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total assets | 3966 | 12502 | 5737 | 770 | 0 | 0 | 0 | 645 | 645 | 645 | 645 | 645 | 645 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 32474 |
| a.Initial fixed investm. cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21509 |
| b.Replacement | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 10965 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1466 |
| Total assets | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 33940 |

Total assets

Table 15-1/E

High quality bauxite tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 3948 | 12364 | 4621 | 382 | 0 | 0 | 0 | 640 | 640 | 640 | 640 | 640 | 640 |
| a.Initial fixed investm. cost | 3948 | 12364 | 4621 | 382 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 640 | 640 | 640 | 640 | 640 | 640 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 1059 | 388 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total assets | 3948 | 12364 | 5680 | 770 | 0 | 0 | 0 | 640 | 640 | 640 | 640 | 640 | 640 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 32195 |
| a.Initial fixed investm. cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21315 |
| b.Replacement | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 10880 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1447 |
| Total assets | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 33642 |

Net income statement

Table 15-2/A

Low quality bauxite sintering process

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 2.Production costs | 0 | 0 | 0 | -4500 | -8422 | -8407 | -8392 | -8377 | -8362 | -8347 | -8332 | -8317 | -8302 |
| 3.Taxable profit | 0 | 0 | 0 | -2500 | -4422 | -4407 | -4392 | -4377 | -4362 | -4347 | -4332 | -4317 | -4302 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 0 | 0 | 0 | -2500 | -4422 | -4407 | -4392 | -4377 | -4362 | -4347 | -4332 | -4317 | -4302 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 0 | 0 | 0 | -2500 | -4422 | -4407 | -4392 | -4377 | -4362 | -4347 | -4332 | -4317 | -4302 |
| 8.Accumulated profit | 0 | 0 | 0 | -2500 | -6922 | -11329 | -15721 | -20098 | -24460 | -28807 | -33139 | -37456 | -41758 |
| Ratios | | | | | | | | | | | | | |
| Taxable profit:Sales (%) | | | | -125 | -111 | -110 | -110 | -109 | -109 | -109 | -108 | -108 | -108 |
| Net profit:sales (%) | | | | -125 | -111 | -110 | -110 | -109 | -109 | -109 | -108 | -108 | -108 |
| Net profit:equity (%) | | | | -8 | -14 | -14 | -14 | -14 | -14 | -14 | -14 | -14 | -14 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 82000 |
| 2.Production costs | -8287 | -8272 | -8257 | -8242 | -8227 | -8212 | -8197 | -8182 | -8167 | -8152 | -8137 | -170090 |
| 3.Taxable profit | -4287 | -4272 | -4257 | -4242 | -4227 | -4212 | -4197 | -4182 | -4167 | -4152 | -4137 | -88090 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | -4287 | -4272 | -4257 | -4242 | -4227 | -4212 | -4197 | -4182 | -4167 | -4152 | -4137 | -88090 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | -4287 | -4272 | -4257 | -4242 | -4227 | -4212 | -4197 | -4182 | -4167 | -4152 | -4137 | -88090 |
| 8.Accumulated undistributed profit | -46045 | -50317 | -54574 | -58816 | -63043 | -67255 | -71452 | -75634 | -79801 | -83953 | -88090 | |
| Ratios | | | | | | | | | | | | |
| Taxable profit:Sales (%) | -107 | -107 | -106 | -106 | -106 | -105 | -105 | -105 | -104 | -104 | -103 | |
| Net profit:Sales (%) | -107 | -107 | -106 | -106 | -106 | -105 | -105 | -105 | -104 | -104 | -103 | |
| Net profit:Equity (%) | -14 | -14 | -13 | -13 | -13 | -13 | -13 | -13 | -13 | -13 | -13 | |

Net income statement

Table 15-2/8

Low quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 2.Production costs | 0 | 0 | 0 | -4414 | -8023 | -8008 | -7993 | -7978 | -7963 | -7948 | -7933 | -7918 | -7903 |
| 3.Taxable profit | 0 | 0 | 0 | -2414 | -4023 | -4008 | -3993 | -3978 | -3963 | -3948 | -3933 | -3918 | -3903 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 0 | 0 | 0 | -2414 | -4023 | -4008 | -3993 | -3978 | -3963 | -3948 | -3933 | -3918 | -3903 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 0 | 0 | 0 | -2414 | -4023 | -4008 | -3993 | -3978 | -3963 | -3948 | -3933 | -3918 | -3903 |
| 8.Accumulated profit | 0 | 0 | 0 | -2414 | -6437 | -10445 | -14438 | -18416 | -22379 | -26327 | -30260 | -34178 | -38081 |
| Ratios | | | | | | | | | | | | | |
| Taxable profit:Sales (%) | | | | -121 | -101 | -100 | -100 | -99 | -99 | -99 | -98 | -98 | -98 |
| Net profit:sales (%) | | | | -121 | -101 | -100 | -100 | -99 | -99 | -99 | -98 | -98 | -98 |
| Net profit:equity (%) | | | | -11 | -18 | -18 | -18 | -18 | -18 | -18 | -18 | -18 | -18 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 82000 |
| 2.Production costs | -7888 | -7873 | -7858 | -7543 | -7828 | -7813 | -7798 | -7783 | -7768 | -7753 | -7738 | -162024 |
| 3.Taxable profit | -3888 | -3873 | -3858 | -3843 | -3828 | -3813 | -3798 | -3783 | -3768 | -3753 | -3738 | -80024 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | -3888 | -3873 | -3858 | -3843 | -3828 | -3813 | -3798 | -3783 | -3768 | -3753 | -3738 | -80024 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | -3888 | -3873 | -3858 | -3843 | -3828 | -3813 | -3798 | -3783 | -3768 | -3753 | -3738 | -80024 |
| 8.Accumulated undistributed profit | -41969 | -45842 | -49700 | -53543 | -57371 | -61184 | -64982 | -68765 | -72533 | -76286 | -80024 | |
| Ratios | | | | | | | | | | | | |
| Taxable profit:Sales (%) | -97 | -97 | -96 | -96 | -96 | -95 | -95 | -95 | -94 | -94 | -93 | |
| Net profit:Sales (%) | -97 | -97 | -96 | -96 | -96 | -95 | -95 | -95 | -94 | -94 | -93 | |
| Net profit:Equity (%) | -18 | -17 | -17 | -17 | -17 | -17 | -17 | -17 | -17 | -17 | -17 | |

Net income statement

Table 15-2/C

Low quality bauxite tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 2.Production costs | 0 | 0 | 0 | -4434 | -7964 | -7949 | -7934 | -7919 | -7904 | -7889 | -7874 | -7859 | -7844 |
| 3.Taxable profit | 0 | 0 | 0 | -2434 | -3964 | -3949 | -3934 | -3919 | -3904 | -3889 | -3874 | -3859 | -3844 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 0 | 0 | 0 | -2434 | -3964 | -3949 | -3934 | -3919 | -3904 | -3889 | -3874 | -3859 | -3844 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 0 | 0 | 0 | -2434 | -3964 | -3949 | -3934 | -3919 | -3904 | -3889 | -3874 | -3859 | -3844 |
| 8.Accumulated profit | 0 | 0 | 0 | -2434 | -6398 | -10347 | -14281 | -18200 | -22104 | -25993 | -29867 | -33726 | -37570 |
| Ratios | | | | | | | | | | | | | |
| Taxable profit:Sales (%) | | | | -122 | -99 | -99 | -98 | -98 | -98 | -97 | -97 | -96 | -96 |
| Net profit:sales (%) | | | | -122 | -99 | -99 | -98 | -98 | -98 | -97 | -97 | -96 | -96 |
| Net profit:equity (%) | | | | -11 | -18 | -19 | -17 | -17 | -17 | -17 | -17 | -17 | -17 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 82000 |
| 2.Production costs | -7829 | -7814 | -7799 | -7784 | -7769 | -7754 | -7739 | -7724 | -7709 | -7694 | -7679 | -160864 |
| 3.Taxable profit | -3829 | -3814 | -3799 | -3784 | -3769 | -3754 | -3739 | -3724 | -3709 | -3694 | -3679 | -78864 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | -3829 | -3814 | -3799 | -3784 | -3769 | -3754 | -3739 | -3724 | -3709 | -3694 | -3679 | -78864 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | -3829 | -3814 | -3799 | -3784 | -3769 | -3754 | -3739 | -3724 | -3709 | -3694 | -3679 | -78864 |
| 8.Accumulated undistributed profit | -41399 | -45213 | -49012 | -52796 | -56565 | -60319 | -64058 | -67782 | -71491 | -75185 | -78864 | |
| Ratios | | | | | | | | | | | | |
| Taxable profit:Sales (%) | -96 | -95 | -95 | -95 | -94 | -94 | -93 | -93 | -93 | -92 | -92 | |
| Net profit:Sales (%) | -96 | -95 | -95 | -95 | -94 | -94 | -93 | -93 | -93 | -92 | -92 | |
| Net profit:Equity (%) | -17 | -17 | -17 | -17 | -17 | -17 | -17 | -17 | -16 | -16 | -16 | |

Net income statement

Table 15-2/3

High quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 2.Production costs | 0 | 0 | 0 | -3466 | -6206 | -6191 | -6176 | -6161 | -6146 | -6131 | -6116 | -6101 | -6086 |
| 3.Taxable profit | 0 | 0 | 0 | -1466 | -2206 | -2191 | -2176 | -2161 | -2146 | -2131 | -2116 | -2101 | -2086 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 0 | 0 | 0 | -1466 | -2206 | -2191 | -2176 | -2161 | -2146 | -2131 | -2116 | -2101 | -2086 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 0 | 0 | 0 | -1466 | -2206 | -2191 | -2175 | -2161 | -2146 | -2131 | -2116 | -2101 | -2086 |
| 8.Accumulated profit | 0 | 0 | 0 | -1466 | -3672 | -5863 | -8039 | -10200 | -12346 | -14477 | -16593 | -18694 | -20780 |
| Ratios | | | | | | | | | | | | | |
| Taxable profit:Sales (%) | | | | -73 | -55 | -55 | -54 | -54 | -54 | -53 | -53 | -53 | -52 |
| Net profit:sales (%) | | | | -73 | -55 | -55 | -54 | -54 | -54 | -53 | -53 | -53 | -52 |
| Net profit:equity (%) | | | | -7 | -11 | -11 | -11 | -11 | -11 | -11 | -11 | -11 | -11 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 82000 |
| 2.Production costs | -6071 | -6056 | -6041 | -6026 | -6011 | -5996 | -5981 | -5966 | -5951 | -5936 | -5921 | -124736 |
| 3.Taxable profit | -2071 | -2056 | -2041 | -2026 | -2011 | -1996 | -1981 | -1966 | -1951 | -1936 | -1921 | -42736 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | -2071 | -2056 | -2041 | -2026 | -2011 | -1996 | -1981 | -1966 | -1951 | -1936 | -1921 | -42736 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | -2071 | -2056 | -2041 | -2026 | -2011 | -1996 | -1981 | -1966 | -1951 | -1936 | -1921 | -42736 |
| 8.Accumulated undistributed profit | -22851 | -24907 | -26948 | -28974 | -30985 | -32981 | -34962 | -36928 | -38879 | -40815 | -42736 | |
| Ratios | | | | | | | | | | | | |
| Taxable profit:Sales (%) | -52 | -51 | -51 | -51 | -50 | -50 | -50 | -49 | -49 | -48 | -48 | |
| Net profit:Sales (%) | -52 | -51 | -51 | -51 | -50 | -50 | -50 | -49 | -49 | -48 | -48 | |
| Net profit:Equity (%) | -10 | -10 | -10 | -10 | -10 | -10 | -10 | -10 | -10 | -10 | -10 | |

Net income statement

Table 15-2/E

High quality bauxite tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 2.Production costs | 0 | 0 | 0 | -3406 | -6114 | -6099 | -6084 | -6069 | -6054 | -6039 | -6024 | -6009 | -5994 |
| 3.Taxable profit | 0 | 0 | 0 | -1406 | -2114 | -2099 | -2084 | -2069 | -2054 | -2039 | -2024 | -2009 | -1994 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 0 | 0 | 0 | -1406 | -2114 | -2099 | -2084 | -2069 | -2054 | -2039 | -2024 | -2009 | -1994 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 0 | 0 | 0 | -1406 | -2114 | -2099 | -2084 | -2069 | -2054 | -2039 | -2024 | -2009 | -1994 |
| 8.Accumulated profit | 0 | 0 | 0 | -1406 | -3520 | -5619 | -7703 | -9772 | -11826 | -13865 | -15889 | -17898 | -19892 |
| Ratios | | | | | | | | | | | | | |
| Taxable profit:Sales (%) | | | | -70 | -53 | -52 | -52 | -52 | -51 | -51 | -51 | -50 | -50 |
| Net profit:sales (%) | | | | -70 | -53 | -52 | -52 | -52 | -51 | -51 | -51 | -50 | -50 |
| Net profit:equity (%) | | | | -7 | -11 | -11 | -11 | -11 | -10 | -10 | -10 | -10 | -10 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 82000 |
| 2.Production costs | -5979 | -5964 | -5949 | -5934 | -5919 | -5904 | -5889 | -5874 | -5859 | -5844 | -5829 | -122836 |
| 3.Taxable profit | -1979 | -1964 | -1949 | -1934 | -1919 | -1904 | -1889 | -1874 | -1859 | -1844 | -1829 | -40836 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | -1979 | -1964 | -1949 | -1934 | -1919 | -1904 | -1889 | -1874 | -1859 | -1844 | -1829 | -40836 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | -1979 | -1964 | -1949 | -1934 | -1919 | -1904 | -1889 | -1874 | -1859 | -1844 | -1829 | -40836 |
| 8.Accumulated undistributed profit | -21871 | -23835 | -25784 | -27718 | -29637 | -31541 | -33430 | -35304 | -37163 | -39007 | -40836 | |
| Ratios | | | | | | | | | | | | |
| Taxable profit:Sales (%) | -49 | -49 | -49 | -48 | -48 | -48 | -47 | -47 | -46 | -46 | -46 | |
| Net profit:Sales (%) | -49 | -49 | -49 | -48 | -48 | -48 | -47 | -47 | -46 | -46 | -46 | |
| Net profit:Equity (%) | -10 | -10 | -10 | -10 | -10 | -10 | -10 | -10 | -9 | -9 | -9 | |

Cash flow table for financing planning

Table 15-3/A

Low quality bauxite sintering process

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 6109 | 19194 | 8511 | 3029 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Financial resources total | 6109 | 19194 | 6511 | 1029 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -6109 | -19194 | -6511 | -4529 | -6531 | -6516 | -6501 | -7471 | -7456 | -7441 | -7426 | -7411 | -7396 |
| 1.Total assets schedule including replacement | -6109 | -19194 | -8511 | -1029 | 0 | 0 | 0 | -985 | -985 | -985 | -985 | -985 | -985 |
| 2.Operating costs | 0 | 0 | 0 | -3500 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 |
| 3.Debt service (total) | 0 | 0 | 0 | 0 | -450 | -435 | -420 | -405 | -390 | -375 | -360 | -345 | -330 |
| - Interest: | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| -Repayments: | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Surplus/deficit | 0 | 0 | 0 | -1500 | -2531 | -2516 | -2501 | -3471 | -3456 | -3441 | -3426 | -3411 | -3396 |
| D.Cumulative cash balance | 0 | 0 | 0 | -1500 | -4031 | -6547 | -9046 | -12519 | -15975 | -19416 | -22842 | -26253 | -29649 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 116943 |
| 1.Financial resources total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 34943 |
| 2.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |  | 82000 |
| B.Cash outflow | -7381 | -7366 | -7351 | -7336 | -7321 | -7306 | -7291 | -7276 | -7261 | -7246 | -7231 | 8382 | -174476 |
| 1.Total assets schedule including replacement | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | 8382 | -43206 |
| 2.Operating costs | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 |  | -125120 |
| 3.Debt service (total) | -315 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 | -165 |  | -6150 |
| - Interest: | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | 0 | -3150 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| -Repayments: | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | 0 | -3000 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Surplus/deficit | -3381 | -3366 | -3351 | -3336 | -3321 | -3306 | -3291 | -3276 | -3261 | -3246 | -3231 | 8382 | -57633 |
| D.Cumulative cash balance | -33030 | -36396 | -39747 | -43083 | -46404 | -49710 | -53001 | -56277 | -59538 | -62784 | -66015 | -57633 |  |

Cash flow table for financing planning

Table 15-3/8

Low quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 4361 | 13748 | 6390 | 2915 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Financial resources total | 4361 | 13748 | 6390 | 915 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -4361 | -13748 | -6390 | -4499 | -6694 | -6679 | -6664 | -7359 | -7344 | -7329 | -7314 | -7299 | -7284 |
| 1.Total assets schedule including replacement | -4361 | -13748 | -6390 | -915 | 0 | 0 | 0 | -710 | -710 | -710 | -710 | -710 | -710 |
| 2.Operating costs | 0 | 0 | 0 | -3584 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 |
| 3.Debt service (total) | 0 | 0 | 0 | 0 | -450 | -435 | -420 | -405 | -390 | -375 | -360 | -345 | -330 |
| - Interest: | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| -Repayments: | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Surplus/deficit | 0 | 0 | 0 | -1584 | -2694 | -2679 | -2664 | -3359 | -3344 | -3329 | -3314 | -3299 | -3284 |
| D.Cumulative cash balance | 0 | 0 | 0 | -1584 | -4278 | -6957 | -9621 | -12980 | -16324 | -19653 | -22967 | -26266 | -29550 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 107414 |
| 1.Financial resources total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 25414 |
| 2.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |  | 82000 |
| B.Cash outflow | -7269 | -7254 | -7239 | -7224 | -7209 | -7194 | -7179 | -7164 | -7149 | -7134 | -7119 | 6302 | -165796 |
| 1.Total assets schedule including replacement | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | 6302 | -31182 |
| 2.Operating costs | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 |  | -128464 |
| 3.Debt service (total) | -315 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 | -165 |  | -6150 |
| - Interest: | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | 0 | -3150 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| -Repayments: | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | 0 | -3000 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Surplus/deficit | -3269 | -3254 | -3239 | -3224 | -3209 | -3194 | -3179 | -3164 | -3149 | -3134 | -3119 | 6302 | -58382 |
| D.Cumulative cash balance | -32819 | -36073 | -39312 | -42536 | -45745 | -48939 | -52118 | -55282 | -58431 | -61565 | -64684 | -58382 |  |

Cash flow table for financing planning

Table 15-3/C

Low quality bauxite tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 4424 | 13918 | 6465 | 2916 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Financial resources total | 4424 | 13918 | 6465 | 916 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -4424 | -13918 | -6465 | -4450 | -6628 | -6613 | -6598 | -7301 | -7286 | -7271 | -7256 | -7241 | -7226 |
| 1.Total assets schedule including replacement | -4424 | -13918 | -6465 | -916 | 0 | 0 | 0 | -718 | -718 | -718 | -718 | -718 | -718 |
| 2.Operating costs | 0 | 0 | 0 | -3534 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 |
| 3.Debt service (total) | 0 | 0 | 0 | 0 | -450 | -435 | -420 | -405 | -390 | -375 | -360 | -345 | -330 |
| - Interest: | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| -Repayments: | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Surplus/deficit | 0 | 0 | 0 | -1534 | -2628 | -2613 | -2598 | -3301 | -3286 | -3271 | -3256 | -3241 | -3226 |
| D.Cumulative cash balance | 0 | 0 | 0 | -1534 | -4162 | -6775 | -9373 | -12674 | -15960 | -19231 | -22487 | -25728 | -28954 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 107723 |
| 1.Financial resources total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 25723 |
| 2.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |  | 82000 |
| B.Cash outflow | -7211 | -7196 | -7181 | -7166 | -7151 | -7136 | -7121 | -7106 | -7091 | -7076 | -7061 | 6363 | -164810 |
| 1.Total assets schedule including replacement | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | 6363 | -31566 |
| 2.Operating costs | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 |  | -127094 |
| 3.Debt service (total) | -315 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 | -165 |  | -6150 |
| - Interest: | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | 0 | -3150 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| -Repayments: | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | 0 | -3000 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Surplus/deficit | -3211 | -3196 | -3181 | -3166 | -3151 | -3136 | -3121 | -3106 | -3091 | -3076 | -3061 | 6363 | -57087 |
| D.Cumulative cash balance | -32165 | -35361 | -38542 | -41708 | -44859 | -47995 | -51116 | -54222 | -57313 | -60389 | -63450 | -57087 |  |

Cash flow table for financing planning

Table 15-3/B

High quality bauxite autoclave digestion

millions of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 3966 | 12502 | 5737 | 2770 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Financial resources total | 3966 | 12502 | 5737 | 770 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -3966 | -12502 | -5737 | -3428 | -5010 | -4995 | -4980 | -5610 | -5595 | -5580 | -5565 | -5550 | -5535 |
| 1.Total assets schedule including replacement | -3966 | -12502 | -5737 | -770 | 0 | 0 | 0 | -645 | -645 | -645 | -645 | -645 | -645 |
| 2.Operating costs | 0 | 0 | 0 | -2658 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 |
| 3.Debt service (total) | 0 | 0 | 0 | 0 | -450 | -435 | -420 | -405 | -390 | -375 | -360 | -345 | -330 |
| - Interest: | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| -Repayments: | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Surplus/deficit | 0 | 0 | 0 | -658 | -1010 | -995 | -980 | -1610 | -1595 | -1580 | -1565 | -1550 | -1535 |
| D.Cumulative cash balance | 0 | 0 | 0 | -658 | -1668 | -2663 | -3643 | -5253 | -6848 | -8428 | -9993 | -11543 | -13078 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 104975 |
| 1.Financial resources total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 22975 |
| 2.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |  | 82000 |
| B.Cash outflow | -5520 | -5505 | -5490 | -5475 | -5460 | -5445 | -5430 | -5415 | -5400 | -5385 | -5370 | 5630 | -128318 |
| 1.Total assets schedule including replacement | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | 5630 | -28310 |
| 2.Operating costs | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 |  | -93858 |
| 3.Debt service (total) | -315 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 | -165 |  | -6150 |
| - Interest: | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | 0 | -3150 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| -Repayments: | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | 0 | -3000 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Surplus/deficit | -1520 | -1505 | -1490 | -1475 | -1460 | -1445 | -1430 | -1415 | -1400 | -1385 | -1370 | 5630 | -23343 |
| D.Cumulative cash balance | -14598 | -16103 | -17593 | -19068 | -20528 | -21973 | -23403 | -24818 | -26218 | -27603 | -28973 | -23343 |  |

Cash flow table for financing planning

Table 15-3/E

High quality bauxite tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 3948 | 12364 | 5680 | 2770 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Financial resources total | 3948 | 12364 | 5680 | 770 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -3948 | -12364 | -5680 | -3388 | -4951 | -4936 | -4921 | -5546 | -5531 | -5516 | -5501 | -5486 | -5471 |
| 1.Total assets schedule including replacement | -3948 | -12364 | -5680 | -770 | 0 | 0 | 0 | -640 | -640 | -640 | -640 | -640 | -640 |
| 2.Operating costs | 0 | 0 | 0 | -2618 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 |
| 3.Debt service (total) | 0 | 0 | 0 | 0 | -450 | -435 | -420 | -405 | -390 | -375 | -360 | -345 | -330 |
| - Interest: | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| -Repayments: | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Surplus/deficit | 0 | 0 | 0 | -618 | -951 | -936 | -921 | -1546 | -1531 | -1516 | -1501 | -1486 | -1471 |
| D.Cumulative cash balance | 0 | 0 | 0 | -618 | -1569 | -2505 | -3426 | -4972 | -6503 | -8019 | -9520 | -11006 | -12477 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 104762 |
| 1.Financial resources total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 22762 |
| 2.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |  | 82000 |
| B.Cash outflow | -5456 | -5441 | -5426 | -5411 | -5396 | -5381 | -5366 | -5351 | -5336 | -5321 | -5306 | 5573 | -126857 |
| 1.Total assets schedule including replacement | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | 5573 | -28069 |
| 2.Operating costs | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 |  | -92638 |
| 3.Debt service (total) | -315 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 | -165 |  | -6150 |
| - Interest: | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | 0 | -3150 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| -Repayments: | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | 0 | -3000 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Surplus/deficit | -1456 | -1441 | -1426 | -1411 | -1396 | -1381 | -1366 | -1351 | -1336 | -1321 | -1306 | 5573 | -22095 |
| D.Cumulative cash balance | -13933 | -15374 | -16800 | -18211 | -19607 | -20988 | -22354 | -23705 | -25041 | -26362 | -27668 | -22095 |  |

Projected balance sheet

Table 15-4/A

Low quality bauxite sintering process

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 6109 | 25303 | 33514 | 34843 | 34693 | 34543 | 34393 | 34243 | 34093 | 33943 | 33793 | 33643 | 33493 |
| 1.Current assets | 0 | 0 | 1528 | 520 | -2011 | -4527 | -7028 | -10499 | -13955 | -17396 | -20822 | -24235 | -27629 |
| (a) Accumulated cash balance | 0 | 0 | 0 | -1500 | -4031 | -6547 | -9048 | -12519 | -15975 | -19416 | -22842 | -26255 | -29649 |
| (b) Current assets | 0 | 0 | 1528 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 |
| 2.Fixed assets | | | | | | | | | | | | | |
| (net of depreciation) | 6109 | 25303 | 32236 | 31823 | 29782 | 27741 | 25700 | 24644 | 23588 | 22532 | 21476 | 20420 | 19364 |
| Initial fixed investment, replacement and preproduction capital expenditures | | | | | | | | | | | | | |
| 3.Losses | 0 | 0 | 0 | 2500 | 6922 | 11329 | 15721 | 20098 | 24460 | 28807 | 33139 | 37458 | 41758 |
| | | | | | | | | | | | | | |
| B.Liabilities | 6109 | 25303 | 33614 | 34843 | 34693 | 34543 | 34393 | 34243 | 34093 | 33943 | 33793 | 33643 | 33493 |
| 1.Current liability | 0 | 0 | 107 | 203 | 203 | 203 | 203 | 203 | 203 | 203 | 203 | 203 | 203 |
| 2.Medium-term loans | 529 | 2192 | 2920 | 3000 | 2850 | 2700 | 2550 | 2400 | 2250 | 2100 | 1950 | 1800 | 1650 |
| 3.Paid up equity | 5580 | 23111 | 30767 | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 33343 | 33193 | 33043 | 32893 | 32743 | 32593 | 32443 | 32293 | 32143 | 31993 | 31843 |
| 1.Current assets | -31010 | -34376 | -37727 | -41063 | -44384 | -47690 | -50981 | -54257 | -57518 | -60764 | -63995 |
| (a) Accumulated cash balance | -33030 | -36396 | -39747 | -43083 | -46404 | -49710 | -53001 | -56277 | -59538 | -62784 | -66015 |
| (b) Current assets | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 |
| 2.Fixed assets | | | | | | | | | | | |
| (net of depreciation) | 18308 | 17252 | 16196 | 15140 | 14084 | 13028 | 11972 | 10916 | 9860 | 8804 | 7748 |
| Initial fixed investment, replacement and preproduction capital expenditures | | | | | | | | | | | |
| 3.Losses | 46045 | 50317 | 54574 | 58816 | 63043 | 67255 | 71452 | 75634 | 79801 | 83953 | 88090 |
| | | | | | | | | | | | |
| B.Liabilities | 33343 | 33193 | 33043 | 32893 | 32743 | 32593 | 32443 | 32293 | 32143 | 31993 | 31843 |
| 1.Current liability | 203 | 203 | 203 | 203 | 203 | 203 | 203 | 203 | 203 | 203 | 203 |
| 2.Medium-term loans | 1500 | 1350 | 1200 | 1050 | 900 | 750 | 600 | 450 | 300 | 150 | 0 |
| 3.Paid up equity | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 | 31640 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Projected balance sheet

Table 15-4/8

Low quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 4361 | 18109 | 24499 | 25414 | 25264 | 25114 | 24964 | 24814 | 24664 | 24514 | 24364 | 24214 | 24064 |
| 1.Current assets | 0 | 0 | 1273 | 200 | -2494 | -5173 | -7837 | -11196 | -14540 | -17869 | -21183 | -24482 | -27766 |
| (a) Accumulated cash balance | 0 | 0 | 0 | -1584 | -4278 | -6957 | -9621 | -12980 | -16324 | -19653 | -22967 | -26266 | -29550 |
| (b) Current assets | 0 | 0 | 1273 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 |
| 2.Fixed assets | | | | | | | | | | | | | |
| (net of depreciation) Initial fixed investment, replacement and preproduction capital expenditures | 4361 | 18109 | 23226 | 22800 | 21321 | 19842 | 18363 | 17594 | 16825 | 16056 | 15287 | 14518 | 13749 |
| 3.Losses | 0 | 0 | 0 | 2414 | 6437 | 10445 | 14438 | 18416 | 22379 | 26327 | 30260 | 34178 | 38081 |
| B.Liabilities | 4361 | 18109 | 24499 | 25414 | 25264 | 25114 | 24964 | 24814 | 24664 | 24514 | 24364 | 24214 | 24064 |
| 1.Current liability | 0 | 0 | 110 | 208 | 208 | 208 | 208 | 208 | 208 | 208 | 208 | 208 | 208 |
| 2.Medium-term loans | 519 | 2155 | 2902 | 3000 | 2850 | 2700 | 2550 | 2400 | 2250 | 2100 | 1950 | 1800 | 1650 |
| 3.Paid up equity | 3842 | 15954 | 21467 | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 23914 | 23764 | 23614 | 23464 | 23314 | 23164 | 23014 | 22864 | 22714 | 22564 | 22414 |
| 1.Current assets | -31035 | -34289 | -37528 | -40752 | -43961 | -47155 | -50334 | -53498 | -56647 | -59781 | -62900 |
| (a) Accumulated cash balance | -32819 | -36073 | -39312 | -42536 | -45745 | -48939 | -52118 | -55282 | -58431 | -61565 | -64684 |
| (b) Current assets | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 | 1784 |
| 2.Fixed assets | | | | | | | | | | | |
| (net of depreciation) Initial fixed investment, replacement and preproduction capital expenditures | 12980 | 12211 | 11442 | 10673 | 9904 | 9135 | 8366 | 7597 | 6828 | 6059 | 5290 |
| 3.Losses | 41969 | 45842 | 49700 | 53543 | 57371 | 61184 | 64982 | 68765 | 72533 | 76286 | 80024 |
| B.Liabilities | 23914 | 23764 | 23614 | 23464 | 23314 | 23164 | 23014 | 22864 | 22714 | 22564 | 22414 |
| 1.Current liability | 208 | 208 | 208 | 208 | 208 | 208 | 208 | 208 | 208 | 208 | 208 |
| 2.Medium-term loans | 1500 | 1350 | 1200 | 1050 | 900 | 750 | 600 | 450 | 300 | 150 | 0 |
| 3.Paid up equity | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 | 22206 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Projected balance sheet

Table 15-4/C

Low quality bagasse base digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 4424 | 18342 | 24807 | 25723 | 25573 | 25423 | 25273 | 25123 | 24973 | 24823 | 24673 | 24523 | 24373 |
| 1.Current assets | 0 | 0 | 1274 | 247 | -2381 | -4994 | -7592 | -10893 | -14179 | -17450 | -20706 | -23947 | -27173 |
| (a) Accumulated cash balance | 0 | 0 | 0 | -1534 | -4162 | -6775 | -9373 | -12674 | -15960 | -19231 | -22487 | -25728 | -28954 |
| (b) Current assets | 0 | 0 | 1274 | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 |
| 2.Fixed assets | | | | | | | | | | | | | |
| (net of depreciation) | 4424 | 18342 | 23533 | 23042 | 21556 | 20070 | 18584 | 17816 | 17048 | 16280 | 15512 | 14744 | 13976 |
| Initial fixed investment, replacement and preproduction capital expenditures | | | | | | | | | | | | | |
| 3.Losses | 0 | 0 | 0 | 2434 | 6398 | 10347 | 14281 | 18200 | 22104 | 25993 | 29867 | 33726 | 37570 |
| | | | | | | | | | | | | | |
| B.Liabilities (total) | 4424 | 18342 | 24807 | 25723 | 25573 | 25423 | 25273 | 25123 | 24973 | 24823 | 24673 | 24523 | 24373 |
| 1.Current liability | 0 | 0 | 109 | 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 |
| 2.Medium-term loans | 520 | 2156 | 2903 | 3000 | 2850 | 2700 | 2550 | 2400 | 2250 | 2100 | 1950 | 1800 | 1650 |
| 3.Paid up equity | 3904 | 16186 | 21795 | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 24223 | 24073 | 23923 | 23773 | 23623 | 23473 | 23323 | 23173 | 23023 | 22873 | 22723 |
| 1.Current assets | -30384 | -33580 | -36761 | -39927 | -43078 | -46214 | -49335 | -52441 | -55532 | -58608 | -61669 |
| (a) Accumulated cash balance | -32165 | -35361 | -38542 | -41708 | -44859 | -47995 | -51116 | -54222 | -57313 | -60389 | -63450 |
| (b) Current assets | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 | 1781 |
| 2.Fixed assets | | | | | | | | | | | |
| (net of depreciation) | 13208 | 12440 | 11672 | 10904 | 10136 | 9368 | 8600 | 7832 | 7064 | 6296 | 5528 |
| Initial fixed investment, replacement and preproduction capital expenditures | | | | | | | | | | | |
| 3.Losses | 41399 | 45213 | 49012 | 52796 | 56565 | 60319 | 64058 | 67782 | 71491 | 75185 | 78864 |
| | | | | | | | | | | | |
| B.Liabilities | 24223 | 24073 | 23923 | 23773 | 23623 | 23473 | 23323 | 23173 | 23023 | 22873 | 22723 |
| 1.Current liability | 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 | 206 |
| 2.Medium-term loans | 1500 | 1350 | 1200 | 1050 | 900 | 750 | 600 | 450 | 300 | 150 | 0 |
| 3.Paid up equity | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 | 22517 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Projected balance sheet

Table 15-4/B

High quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 3966 | 16468 | 22205 | 22975 | 22825 | 22675 | 22525 | 22375 | 22225 | 22075 | 21925 | 21775 | 21625 |
| 1.Current assets | 0 | 0 | 1074 | 808 | -202 | -1197 | -2177 | -3787 | -5382 | -6962 | -8527 | -10077 | -11612 |
| (a) Accumulated cash balance | 0 | 0 | 0 | -658 | -1668 | -2663 | -3643 | -5253 | -6848 | -8428 | -9993 | -11543 | -13078 |
| (b) Current assets | 0 | 0 | 1074 | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 |
| 2.Fixed assets | | | | | | | | | | | | | |
| (net of depreciation) Initial fixed investment, replacement and preproduction capital expenditures | 3966 | 16468 | 21131 | 20701 | 19355 | 18009 | 16663 | 15962 | 15261 | 14560 | 13859 | 13158 | 12457 |
| 3.Losses | 0 | 0 | 0 | 1466 | 3672 | 5863 | 8039 | 10200 | 12346 | 14477 | 16593 | 18694 | 20780 |
| B.Liabilities (total) | 3966 | 16468 | 22205 | 22975 | 22825 | 22675 | 22525 | 22375 | 22225 | 22075 | 21925 | 21775 | 21625 |
| 1.Current liability | 0 | 0 | 72 | 138 | 138 | 138 | 138 | 138 | 138 | 138 | 138 | 138 | 138 |
| 2.Medium-term loans | 521 | 2163 | 2907 | 3000 | 2850 | 2700 | 2550 | 2400 | 2250 | 2100 | 1950 | 1800 | 1650 |
| 3.Paid up equity | 3445 | 14305 | 19226 | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 21475 | 21325 | 21175 | 21025 | 20875 | 20725 | 20575 | 20425 | 20275 | 20125 | 19975 |
| 1.Current assets | -13132 | -14637 | -16127 | -17602 | -19062 | -20507 | -21937 | -23352 | -24752 | -26137 | -27507 |
| (a) Accumulated cash balance | -14598 | -16103 | -17593 | -19068 | -20528 | -21973 | -23403 | -24818 | -26218 | -27603 | -28973 |
| (b) Current assets | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 | 1466 |
| 2.Fixed assets | | | | | | | | | | | |
| (net of depreciation) Initial fixed investment, replacement and preproduction capital expenditures | 11756 | 11055 | 10354 | 9653 | 8952 | 8251 | 7550 | 6849 | 6148 | 5447 | 4746 |
| 3.Losses | 22851 | 24907 | 26948 | 28974 | 30985 | 32981 | 34962 | 36928 | 38879 | 40815 | 42736 |
| B.Liabilities | 21475 | 21325 | 21175 | 21025 | 20875 | 20725 | 20575 | 20425 | 20275 | 20125 | 19975 |
| 1.Current liability | 138 | 138 | 138 | 138 | 138 | 138 | 138 | 138 | 138 | 138 | 138 |
| 2.Medium-term loans | 1500 | 1350 | 1200 | 1050 | 900 | 750 | 600 | 450 | 300 | 150 | 0 |
| 3.Paid up equity | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 | 19837 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Projected balance sheet

Table 15-7/E

High quality bagasse tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 3948 | 16312 | 21992 | 22762 | 22612 | 22462 | 22312 | 22162 | 22012 | 21862 | 21712 | 21562 | 21412 |
| 1.Current assets | 0 | 0 | 1059 | 829 | -122 | -1058 | -1979 | -3525 | -5056 | -6572 | -8073 | -9559 | -11030 |
| (a) Accumulated cash balance | 0 | 0 | 0 | -618 | -1569 | -2505 | -3426 | -4972 | -6503 | -8019 | -9520 | -11006 | -12477 |
| (b) Current assets | 0 | 0 | 1059 | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 |
| 2.Fixed assets | | | | | | | | | | | | | |
| (net of depreciation) | 3948 | 16312 | 20933 | 20527 | 19214 | 17901 | 16583 | 15915 | 15242 | 14569 | 13896 | 13223 | 12550 |
| Initial fixed investment, replacement and preproduction capital expenditures | | | | | | | | | | | | | |
| 3.Losses | 0 | 0 | 0 | 1406 | 3520 | 5619 | 7703 | 9772 | 11826 | 13865 | 15889 | 17898 | 19892 |
| B.Liabilities (total) | 3948 | 16312 | 21992 | 22762 | 22612 | 22462 | 22312 | 22162 | 22012 | 21862 | 21712 | 21562 | 21412 |
| 1.Current liability | 0 | 0 | 72 | 137 | 137 | 137 | 137 | 137 | 137 | 137 | 137 | 137 | 137 |
| 2.Medium-term loans | 523 | 2162 | 2906 | 3000 | 2850 | 2700 | 2550 | 2400 | 2250 | 2100 | 1950 | 1800 | 1650 |
| 3.Paid up equity | 3425 | 14150 | 19014 | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 21262 | 21112 | 20962 | 20812 | 20662 | 20512 | 20362 | 20212 | 20062 | 19912 | 19762 |
| 1.Current assets | -12486 | -13927 | -15353 | -16764 | -18160 | -19541 | -20907 | -22258 | -23594 | -24915 | -26221 |
| (a) Accumulated cash balance | -13933 | -15374 | -16800 | -18211 | -19607 | -20988 | -22354 | -23705 | -25041 | -26362 | -27668 |
| (b) Current assets | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 | 1447 |
| 2.Fixed assets | | | | | | | | | | | |
| (net of depreciation) | 11877 | 11204 | 10531 | 9858 | 9185 | 8512 | 7839 | 7166 | 6493 | 5820 | 5147 |
| Initial fixed investment, replacement and preproduction capital expenditures | | | | | | | | | | | |
| 3.Losses | 21871 | 23835 | 25784 | 27718 | 29637 | 31541 | 33430 | 35304 | 37163 | 39007 | 40836 |
| B.Liabilities | 21262 | 21112 | 20962 | 20812 | 20662 | 20512 | 20362 | 20212 | 20062 | 19912 | 19762 |
| 1.Current liability | 137 | 137 | 137 | 137 | 137 | 137 | 137 | 137 | 137 | 137 | 137 |
| 2.Medium-term loans | 1500 | 1350 | 1200 | 1050 | 900 | 750 | 600 | 450 | 300 | 150 | 0 |
| 3.Paid up equity | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 | 19625 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Cash Flow table for project Table 15-5/A

Low quality bauxite sintering process million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -6109 | -19194 | -8404 | -4433 | -6081 | -6081 | -6081 | -7066 | -7066 | -7066 | -7066 | -7066 | -7066 |
| 1.Total investment outlay | -6109 | -19194 | -8404 | -933 | 0 | 0 | 0 | -985 | -985 | -985 | -985 | -985 | -985 |
| 2.Operating costs | 0 | 0 | 0 | -3500 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -60[illegible] |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| C.Net cash flow | -6109 | -19194 | -8404 | -2433 | -2081 | -2081 | -2081 | -3066 | -3066 | -3066 | -3066 | -3066 | -3066 |
| D.Cumulative net cash flow | -6109 | -25303 | -33707 | -36140 | -38221 | -40302 | -42383 | -45449 | -48515 | -51581 | -54647 | -57713 | -60779 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 82000 |
| 1.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | | 82000 |
| B.Cash outflow | -7066 | -7066 | -7066 | -7066 | -7066 | -7066 | -7066 | -7066 | -7066 | -7066 | -7066 | 8382 | -168123 |
| 1.Total investment outlay | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | 8382 | -43003 |
| 2.Operating costs | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | | -125120 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| C.Net cash flow | -3066 | -3066 | -3066 | -3066 | -3066 | -3066 | -3066 | -3066 | -3066 | -3066 | -3066 | 8382 | -86123 |
| D.Cumulative net cash flow | -63845 | -66911 | -69977 | -73043 | -76109 | -79175 | -82241 | -85307 | -88373 | -91439 | -94505 | -86123 | |

Cash Flow table for project Table 15-5/8

Low quality bauxite autoclave digestion million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -4361 | -13748 | -6280 | -4401 | -6244 | -6244 | -6244 | -6954 | -6954 | -6954 | -6954 | -6954 | -6954 |
| 1.Total investment outlay | -4361 | -13748 | -6280 | -817 | 0 | 0 | 0 | -710 | -710 | -710 | -710 | -710 | -710 |
| 2.Operating costs | 0 | 0 | 0 | -3584 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -4361 | -13748 | -6280 | -2401 | -2244 | -2244 | -2244 | -2954 | -2954 | -2954 | -2954 | -2954 | -2954 |
| D.Cumulative net cash flow | -4361 | -18109 | -24389 | -26790 | -29034 | -31278 | -33522 | -36476 | -39430 | -42384 | -45338 | -48292 | -51246 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 82000 |
| 1.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |  | 82000 |
| B.Cash outflow | -6954 | -6954 | -6954 | -6954 | -6954 | -6954 | -6954 | -6954 | -6954 | -6954 | -6954 | 6302 | -159438 |
| 1.Total investment outlay | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | 6302 | -30974 |
| 2.Operating costs | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 |  | -128464 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |  |
| C.Net cash flow | -2954 | -2954 | -2954 | -2954 | -2954 | -2954 | -2954 | -2954 | -2954 | -2954 | -2954 | 6302 | -77438 |
| D.Cumulative net cash flow | -54200 | -57154 | -60108 | -63062 | -66016 | -68970 | -71924 | -74878 | -77832 | -80786 | -83740 | -77438 |  |

Cash Flow table for project Table 15-5/C

Low quality bauxite tube digestion million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -4424 | -13918 | -6356 | -4353 | -6178 | -6178 | -6178 | -6896 | -6896 | -6896 | -6896 | -6896 | -6896 |
| 1.Total investment outlay | -4424 | -13918 | -6356 | -819 | 0 | 0 | 0 | -718 | -718 | -718 | -718 | -718 | -718 |
| 2.Operating costs | 0 | 0 | 0 | -3534 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -4424 | -13918 | -6356 | -2353 | -2178 | -2178 | -2178 | -2896 | -2896 | -2896 | -2896 | -2896 | -2896 |
| D.Cumulative net cash flow | -4424 | -18342 | -24698 | -27051 | -29229 | -31407 | -33585 | -36481 | -39377 | -42273 | -45169 | -48065 | -50961 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 82000 |
| 1.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |  | 82000 |
| B.Cash outflow | -6896 | -6896 | -6896 | -6896 | -6896 | -6896 | -6896 | -6896 | -6896 | -6896 | -6896 | 6363 | -158454 |
| 1.Total investment outlay | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | 6363 | -31360 |
| 2.Operating costs | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 |  | -127094 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |  |
| C.Net cash flow | -2896 | -2896 | -2896 | -2896 | -2896 | -2896 | -2896 | -2896 | -2896 | -2896 | -2896 | 6363 | -76454 |
| D.Cumulative net cash flow | -53857 | -56753 | -59649 | -62545 | -65441 | -68337 | -71233 | -74129 | -77025 | -79921 | -82817 | -76454 |  |

Cash Flow table for project

Table 15-5/D

High quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -3966 | -12502 | -5665 | -3362 | -4560 | -4560 | -4560 | -5205 | -5205 | -5205 | -5205 | -5205 | -5205 |
| 1.Total investment outlay | -3966 | -12502 | -5665 | -704 | 0 | 0 | 0 | -645 | -645 | -645 | -645 | -645 | -645 |
| 2.Operating costs | 0 | 0 | 0 | -2658 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -3966 | -12502 | -5665 | -1362 | -560 | -560 | -560 | -1205 | -1205 | -1205 | -1205 | -1205 | -1205 |
| D.Cumulative net cash flow | -3966 | -16468 | -22133 | -23495 | -24055 | -24615 | -25175 | -26380 | -27585 | -28790 | -29995 | -31200 | -32405 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 82000 |
| 1.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | | 82000 |
| B.Cash outflow | -5205 | -5205 | -5205 | -5205 | -5205 | -5205 | -5205 | -5205 | -5205 | -5205 | -5205 | 5630 | -122030 |
| 1.Total investment outlay | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | 5630 | -28172 |
| 2.Operating costs | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | | -93858 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| C.Net cash flow | -1205 | -1205 | -1205 | -1205 | -1205 | -1205 | -1205 | -1205 | -1205 | -1205 | -1205 | 5630 | -40030 |
| D.Cumulative net cash flow | -33610 | -34815 | -36020 | -37225 | -38430 | -39635 | -40840 | -42045 | -43250 | -44455 | -45660 | -40030 | |

Cash Flow table for project

Table 15-5/E

High quality bauxite tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -3948 | -12364 | -5608 | -3323 | -4501 | -4501 | -4501 | -5141 | -5141 | -5141 | -5141 | -5141 | -5141 |
| 1.Total investment outlay | -3948 | -12364 | -5608 | -705 | 0 | 0 | 0 | -640 | -640 | -640 | -640 | -640 | -640 |
| 2.Operating costs | 0 | 0 | 0 | -2618 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -3948 | -12364 | -5608 | -1323 | -501 | -501 | -501 | -1141 | -1141 | -1141 | -1141 | -1141 | -1141 |
| D.Cumulative net cash flow | -3948 | -16312 | -21920 | -23243 | -23744 | -24245 | -24746 | -25887 | -27028 | -28169 | -29310 | -30451 | -31592 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 82000 |
| 1.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |  | 82000 |
| B.Cash outflow | -5141 | -5141 | -5141 | -5141 | -5141 | -5141 | -5141 | -5141 | -5141 | -5141 | -5141 | 5573 | -120570 |
| 1.Total investment outlay | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | 5573 | -27932 |
| 2.Operating costs | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 |  | -92638 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |  |
| C.Net cash flow | -1141 | -1141 | -1141 | -1141 | -1141 | -1141 | -1141 | -1141 | -1141 | -1141 | -1141 | 5573 | -38570 |
| D.Cumulative net cash flow | -32733 | -33874 | -35015 | -36156 | -37297 | -38438 | -39579 | -40720 | -41861 | -43002 | -44143 | -38570 |  |

Cash Flow table for equity

Table 15-6/A

Low quality bauxite sintering process

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -5580 | -17531 | -7676 | -4353 | -6531 | -6516 | -6501 | -7471 | -7456 | -7441 | -7426 | -7411 | -7396 |
| 1.Total equity | -5580 | -17531 | -7676 | -853 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -985 | -985 | -985 | -985 | -985 | -985 |
| 3.Repayment of outside financing | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Interest on outside financing | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| 5.Operating costs | 0 | 0 | 0 | -3500 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -5580 | -17531 | -7676 | -2353 | -2531 | -2516 | -2501 | -3471 | -3456 | -3441 | -3426 | -3411 | -3396 |
| D.Cumulative net cash flow | -5580 | -23111 | -30787 | -33140 | -35671 | -38187 | -40688 | -44159 | -47615 | -51056 | -54482 | -57893 | -61289 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 82000 |
| 1.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | | 82000 |
| B.Cash outflow | -7381 | -7366 | -7351 | -7336 | -7321 | -7306 | -7291 | -7276 | -7261 | -7246 | -7231 | 8382 | -171273 |
| 1.Total equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8382 | -23258 |
| 2.Replacement | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | | -16745 |
| 3.Repayment of outside financing | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | | -3000 |
| 4.Interest on outside financing | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | | -3150 |
| 5.Operating costs | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | -6081 | | -125120 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| C.Net cash flow | -3381 | -3366 | -3351 | -3336 | -3321 | -3306 | -3291 | -3276 | -3261 | -3246 | -3231 | 8382 | -89273 |
| D.Cumulative net cash flow | -64670 | -68036 | -71387 | -74723 | -78044 | -81350 | -84641 | -87917 | -91178 | -94424 | -97655 | -89273 | |

Cash Flow table for equity

Table 15-6/8

Low quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -3842 | -12112 | -5533 | -4303 | -6694 | -6679 | -6664 | -7359 | -7344 | -7329 | -7314 | -7299 | -7284 |
| 1.Total equity | -3842 | -12112 | -5533 | -719 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -710 | -710 | -710 | -710 | -710 | -710 |
| 3.Repayment of outside financing | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Interest on outside financing | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| 5.Operating costs | 0 | 0 | 0 | -3584 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -3842 | -12112 | -5533 | -2303 | -2694 | -2679 | -2664 | -3359 | -3344 | -3329 | -3314 | -3299 | -3284 |
| D.Cumulative net cash flow | -3842 | -15954 | -21487 | -23790 | -26484 | -29163 | -31827 | -35186 | -38530 | -41859 | -45173 | -48472 | -51756 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 82000 |
| 1.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | | 82000 |
| B.Cash outflow | -7269 | -7254 | -7239 | -7224 | -7209 | -7194 | -7179 | -7164 | -7149 | -7134 | -7119 | 6302 | -162588 |
| 1.Total equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6302 | -15904 |
| 2.Replacement | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | | -12070 |
| 3.Repayment of outside financing | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | | -3000 |
| 4.Interest on outside financing | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | | -3150 |
| 5.Operating costs | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | -6244 | | -128464 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| C.Net cash flow | -3269 | -3254 | -3239 | -3224 | -3209 | -3194 | -3179 | -3164 | -3149 | -3134 | -3119 | 6302 | -80588 |
| D.Cumulative net cash flow | -55025 | -58279 | -61518 | -64742 | -67951 | -71145 | -74324 | -77488 | -80637 | -83771 | -86890 | -80588 | |

Cash Flow table for equity

Table 15-6/C

Low quality bauxite tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -3904 | -12282 | -5609 | -4256 | -6628 | -6613 | -6598 | -7301 | -7286 | -7271 | -7256 | -7241 | -7226 |
| 1.Total equity | -3904 | -12282 | -5609 | -722 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -718 | -718 | -718 | -718 | -718 | -718 |
| 3.Repayment of outside financing | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Interest on outside financing | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| 5.Operating costs | 0 | 0 | 0 | -3534 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -3904 | -12282 | -5609 | -2256 | -2628 | -2613 | -2598 | -3301 | -3286 | -3271 | -3256 | -3241 | -3226 |
| D.Cumulative net cash flow | -3904 | -16186 | -21795 | -24051 | -26679 | -29292 | -31890 | -35191 | -38477 | -41748 | -45004 | -48245 | -51471 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 82000 |
| 1.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |  | 82000 |
| B.Cash outflow | -7211 | -7196 | -7181 | -7166 | -7151 | -7136 | -7121 | -7106 | -7091 | -7076 | -7061 | 6363 | -161604 |
| 1.Total equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6363 | -16154 |
| 2.Replacement | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 |  | -12206 |
| 3.Repayment of outside financing | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Interest on outside financing | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| 5.Operating costs | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 | -6178 |  | -127094 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Net cash flow | -3211 | -3196 | -3181 | -3166 | -3151 | -3136 | -3121 | -3106 | -3091 | -3076 | -3061 | 6363 | -79604 |
| D.Cumulative net cash flow | -54682 | -57878 | -61059 | -64225 | -67376 | -70512 | -73633 | -76739 | -79830 | -82906 | -85967 | -79604 |  |

Cash Flow table for equity

Table 15-6/3

High quality bauxite autoclave digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -3445 | -10860 | -4921 | -3269 | -5010 | -4995 | -4980 | -5610 | -5595 | -5580 | -5565 | -5550 | -5535 |
| 1.Total equity | -3445 | -10860 | -4921 | -611 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -645 | -645 | -645 | -645 | -645 | -645 |
| 3.Repayment of outside financing | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Interest on outside financing | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| 5.Operating costs | 0 | 0 | 0 | -2658 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -3445 | -10860 | -4921 | -1269 | -1010 | -995 | -980 | -1610 | -1595 | -1580 | -1565 | -1550 | -1535 |
| D.Cumulative net cash flow | -3445 | -14305 | -19226 | -20495 | -21505 | -22500 | -23480 | -25090 | -26685 | -28265 | -29830 | -31380 | -32915 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 82000 |
| 1.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |  | 82000 |
| B.Cash outflow | -5520 | -5505 | -5490 | -5475 | -5460 | -5445 | -5430 | -5415 | -5400 | -5385 | -5370 | 5630 | -125180 |
| 1.Total equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5630 | -14207 |
| 2.Replacement | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 |  | -10965 |
| 3.Repayment of outside financing | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Interest on outside financing | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| 5.Operating costs | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 | -4560 |  | -93858 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Net cash flow | -1520 | -1505 | -1490 | -1475 | -1460 | -1445 | -1430 | -1415 | -1400 | -1385 | -1370 | 5630 | -43180 |
| D.Cumulative net cash flow | -34435 | -35940 | -37430 | -38905 | -40365 | -41810 | -43240 | -44655 | -46055 | -47440 | -48810 | -43180 |  |

Cash Flow table for equity

Table 15-6/E

High quality bauxite tube digestion

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| 1.Sales revenue | 0 | 0 | 0 | 2000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| B.Cash outflow | -3425 | -10725 | -4864 | -3229 | -4951 | -4936 | -4921 | -5546 | -5531 | -5516 | -5501 | -5486 | -5471 |
| 1.Total equity | -3425 | -10725 | -4864 | -611 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -640 | -640 | -640 | -640 | -640 | -640 |
| 3.Repayment of outside financing | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Interest on outside financing | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| 5.Operating costs | 0 | 0 | 0 | -2618 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -3425 | -10725 | -4864 | -1229 | -951 | -936 | -921 | -1546 | -1531 | -1516 | -1501 | -1486 | -1471 |
| D.Cumulative net cash flow | -3425 | -14150 | -19014 | -20243 | -21194 | -22130 | -23051 | -24597 | -26128 | -27644 | -29145 | -30631 | -32102 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 0 | 82000 |
| 1.Sales revenue | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 | | 82000 |
| B.Cash outflow | -5456 | -5441 | -5426 | -5411 | -5396 | -5381 | -5366 | -5351 | -5336 | -5321 | -5306 | 5573 | -123720 |
| 1.Total equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5573 | -14052 |
| 2.Replacement | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | | -10880 |
| 3.Repayment of outside financing | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | | -3000 |
| 4.Interest on outside financing | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | | -3150 |
| 5.Operating costs | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | -4501 | | -92638 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| C.Net cash flow | -1456 | -1441 | -1426 | -1411 | -1396 | -1381 | -1366 | -1351 | -1336 | -1321 | -1306 | 5573 | -41720 |
| D.Cumulative net cash flow | -33558 | -34999 | -36425 | -37836 | -39232 | -40613 | -41979 | -43330 | -44666 | -45987 | -47293 | -41720 | |

Total assets

Table 15-7/A

Low quality bauxite sintering process

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 13611 | 42764 | 15558 | 1183 | 0 | 0 | 0 | 985 | 985 | 985 | 985 | 985 | 985 |
| a.Initial fixed investm. cost | 13611 | 42764 | 15558 | 1183 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 985 | 985 | 985 | 985 | 985 | 985 |
| 2.Pre-production capital |  |  |  |  |  |  |  |  |  |  |  |  |  |
| expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 2968 | 825 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total assets | 13611 | 42764 | 18526 | 2008 | 0 | 0 | 0 | 985 | 985 | 985 | 985 | 985 | 985 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 89861 |
| a.Initial fixed inves.m. cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 73116 |
| b.Replacement | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 16745 |
| 2.Pre-production capital |  |  |  |  |  |  |  |  |  |  |  |  |
| expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3793 |
| Total assets | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 985 | 93654 |

Total assets

Table 15-7/8

Low quality bauxite autoclave digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 9124 | 28765 | 10706 | 846 | 0 | 0 | 0 | 710 | 710 | 710 | 710 | 710 | 710 |
| a.Initial fixed investm. cost | 9124 | 28765 | 10706 | 846 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 710 | 710 | 710 | 710 | 710 | 710 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 2305 | 799 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total assets | 9124 | 28765 | 13011 | 1645 | 0 | 0 | 0 | 710 | 710 | 710 | 710 | 710 | 710 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 61511 |
| a.Initial fixed investm. cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49441 |
| b.Replacement | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 12070 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3104 |
| Total assets | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 710 | 64615 |

Total assets

Table 15-7/C

Low quality bauxite tube digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 9061 | 28507 | 10632 | 839 | 0 | 0 | 0 | 718 | 718 | 718 | 718 | 718 | 718 |
| a.Initial fixed investm. cost | 9061 | 28507 | 10632 | 839 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 718 | 718 | 718 | 718 | 718 | 718 |
| 2.Pre-production capital | | | | | | | | | | | | | |
| expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 2291 | 798 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total assets | 9061 | 28507 | 12923 | 1637 | 0 | 0 | 0 | 718 | 718 | 718 | 718 | 718 | 718 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 61245 |
| a.Initial fixed investm. cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49039 |
| b.Replacement | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 12206 |
| 2.Pre-production capital | | | | | | | | | | | | |
| expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3089 |
| Total assets | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 718 | 64334 |

Total assets

Table 15-7/3

High quality bauxite autoclave digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 8362 | 26359 | 9832 | 797 | 0 | 0 | 0 | 645 | 645 | 645 | 645 | 645 | 645 |
| a.Initial fixed investm. cost | 8362 | 26359 | 9832 | 797 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 645 | 645 | 645 | 645 | 645 | 645 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 1984 | 634 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total assets | 8362 | 26359 | 11816 | 1431 | 0 | 0 | 0 | 645 | 645 | 645 | 645 | 645 | 645 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 56315 |
| a.Initial fixed investm. cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45350 |
| b.Replacement | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 10965 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2618 |
| Total assets | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 645 | 58933 |

### Total assets

Table 15-7/E

High quality bauxite tube digestion | Exchange rate RLS 200 per USD | million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 8125 | 25444 | 9510 | 786 | 0 | 0 | 0 | 640 | 640 | 640 | 640 | 640 | 640 |
| a.Initial fixed investm. cost | 8125 | 25444 | 9510 | 786 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| b.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 640 | 640 | 640 | 640 | 640 | 640 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 1927 | 626 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total assets | 8125 | 25444 | 11437 | 1412 | 0 | 0 | 0 | 640 | 640 | 640 | 640 | 640 | 640 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Fixed investment costs | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 54745 |
| a.Initial fixed investm. cost | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43865 |
| b.Replacement | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 10880 |
| 2.Pre-production capital expenditures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3.Current assets increase | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2553 |
| Total assets | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 640 | 57298 |

Net income statement

Table 15-8/A

Low quality bauxite sintering process

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 2.Production costs | 0 | 0 | 0 | -6384 | -12022 | -12007 | -11992 | -11977 | -11962 | -11947 | -11932 | -11917 | -11902 |
| 3.Taxable profit | 0 | 0 | 0 | -784 | -822 | -807 | -792 | -777 | -762 | -747 | -732 | -717 | -702 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 0 | 0 | 0 | -784 | -822 | -807 | -792 | -777 | -762 | -747 | -732 | -717 | -702 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 0 | 0 | 0 | -784 | -822 | -807 | -792 | -777 | -762 | -747 | -732 | -717 | -702 |
| 8.Accumulated profit | 0 | 0 | 0 | -784 | -1606 | -2413 | -3205 | -3982 | -4744 | -5491 | -6223 | -6940 | -7642 |
| Ratios | | | | | | | | | | | | | |
| Taxable profit:Sales (%) | | | | -14 | -7 | -7 | -7 | -7 | -7 | -7 | -7 | -6 | -6 |
| Net profit:sales (%) | | | | -14 | -7 | -7 | -7 | -7 | -7 | -7 | -7 | -6 | -6 |
| Net profit:equity (%) | | | | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 229600 |
| 2.Production costs | -11887 | -11872 | -11857 | -11842 | -11827 | -11812 | -11797 | -11782 | -11767 | -11752 | -11737 | -243974 |
| 3.Taxable profit | -687 | -672 | -657 | -642 | -627 | -612 | -597 | -582 | -567 | -552 | -537 | -14374 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | -687 | -672 | -657 | -642 | -627 | -612 | -597 | -582 | -567 | -552 | -537 | -14374 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | -687 | -672 | -657 | -642 | -627 | -612 | -597 | -582 | -567 | -552 | -537 | -14374 |
| 8.Accumulated undistributed profit | -8329 | -9001 | -9658 | -10300 | -10927 | -11539 | -12136 | -12718 | -13285 | -13837 | -14374 | |
| Ratios | | | | | | | | | | | | |
| Taxable profit:Sales (%) | -6 | -6 | -6 | -6 | -6 | -5 | -5 | -5 | -5 | -5 | -5 | |
| Net profit:Sales (%) | -6 | -6 | -6 | -6 | -6 | -5 | -5 | -5 | -5 | -5 | -5 | |
| Net profit:Equity (%) | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | |

Net income statement

Table 15-8/8

Low quality bauxite autoclave digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 2.Production costs | 0 | 0 | 0 | -6161 | -11037 | -11022 | -11007 | -10992 | -10977 | -10962 | -10947 | -10932 | -10917 |
| 3.Taxable profit | 0 | 0 | 0 | -561 | 163 | 178 | 193 | 208 | 223 | 238 | 253 | 268 | 283 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 0 | 0 | 0 | -561 | 163 | 178 | 193 | 208 | 223 | 238 | 253 | 268 | 283 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 0 | 0 | 0 | -561 | 163 | 178 | 193 | 208 | 223 | 238 | 253 | 268 | 283 |
| 8.Accumulated profit | 0 | 0 | 0 | -561 | -398 | -220 | -27 | 181 | 404 | 642 | 895 | 1163 | 1446 |
| Ratios | | | | | | | | | | | | | |
| Taxable profit:Sales (%) | | | | -10 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 |
| Net profit:sales (%) | | | | -10 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 |
| Net profit:equity (%) | | | | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 227600 |
| 2.Production costs | -10902 | -10887 | -10872 | -10857 | -10842 | -10827 | -10812 | -10797 | -10782 | -10767 | -10752 | -224051 |
| 3.Taxable profit | 298 | 313 | 328 | 343 | 358 | 373 | 388 | 403 | 418 | 433 | 448 | 5549 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 298 | 313 | 328 | 343 | 358 | 373 | 388 | 403 | 418 | 433 | 448 | 5549 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 298 | 313 | 328 | 343 | 358 | 373 | 388 | 403 | 418 | 433 | 448 | 5549 |
| 8.Accumulated undistributed profit | 1744 | 2057 | 2385 | 2728 | 3086 | 3459 | 3847 | 4250 | 4668 | 5101 | 5549 | |
| Ratios | | | | | | | | | | | | |
| Taxable profit:Sales (%) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | |
| Net profit:Sales (%) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | |
| Net profit:Equity (%) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |

Net income statement

Table 15-8/C

Low quality bauxite tube digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 2.Production costs | 0 | 0 | 0 | -6183 | -10863 | -10848 | -10833 | -10818 | -10803 | -10788 | -10773 | -10758 | -10743 |
| 3.Taxable profit | 0 | 0 | 0 | -583 | 337 | 352 | 367 | 382 | 397 | 412 | 427 | 442 | 457 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 0 | 0 | 0 | -583 | 337 | 352 | 367 | 382 | 397 | 412 | 427 | 442 | 457 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 0 | 0 | 0 | -583 | 337 | 352 | 367 | 382 | 397 | 412 | 427 | 442 | 457 |
| 8.Accumulated profit | 0 | 0 | 0 | -583 | -246 | 106 | 473 | 855 | 1252 | 1664 | 2091 | 2533 | 2990 |
| Ratios | | | | | | | | | | | | | |
| Taxable profit:Sales (%) | | | | -10 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| Net profit:sales (%) | | | | -10 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| Net profit:equity (%) | | | | -1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 229600 |
| 2.Production costs | -10728 | -10713 | -10698 | -10683 | -10668 | -10653 | -10638 | -10623 | -10608 | -10593 | -10578 | -220593 |
| 3.Taxable profit | 472 | 487 | 502 | 517 | 532 | 547 | 562 | 577 | 592 | 607 | 622 | 9007 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 472 | 487 | 502 | 517 | 532 | 547 | 562 | 577 | 592 | 607 | 622 | 9007 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 472 | 487 | 502 | 517 | 532 | 547 | 562 | 577 | 592 | 607 | 622 | 9007 |
| 8.Accumulated undistributed profit | 3462 | 3949 | 4451 | 4968 | 5500 | 6047 | 6609 | 7186 | 7778 | 8385 | 9007 | |
| Ratios | | | | | | | | | | | | |
| Taxable profit:Sales (%) | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | |
| Net profit:Sales (%) | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | |
| Net profit:Equity (%) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |

Net income statement

Table 15-8/B

High quality bauxite autoclave digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 2.Production costs | 0 | 0 | 0 | -4735 | -8318 | -8303 | -8288 | -8273 | -8258 | -8243 | -8228 | -8213 | -8198 |
| 3.Taxable profit | 0 | 0 | 0 | 865 | 2882 | 2897 | 2912 | 2927 | 2942 | 2957 | 2972 | 2987 | 3002 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 0 | 0 | 0 | 865 | 2882 | 2897 | 2912 | 2927 | 2942 | 2957 | 2972 | 2987 | 3002 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 0 | 0 | 0 | 865 | 2882 | 2897 | 2912 | 2927 | 2942 | 2957 | 2972 | 2987 | 3002 |
| 8.Accumulated profit | 0 | 0 | 0 | 865 | 3747 | 6644 | 9556 | 12483 | 15425 | 18382 | 21354 | 24341 | 27343 |
| Ratios | | | | | | | | | | | | | |
| Taxable profit:Sales (%) | | | | 15 | 26 | 26 | 26 | 26 | 26 | 26 | 27 | 27 | 27 |
| Net profit:sales (%) | | | | 15 | 26 | 26 | 26 | 26 | 26 | 26 | 27 | 27 | 27 |
| Net profit:equity (%) | | | | 2 | 6 | 6 | 6 | 6 | 7 | 7 | 7 | 7 | 7 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 229600 |
| 2.Production costs | -8183 | -8168 | -8153 | -8138 | -8123 | -8108 | -8093 | -8078 | -8063 | -8048 | -8033 | -168245 |
| 3.Taxable profit | 3017 | 3032 | 3047 | 3062 | 3077 | 3092 | 3107 | 3122 | 3137 | 3152 | 3167 | 61355 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 3017 | 3032 | 3047 | 3062 | 3077 | 3092 | 3107 | 3122 | 3137 | 3152 | 3167 | 61355 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 3017 | 3032 | 3047 | 3062 | 3077 | 3092 | 3107 | 3122 | 3137 | 3152 | 3167 | 61355 |
| 8.Accumulated undistributed profit | 30360 | 33392 | 36439 | 39501 | 42578 | 45670 | 48777 | 51899 | 55036 | 58188 | 61355 | |
| Ratios | | | | | | | | | | | | |
| Taxable profit:Sales (%) | 27 | 27 | 27 | 27 | 27 | 28 | 28 | 28 | 28 | 28 | 28 | |
| Net profit:Sales (%) | 27 | 27 | 27 | 27 | 27 | 28 | 28 | 28 | 28 | 28 | 28 | |
| Net profit:Equity (%) | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | |

Net income statement

Table 15-8/E

High quality bauxite tube digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 2.Production costs | 0 | 0 | 0 | -4599 | -8102 | -8087 | -8072 | -8057 | -8042 | -8027 | -8012 | -7997 | -7982 |
| 3.Taxable profit | 0 | 0 | 0 | 1001 | 3098 | 3113 | 3128 | 3143 | 3158 | 3173 | 3188 | 3203 | 3218 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 0 | 0 | 0 | 1001 | 3098 | 3113 | 3128 | 3143 | 3158 | 3173 | 3188 | 3203 | 3218 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 0 | 0 | 0 | 1001 | 3098 | 3113 | 3128 | 3143 | 3158 | 3173 | 3188 | 3203 | 3218 |
| 8.Accumulated profit | 0 | 0 | 0 | 1001 | 4099 | 7212 | 10340 | 13483 | 16541 | 19814 | 23002 | 26205 | 29423 |
| Ratios | | | | | | | | | | | | | |
| Taxable profit:Sales (%) | | | | 18 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 29 | 29 |
| Net profit:sales (%) | | | | 18 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 29 | 29 |
| Net profit:equity (%) | | | | 2 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.Sales | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 229600 |
| 2.Production costs | -7967 | -7952 | -7937 | -7922 | -7907 | -7892 | -7877 | -7862 | -7847 | -7832 | -7817 | -163789 |
| 3.Taxable profit | 3233 | 3248 | 3263 | 3278 | 3293 | 3308 | 3323 | 3338 | 3353 | 3368 | 3383 | 65811 |
| 4.Tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Net profit | 3233 | 3248 | 3263 | 3278 | 3293 | 3308 | 3323 | 3338 | 3353 | 3368 | 3383 | 65811 |
| 6.Dividends | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7.Undistributed profit | 3233 | 3248 | 3263 | 3278 | 3293 | 3308 | 3323 | 3338 | 3353 | 3368 | 3383 | 65811 |
| 8.Accumulated undistributed profit | 32656 | 35904 | 39167 | 42445 | 45738 | 49046 | 52369 | 55707 | 59060 | 62428 | 65811 | |
| Ratios | | | | | | | | | | | | |
| Taxable profit:Sales (%) | 29 | 29 | 29 | 29 | 29 | 30 | 30 | 30 | 30 | 30 | 30 | |
| Net profit:Sales (%) | 29 | 29 | 29 | 29 | 29 | 30 | 30 | 30 | 30 | 30 | 30 | |
| Net profit:Equity (%) | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | |

Cash flow table for financing planning

Table 15-9/A

Low quality bauxite sintering process

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 13520 | 42477 | 18732 | 7700 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Financial resources total | 13520 | 42477 | 18732 | 2100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -13611 | -42764 | -18526 | -6164 | -7625 | -7610 | -7595 | -8565 | -8550 | -8535 | -8520 | -8505 | -8490 |
| 1.Total assets schedule including replacement | -13611 | -42764 | -18526 | -2008 | 0 | 0 | 0 | -985 | -985 | -985 | -985 | -985 | -985 |
| 2.Operating costs | 0 | 0 | 0 | -4156 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 |
| 3.Debt service (total) | 0 | 0 | 0 | 0 | -450 | -435 | -420 | -405 | -390 | -375 | -360 | -345 | -330 |
| - Interest: | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| -Repayments: | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Surplus/deficit | -91 | -287 | 206 | 1616 | 3575 | 3590 | 3605 | 2635 | 2650 | 2665 | 2680 | 2695 | 2710 |
| D.Cumulative cash balance | -91 | -378 | -172 | 1444 | 5019 | 8609 | 12214 | 14849 | 17499 | 20164 | 22844 | 25539 | 28249 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 306509 |
| 1.Financial resources total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 76909 |
| 2.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |  | 229600 |
| B.Cash outflow | -8475 | -8460 | -8445 | -8430 | -8415 | -8400 | -8385 | -8370 | -8355 | -8340 | -8325 | 8382 | -239078 |
| 1.Total assets schedule including replacement | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | 8382 | -65272 |
| 2.Operating costs | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 |  | -147656 |
| 3.Debt service (total) | -315 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 | -165 |  | -6150 |
| - Interest: | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | 0 | -3150 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| -Repayments: | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | 0 | -3000 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Surplus/deficit | 2725 | 2740 | 2755 | 2770 | 2785 | 2800 | 2815 | 2830 | 2845 | 2860 | 2875 | 8382 | 67431 |
| D.Cumulative cash balance | 30974 | 33714 | 36469 | 39239 | 42024 | 44824 | 47639 | 50469 | 53314 | 56174 | 59049 | 67431 |  |

Cash flow table for financing planning Table 15-9/B

Low quality bauxite autoclave digestion Exchange rate RLS 200 per USD million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 9046 | 28519 | 13168 | 7412 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Financial resources total | 9046 | 28519 | 13168 | 1812 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -9124 | -28765 | -13011 | -6069 | -8093 | -8078 | -8063 | -8758 | -8743 | -8728 | -8713 | -8698 | -8683 |
| 1.Total assets schedule including replacement | -9124 | -28765 | -13011 | -1645 | 0 | 0 | 0 | -710 | -710 | -710 | -710 | -710 | -710 |
| 2.Operating costs | 0 | 0 | 0 | -4424 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 |
| 3.Debt service (total) | 0 | 0 | 0 | 0 | -450 | -435 | -420 | -405 | -390 | -375 | -360 | -345 | -330 |
| - Interest: | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| -Repayments: | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Surplus/deficit | -78 | -246 | 157 | 1343 | 3107 | 3122 | 3137 | 2442 | 2457 | 2472 | 2487 | 2502 | 2517 |
| D.Cumulative cash balance | -78 | -324 | -167 | 1176 | 4283 | 7405 | 10542 | 12984 | 15441 | 17913 | 20400 | 22902 | 25419 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 282145 |
| 1.Financial resources total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 52545 |
| 2.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |  | 229600 |
| B.Cash outflow | -8668 | -8653 | -8638 | -8623 | -8608 | -8593 | -8578 | -8563 | -8548 | -8533 | -8518 | 6302 | -221747 |
| 1.Total assets schedule including replacement | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | 6302 | -58313 |
| 2.Operating costs | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 |  | -157284 |
| 3.Debt service (total) | -315 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 | -165 |  | -6150 |
| - Interest: | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | 0 | -3150 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| -Repayments: | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | 0 | -3000 |
| Suppliers' credits |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank overdrafts |  |  |  |  |  |  |  |  |  |  |  |  | 0 |
| Bank term loans | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Surplus/deficit | 2532 | 2547 | 2562 | 2577 | 2592 | 2607 | 2622 | 2637 | 2652 | 2667 | 2682 | 6302 | 60398 |
| D.Cumulative cash balance | 27951 | 30498 | 33060 | 35637 | 38229 | 40836 | 43458 | 46095 | 48747 | 51414 | 54096 | 60398 |  |

Cash flow table for financing planning

Table 15-9/C

Low quality bauxite tube digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 8993 | 28291 | 13061 | 7383 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Financial resources total | 8993 | 28291 | 13061 | 1783 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -9061 | -28507 | -12923 | -5977 | -7970 | -7955 | -7940 | -8643 | -8628 | -8613 | -8598 | -8583 | -8568 |
| 1.Total assets schedule including replacement | -9061 | -28507 | -12923 | -1637 | 0 | 0 | 0 | -718 | -718 | -718 | -718 | -718 | -718 |
| 2.Operating costs | 0 | 0 | 0 | -4340 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 |
| 3.Debt service (total) | 0 | 0 | 0 | 0 | -450 | -435 | -420 | -405 | -390 | -375 | -360 | -345 | -330 |
| - Interest: | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| -Repayments: | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Surplus/deficit | -68 | -216 | 138 | 1406 | 3230 | 3245 | 3260 | 2557 | 2572 | 2587 | 2602 | 2617 | 2632 |
| D.Cumulative cash balance | -68 | -284 | -146 | 1260 | 4490 | 7735 | 10995 | 13552 | 16124 | 18711 | 21313 | 23930 | 26562 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 281728 |
| 1.Financial resources total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 52128 |
| 2.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | | 229600 |
| B.Cash outflow | -8553 | -8538 | -8523 | -8508 | -8493 | -8478 | -8463 | -8448 | -8433 | -8418 | -8403 | 6363 | -218861 |
| 1.Total assets schedule including replacement | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | 6363 | -57971 |
| 2.Operating costs | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | | -154740 |
| 3.Debt service (total) | -315 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 | -165 | | -6150 |
| - Interest: | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | 0 | -3150 |
| Suppliers' credits | | | | | | | | | | | | | 0 |
| Bank overdrafts | | | | | | | | | | | | | 0 |
| Bank term loans | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | | -3150 |
| -Repayments: | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | 0 | -3000 |
| Suppliers' credits | | | | | | | | | | | | | 0 |
| Bank overdrafts | | | | | | | | | | | | | 0 |
| Bank term loans | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | | -3000 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| C.Surplus/deficit | 2647 | 2662 | 2677 | 2692 | 2707 | 2722 | 2737 | 2752 | 2767 | 2782 | 2797 | 6363 | 62867 |
| D.Cumulative cash balance | 29209 | 31871 | 34548 | 37240 | 39947 | 42669 | 45406 | 48158 | 50925 | 53707 | 56504 | 62867 | |

Cash flow table for financing planning

Table 15-9/8

High quality bauxite autoclave digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 8359 | 26349 | 12027 | 6833 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Financial resources total | 8359 | 26349 | 12027 | 1233 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -8362 | -26359 | -11816 | -4463 | -5631 | -5616 | -5601 | -6231 | -6216 | -6201 | -6186 | -6171 | -6156 |
| 1.Total assets schedule including replacement | -8362 | -26359 | -11816 | -1431 | 0 | 0 | 0 | -645 | -645 | -645 | -645 | -645 | -645 |
| 2.Operating costs | 0 | 0 | 0 | -3032 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 |
| 3.Debt service (total) | 0 | 0 | 0 | 0 | -450 | -435 | -420 | -405 | -390 | -375 | -360 | -345 | -330 |
| - Interest: | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| -Repayments: | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Surplus/deficit | -3 | -10 | 211 | 2370 | 5569 | 5584 | 5599 | 4969 | 4984 | 4999 | 5014 | 5029 | 5044 |
| D.Cumulative cash balance | -3 | -13 | 198 | 2568 | 8137 | 13721 | 19320 | 24289 | 29273 | 34272 | 39286 | 44315 | 49359 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 277568 |
| 1.Financial resources total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 47968 |
| 2.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | | 229600 |
| B.Cash outflow | -6141 | -6126 | -6111 | -6096 | -6081 | -6066 | -6051 | -6036 | -6021 | -6006 | -5991 | 5630 | -166105 |
| 1.Total assets schedule including replacement | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | 5630 | -53303 |
| 2.Operating costs | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | | -106652 |
| 3.Debt service (total) | -315 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 | -165 | | -6150 |
| - Interest: | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | 0 | -3150 |
| Suppliers' credits | | | | | | | | | | | | | 0 |
| Bank overdrafts | | | | | | | | | | | | | 0 |
| Bank term loans | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | | -3150 |
| -Repayments: | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | 0 | -3000 |
| Suppliers' credits | | | | | | | | | | | | | 0 |
| Bank overdrafts | | | | | | | | | | | | | 0 |
| Bank term loans | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | | -3000 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| C.Surplus/deficit | 5059 | 5074 | 5089 | 5104 | 5119 | 5134 | 5149 | 5164 | 5179 | 5194 | 5209 | 5630 | 111463 |
| D.Cumulative cash balance | 54418 | 59492 | 64581 | 69685 | 74804 | 79938 | 85087 | 90251 | 95430 | 100624 | 105833 | 111463 | |

Cash flow table for financing planning

Table 15-9/E

High quality bauxite tube digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 8072 | 25279 | 11551 | 7116 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Financial resources total | 8072 | 25279 | 11551 | 1516 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -8125 | -25444 | -11437 | -4389 | -5550 | -5535 | -5520 | -6145 | -6130 | -6115 | -6100 | -6085 | -6070 |
| 1.Total assets schedule including replacement | -8125 | -25444 | -11437 | -1412 | 0 | 0 | 0 | -640 | -640 | -640 | -640 | -640 | -640 |
| 2.Operating costs | 0 | 0 | 0 | -2977 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 |
| 3.Debt service (total) | 0 | 0 | 0 | 0 | -450 | -435 | -420 | -405 | -390 | -375 | -360 | -345 | -330 |
| - Interest: | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| -Repayments: | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| Suppliers' credits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank overdrafts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bank term loans | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Surplus/deficit | -53 | -165 | 114 | 2727 | 5650 | 5665 | 5680 | 5055 | 5070 | 5085 | 5100 | 5115 | 5130 |
| D.Cumulative cash balance | -53 | -218 | -104 | 2623 | 8273 | 13938 | 19618 | 24673 | 29743 | 34828 | 39928 | 45043 | 50173 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 276018 |
| 1.Financial resources total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 46418 |
| 2.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | | 229600 |
| B.Cash outflow | -6055 | -6040 | -6025 | -6010 | -5995 | -5980 | -5965 | -5950 | -5935 | -5920 | -5905 | 5573 | -162852 |
| 1.Total assets schedule including replacement | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | 5573 | -51725 |
| 2.Operating costs | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | | -104977 |
| 3.Debt service (total) | -315 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 | -165 | | -6150 |
| - Interest: | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | 0 | -3150 |
| Suppliers' credits | | | | | | | | | | | | | 0 |
| Bank overdrafts | | | | | | | | | | | | | 0 |
| Bank term loans | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | | -3150 |
| -Repayments: | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | 0 | -3000 |
| Suppliers' credits | | | | | | | | | | | | | 0 |
| Bank overdrafts | | | | | | | | | | | | | 0 |
| Bank term loans | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | | -3000 |
| 4.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 5.Dividends on equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| C.Surplus/deficit | 5145 | 5160 | 5175 | 5190 | 5205 | 5220 | 5235 | 5250 | 5265 | 5280 | 5295 | 5573 | 113166 |
| D.Cumulative cash balance | 55318 | 60478 | 65653 | 70843 | 76048 | 81268 | 86503 | 91753 | 97018 | 102298 | 107593 | 113166 | |

Projected balance sheet

Table 15-10/A

Low quality bauxite sintering process

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 13520 | 55997 | 74729 | 76909 | 76759 | 76609 | 76459 | 76309 | 76159 | 76009 | 75859 | 75709 | 75559 |
| 1.Current assets | -91 | -378 | 2796 | 5237 | 8812 | 12402 | 16007 | 18642 | 21292 | 23957 | 26637 | 29332 | 32042 |
| (a) Accumulated cash balance | -91 | -378 | -172 | 1444 | 5019 | 8609 | 12214 | 14849 | 17499 | 20164 | 22844 | 25539 | 28249 |
| (b) Current assets | 0 | 0 | 2968 | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 |
| 2.Fixed assets | | | | | | | | | | | | | |
| (net of depreciation) Initial fixed investment, replacement and preproduction capital expenditures | 13611 | 56375 | 71933 | 70888 | 66341 | 61794 | 57247 | 53685 | 50123 | 46561 | 42999 | 39437 | 35875 |
| 3.Losses | 0 | 0 | 0 | 784 | 1606 | 2413 | 3205 | 3982 | 4744 | 5491 | 6223 | 6940 | 7642 |
| B.Liabilities | 13520 | 55997 | 74729 | 76909 | 76759 | 76609 | 76459 | 76309 | 76159 | 76009 | 75859 | 75709 | 75559 |
| 1.Current liability | 0 | 0 | 134 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 |
| 2.Medium-term loans | 529 | 2192 | 2920 | 3000 | 2850 | 2700 | 2550 | 2400 | 2250 | 2100 | 1950 | 1800 | 1650 |
| 3.Paid up equity | 12991 | 53805 | 71675 | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 75409 | 75259 | 75109 | 74959 | 74809 | 74659 | 74509 | 74359 | 74209 | 74059 | 73909 |
| 1.Current assets | 34767 | 37507 | 40262 | 43032 | 45817 | 48617 | 51432 | 54262 | 57107 | 59967 | 62842 |
| (a) Accumulated cash balance | 30974 | 33714 | 36469 | 39239 | 42024 | 44824 | 47639 | 50469 | 53314 | 56174 | 59049 |
| (b) Current assets | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 | 3793 |
| 2.Fixed assets | | | | | | | | | | | |
| (net of depreciation) Initial fixed investment, replacement and preproduction capital expenditures | 32313 | 28751 | 25189 | 21627 | 18065 | 14503 | 10941 | 7379 | 3817 | 255 | -3307 |
| 3.Losses | 8329 | 9001 | 9658 | 10300 | 10927 | 11539 | 12136 | 12718 | 13285 | 13837 | 14374 |
| B.Liabilities | 75409 | 75259 | 75109 | 74959 | 74809 | 74659 | 74509 | 74359 | 74209 | 74059 | 73909 |
| 1.Current liability | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 | 248 |
| 2.Medium-term loans | 1500 | 1350 | 1200 | 1050 | 900 | 750 | 600 | 450 | 300 | 150 | 0 |
| 3.Paid up equity | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 | 73661 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Projected balance sheet

Table 15-10/E

Low quality bauxite autoclave digestion

Exchange rate RLS 200 per US$

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 9046 | 37565 | 50733 | 52545 | 52395 | 52245 | 52095 | 52126 | 52199 | 52287 | 52370 | 52508 | 52641 |
| 1.Current assets | -78 | -324 | 2138 | 4280 | 7387 | 10509 | 13646 | 16088 | 18545 | 21017 | 23504 | 26006 | 28523 |
| (a) Accumulated cash balance | -78 | -324 | -167 | 1176 | 4283 | 7405 | 10542 | 12984 | 15441 | 17913 | 20400 | 22902 | 25419 |
| (b) Current assets | 0 | 0 | 2305 | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 |
| 2.Fixed assets (net of depreciation) Initial fixed investment, replacement and preproduction capital expenditures | 9124 | 37889 | 48595 | 47704 | 44610 | 41516 | 38422 | 36038 | 33654 | 31270 | 28886 | 26502 | 24118 |
| 3.Losses | 0 | 0 | 0 | 561 | 398 | 220 | 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| B.Liabilities | 9046 | 37565 | 50733 | 52545 | 52395 | 52245 | 52095 | 52126 | 52199 | 52287 | 52370 | 52508 | 52641 |
| 1.Current liability | 0 | 0 | 140 | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 |
| 2.Medium-term loans | 519 | 2155 | 2902 | 3000 | 2850 | 2700 | 2550 | 2400 | 2250 | 2100 | 1950 | 1800 | 1650 |
| 3.Paid up equity | 8527 | 35410 | 47691 | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 181 | 404 | 642 | 875 | 1163 | 1446 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 52789 | 52952 | 53130 | 53323 | 53531 | 53754 | 53992 | 54245 | 54513 | 54796 | 55094 |
| 1.Current assets | 31055 | 33602 | 36164 | 38741 | 41333 | 43940 | 46562 | 49199 | 51851 | 54518 | 57200 |
| (a) Accumulated cash balance | 27951 | 30498 | 33060 | 35637 | 38229 | 40836 | 43458 | 46095 | 48747 | 51414 | 54096 |
| (b) Current assets | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 | 3104 |
| 2.Fixed assets (net of depreciation) Initial fixed investment, replacement and preproduction capital expenditures | 21734 | 19350 | 16966 | 14582 | 12198 | 9814 | 7430 | 5046 | 2662 | 278 | -2106 |
| 3.Losses | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B.Liabilities | 52789 | 52952 | 53130 | 53323 | 53531 | 53754 | 53992 | 54245 | 54513 | 54796 | 55094 |
| 1.Current liability | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 | 258 |
| 2.Medium-term loans | 1500 | 1350 | 1200 | 1050 | 900 | 750 | 600 | 450 | 300 | 150 | 0 |
| 3.Paid up equity | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 | 49287 |
| 4.Retained profits | 1744 | 2057 | 2385 | 2728 | 3086 | 3459 | 3847 | 4250 | 4668 | 5101 | 5549 |

Projected balance sheet

Table 15-10/C

Low quality bauxite tube digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 8993 | 37284 | 50345 | 52128 | 51978 | 51934 | 52151 | 52383 | 52630 | 52892 | 53169 | 53461 | 53768 |
| 1.Current assets | -68 | -294 | 2145 | 4349 | 7579 | 10824 | 14084 | 16641 | 19213 | 21800 | 24402 | 27019 | 29651 |
| (a) Accumulated cash balance | -68 | -284 | -146 | 1260 | 4490 | 7735 | 10995 | 13552 | 16124 | 18711 | 21313 | 23930 | 26562 |
| (b) Current assets | 0 | 0 | 2291 | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 |
| 2.Fixed assets (net of depreciation) Initial fixed investment, replacement and preproduction capital expenditures | 9061 | 37568 | 48200 | 47196 | 44153 | 41110 | 38067 | 35742 | 33417 | 31092 | 28767 | 26442 | 24117 |
| 3.Losses | 0 | 0 | 0 | 583 | 246 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B.Liabilities (total) | 8993 | 37284 | 50345 | 52128 | 51978 | 51934 | 52151 | 52383 | 52630 | 52892 | 53169 | 53461 | 53768 |
| 1.Current liability | 0 | 0 | 141 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 |
| 2.Medium-term loans | 520 | 2156 | 2903 | 3000 | 2850 | 2700 | 2550 | 2400 | 2250 | 2100 | 1950 | 1800 | 1650 |
| 3.Paid up equity | 8473 | 35128 | 47301 | 48868 | 48858 | 48868 | 48868 | 48868 | 48868 | 48868 | 48868 | 48868 | 48868 |
| 4.Retained profits | 0 | 0 | 0 | 0 | 0 | 106 | 473 | 855 | 1252 | 1664 | 2091 | 2533 | 2990 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 54090 | 54427 | 54779 | 55146 | 55528 | 55925 | 56337 | 56764 | 57206 | 57663 | 58135 |
| 1.Current assets | 32298 | 34960 | 37637 | 40329 | 43036 | 45758 | 48495 | 51247 | 54014 | 56796 | 59593 |
| (a) Accumulated cash balance | 29209 | 31871 | 34548 | 37240 | 39947 | 42669 | 45406 | 48158 | 50925 | 53707 | 56504 |
| (b) Current assets | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 | 3089 |
| 2.Fixed assets (net of depreciation) Initial fixed investment, replacement and preproduction capital expenditures | 21792 | 19467 | 17142 | 14817 | 12492 | 10167 | 7842 | 5517 | 3192 | 867 | -1458 |
| 3.Losses | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B.Liabilities | 54090 | 54427 | 54779 | 55146 | 55528 | 55925 | 56337 | 56764 | 57206 | 57663 | 58135 |
| 1.Current liability | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 |
| 2.Medium-term loans | 1500 | 1350 | 1200 | 1050 | 900 | 750 | 600 | 450 | 300 | 150 | 0 |
| 3.Paid up equity | 48868 | 48868 | 48868 | 48868 | 48868 | 48868 | 48868 | 48868 | 48868 | 48868 | 48868 |
| 4.Retained profits | 3462 | 3949 | 4451 | 4968 | 5500 | 6047 | 6609 | 7186 | 7778 | 8385 | 9007 |

Projected balance sheet

Table 15-10/D

High quality bauxite autoclave digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 8359 | 34708 | 46735 | 48833 | 51565 | 54312 | 57074 | 59851 | 62643 | 65450 | 68272 | 71109 | 73961 |
| 1.Current assets | -3 | -13 | 2182 | 5186 | 10755 | 16339 | 21938 | 26907 | 31891 | 36890 | 41904 | 46933 | 51977 |
| (a) Accumulated cash balance | -3 | -13 | 198 | 2568 | 8137 | 13721 | 19320 | 24289 | 29273 | 34272 | 39286 | 44315 | 49359 |
| (b) Current assets | 0 | 0 | 1984 | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 |
| 2.Fixed assets | | | | | | | | | | | | | |
| (net of depreciation) | 8362 | 34721 | 44553 | 43647 | 40810 | 37973 | 35136 | 32944 | 30752 | 28560 | 26368 | 24176 | 21984 |
| Initial fixed investment, replacement and preproduction capital expenditures | | | | | | | | | | | | | |
| 3.Losses | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B.Liabilities (total) | 8359 | 34708 | 46735 | 48833 | 51565 | 54312 | 57074 | 59851 | 62643 | 65450 | 68272 | 71109 | 73961 |
| 1.Current liability | 0 | 0 | 87 | -163 | -163 | -163 | -163 | -163 | -163 | -163 | -163 | -163 | -163 |
| 2.Medium-term loans | 521 | 2163 | 2907 | 3000 | 2850 | 2700 | 2550 | 2400 | 2250 | 2100 | 1950 | 1800 | 1650 |
| 3.Paid up equity | 7838 | 32545 | 43741 | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 |
| 4.Retained profits | 0 | 0 | 0 | 865 | 3747 | 6644 | 9556 | 12483 | 15425 | 18382 | 21354 | 24341 | 27343 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 76828 | 79710 | 82607 | 85519 | 88446 | 91388 | 94345 | 97317 | 100304 | 103306 | 106323 |
| 1.Current assets | 57036 | 62110 | 67199 | 72303 | 77422 | 82556 | 87705 | 92869 | 98048 | 103242 | 108451 |
| (a) Accumulated cash balance | 54418 | 59492 | 64581 | 69685 | 74804 | 79938 | 85087 | 90251 | 95430 | 100624 | 105833 |
| (b) Current assets | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 | 2618 |
| 2.Fixed assets | | | | | | | | | | | |
| (net of depreciation) | 19792 | 17600 | 15408 | 13216 | 11024 | 8832 | 6640 | 4448 | 2256 | 64 | -2128 |
| Initial fixed investment, replacement and preproduction capital expenditures | | | | | | | | | | | |
| 3.Losses | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B.Liabilities | 76828 | 79710 | 82607 | 85519 | 88446 | 91388 | 94345 | 97317 | 100304 | 103306 | 106323 |
| 1.Current liability | -163 | -163 | -163 | -163 | -163 | -163 | -163 | -163 | -163 | -163 | -163 |
| 2.Medium-term loans | 1500 | 1350 | 1200 | 1050 | 900 | 750 | 600 | 450 | 300 | 150 | 0 |
| 3.Paid up equity | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 | 45131 |
| 4.Retained profits | 30360 | 33392 | 36439 | 39501 | 42578 | 45670 | 48777 | 51899 | 55036 | 58188 | 61355 |

Projected balance sheet

Table 15-10/E

High quality bauxite tube digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 8072 | 33351 | 44902 | 47419 | 50367 | 53330 | 56308 | 59301 | 62309 | 65332 | 68370 | 71423 | 74491 |
| 1.Current assets | -53 | -218 | 1823 | 5176 | 10826 | 16491 | 22171 | 27226 | 32296 | 37381 | 42481 | 47596 | 52726 |
| (a) Accumulated cash balance | -53 | -218 | -104 | 2623 | 8273 | 13938 | 19618 | 24673 | 29743 | 34828 | 39928 | 45043 | 50173 |
| (b) Current assets | 0 | 0 | 1927 | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 |
| 2.Fixed assets | | | | | | | | | | | | | |
| (net of depreciation) | 8125 | 33569 | 43079 | 42243 | 39541 | 36839 | 34137 | 32075 | 30013 | 27951 | 25889 | 23827 | 21765 |
| Initial fixed investment, replacement and preproduction capital expenditures | | | | | | | | | | | | | |
| 3.Losses | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B.Liabilities (total) | 8072 | 33351 | 44902 | 47419 | 50367 | 53330 | 56308 | 59301 | 62309 | 65332 | 68370 | 71423 | 74491 |
| 1.Current liability | 0 | 0 | 86 | 161 | 161 | 161 | 161 | 161 | 161 | 161 | 161 | 161 | 161 |
| 2.Medium-term loans | 523 | 2162 | 2906 | 3000 | 2950 | 2700 | 2550 | 2400 | 2250 | 2100 | 1950 | 1800 | 1650 |
| 3.Paid up equity | 7549 | 31189 | 41910 | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 |
| 4.Retained profits | 0 | 0 | 0 | 1001 | 4099 | 7212 | 10340 | 13483 | 16641 | 19814 | 23002 | 26205 | 29423 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Assets (total) | 77574 | 80672 | 83785 | 86913 | 90056 | 93214 | 96387 | 99575 | 102778 | 105996 | 109229 |
| 1.Current assets | 57871 | 63031 | 68206 | 73396 | 78601 | 83821 | 89056 | 94306 | 99571 | 104851 | 110146 |
| (a) Accumulated cash balance | 55318 | 60478 | 65653 | 70843 | 76048 | 81268 | 86503 | 91753 | 97018 | 102298 | 107593 |
| (b) Current assets | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 | 2553 |
| 2.Fixed assets | | | | | | | | | | | |
| (net of depreciation) | 19703 | 17641 | 15579 | 13517 | 11455 | 9393 | 7331 | 5269 | 3207 | 1145 | -917 |
| Initial fixed investment, replacement and preproduction capital expenditures | | | | | | | | | | | |
| 3.Losses | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B.Liabilities | 77574 | 80672 | 83785 | 86913 | 90056 | 93214 | 96387 | 99575 | 102778 | 105996 | 109229 |
| 1.Current liability | 161 | 161 | 161 | 161 | 161 | 161 | 161 | 161 | 161 | 161 | 161 |
| 2.Medium-term loans | 1500 | 1350 | 1200 | 1050 | 900 | 750 | 600 | 450 | 300 | 150 | 0 |
| 3.Paid up equity | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 | 43257 |
| 4.Retained profits | 32656 | 35904 | 39167 | 42445 | 45738 | 49046 | 52369 | 55707 | 59060 | 62428 | 65811 |

Cash Flow table for project Table 15-11/A

Low quality bauxite sintering process Exchange rate RLS 200 per USD million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -13611 | -42764 | -18392 | -6050 | -7175 | -7175 | -7175 | -8160 | -8160 | -8160 | -8160 | -8160 | -8160 |
| 1.Total investment outlay | -13611 | -42764 | -18392 | -1894 | 0 | 0 | 0 | -985 | -985 | -985 | -985 | -985 | -985 |
| 2.Operating costs | 0 | 0 | 0 | -4156 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -13611 | -42764 | -18392 | -450 | 4025 | 4025 | 4025 | 3040 | 3040 | 3040 | 3040 | 3040 | 3040 |
| D.Cumulative net cash flow | -13611 | -56375 | -74767 | -75217 | -71192 | -67167 | -63142 | -60102 | -57062 | -54022 | -50982 | -47942 | -44902 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 229600 |
| 1.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | | 229600 |
| B.Cash outflow | -8160 | -8160 | -8160 | -8160 | -8160 | -8160 | -8160 | -8160 | -8160 | -8160 | -8160 | 8382 | -232680 |
| 1.Total investment outlay | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | 8382 | -85024 |
| 2.Operating costs | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | | -147656 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| C.Net cash flow | 3040 | 3040 | 3040 | 3040 | 3040 | 3040 | 3040 | 3040 | 3040 | 3040 | 3040 | 8382 | -3080 |
| D.Cumulative net cash flow | -41862 | -38822 | -35782 | -32742 | -29702 | -26662 | -23622 | -20582 | -17542 | -14502 | -11462 | -3080 | |

Table 15-11/B

## Cash Flow table for project

Low quality bauxite autoclave digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -9124 | -28765 | -12871 | -5951 | -7643 | -7643 | -7643 | -8353 | -8353 | -8353 | -8353 | -8353 | -8353 |
| 1.Total investment outlay | -9124 | -28765 | -12871 | -1527 | 0 | 0 | 0 | -710 | -710 | -710 | -710 | -710 | -710 |
| 2.Operating costs | 0 | 0 | 0 | -4424 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -9124 | -28765 | -12871 | -351 | 3557 | 3557 | 3557 | 2847 | 2847 | 2847 | 2847 | 2847 | 2847 |
| D.Cumulative net cash flow | -9124 | -37889 | -50760 | -51111 | -47554 | -43997 | -40440 | -37593 | -34746 | -31899 | -29052 | -26205 | -23358 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 229600 |
| 1.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |  | 229600 |
| B.Cash outflow | -8353 | -8353 | -8353 | -8353 | -8353 | -8353 | -8353 | -8353 | -8353 | -8353 | -8353 | 6302 | -215339 |
| 1.Total investment outlay | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | 6302 | -58055 |
| 2.Operating costs | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 |  | -157284 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |  |
| C.Net cash flow | 2847 | 2847 | 2847 | 2847 | 2847 | 2847 | 2847 | 2847 | 2847 | 2847 | 2847 | 6302 | 14261 |
| D.Cumulative net cash flow | -20511 | -17664 | -14817 | -11970 | -9123 | -6276 | -3429 | -582 | 2265 | 5112 | 7959 | 14261 |  |

Cash Flow table for project Table 15-11/C

Low quality bauxite tube digestion Exchange rate RLS 200 per USD million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -9061 | -28507 | -12782 | -5858 | -7520 | -7520 | -7520 | -8238 | -8238 | -8238 | -8238 | -8238 | -8238 |
| 1.Total investment outlay | -9061 | -28507 | -12782 | -1518 | 0 | 0 | 0 | -718 | -718 | -718 | -718 | -718 | -718 |
| 2.Operating costs | 0 | 0 | 0 | -4340 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -9061 | -28507 | -12782 | -258 | 3680 | 3680 | 3680 | 2962 | 2962 | 2962 | 2962 | 2962 | 2962 |
| D.Cumulative net cash flow | -9061 | -37568 | -50350 | -50608 | -46928 | -43248 | -39568 | -36606 | -33644 | -30682 | -27720 | -24758 | -21796 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 229600 |
| 1.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | | 229600 |
| B.Cash outflow | -8238 | -8238 | -8238 | -8238 | -8238 | -8238 | -8238 | -8238 | -8238 | -8238 | -8238 | 6363 | -212451 |
| 1.Total investment outlay | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | 6363 | -57711 |
| 2.Operating costs | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | | -154740 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| C.Net cash flow | 2962 | 2962 | 2962 | 2962 | 2962 | 2962 | 2962 | 2962 | 2962 | 2962 | 2962 | 6363 | 17149 |
| D.Cumulative net cash flow | -18834 | -15872 | -12910 | -9948 | -6986 | -4024 | -1062 | 1900 | 4862 | 7824 | 10786 | 17149 | |

Cash Flow table for project

Table 15-11/D

High quality bauxite autoclave digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -8362 | -26359 | -11729 | -4713 | -5181 | -5181 | -5181 | -5826 | -5826 | -5826 | -5826 | -5826 | -5826 |
| 1.Total investment outlay | -8362 | -26359 | -11729 | -1681 | 0 | 0 | 0 | -645 | -645 | -645 | -645 | -645 | -645 |
| 2.Operating costs | 0 | 0 | 0 | -3032 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -8362 | -26359 | -11729 | 887 | 6019 | 6019 | 6019 | 5374 | 5374 | 5374 | 5374 | 5374 | 5374 |
| D.Cumulative net cash flow | -8362 | -34721 | -46450 | -45563 | -39544 | -33525 | -27506 | -22132 | -16758 | -11384 | -6010 | -636 | 4738 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 229600 |
| 1.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | | 229600 |
| B.Cash outflow | -5826 | -5826 | -5826 | -5826 | -5826 | -5826 | -5826 | -5826 | -5826 | -5826 | -5826 | 5630 | -160118 |
| 1.Total investment outlay | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | 5630 | -53466 |
| 2.Operating costs | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | | -106652 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| C.Net cash flow | 5374 | 5374 | 5374 | 5374 | 5374 | 5374 | 5374 | 5374 | 5374 | 5374 | 5374 | 5630 | 69482 |
| D.Cumulative net cash flow | 10112 | 15486 | 20860 | 26234 | 31608 | 36982 | 42356 | 47730 | 53104 | 58478 | 63852 | 69482 | |

Cash Flow table for project Table 15-11/E

High quality bauxite tube digestion Exchange rate RLS 200 per USD million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -8125 | -25444 | -11351 | -4314 | -5100 | -5100 | -5100 | -5740 | -5740 | -5740 | -5740 | -5740 | -5740 |
| 1.Total investment outlay | -8125 | -25444 | -11351 | -1337 | 0 | 0 | 0 | -640 | -640 | -640 | -640 | -640 | -640 |
| 2.Operating costs | 0 | 0 | 0 | -2977 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -8125 | -25444 | -11351 | 1286 | 6100 | 6100 | 6100 | 5460 | 5460 | 5460 | 5460 | 5460 | 5460 |
| D.Cumulative net cash flow | -8125 | -33569 | -44920 | -43634 | -37534 | -31434 | -25334 | -19874 | -14414 | -8954 | -3494 | 1966 | 7426 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 229600 |
| 1.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |  | 229600 |
| B.Cash outflow | -5740 | -5740 | -5740 | -5740 | -5740 | -5740 | -5740 | -5740 | -5740 | -5740 | -5740 | 5573 | -156541 |
| 1.Total investment outlay | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | 5573 | -51564 |
| 2.Operating costs | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 |  | -104977 |
| 3.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |  |
| C.Net cash flow | 5460 | 5460 | 5460 | 5460 | 5460 | 5460 | 5460 | 5460 | 5460 | 5460 | 5460 | 5573 | 73059 |
| D.Cumulative net cash flow | 12886 | 18346 | 23806 | 29266 | 34726 | 40186 | 45646 | 51106 | 56566 | 62026 | 67486 | 73059 |  |

Cash Flow table for equity Table 15-12/A

Low quality Bauxite sintering process Exchange rate RLS 200 per USD million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -12791 | -40814 | -17870 | -6142 | -7625 | -7610 | -7595 | -8565 | -8550 | -8535 | -8520 | -8505 | -8490 |
| 1.Total equity | -12791 | -40814 | -17870 | -1986 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -985 | -985 | -985 | -985 | -985 | -985 |
| 3.Repayment of outside financing | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Interest on outside financing | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| 5.Operating costs | 0 | 0 | 0 | -4156 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -12791 | -40814 | -17870 | -542 | 3575 | 3590 | 3605 | 2635 | 2650 | 2665 | 2680 | 2695 | 2710 |
| D.Cumulative net cash flow | -12791 | -53805 | -71675 | -72217 | -68642 | -65052 | -61447 | -58812 | -56162 | -53497 | -50817 | -48122 | -45412 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 229600 |
| 1.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | | 229600 |
| B.Cash outflow | -8475 | -8460 | -8445 | -8430 | -8415 | -8400 | -8385 | -8370 | -8355 | -8340 | -8325 | 8382 | -235830 |
| 1.Total equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8382 | -65279 |
| 2.Replacement | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | -985 | | -16745 |
| 3.Repayment of outside financing | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | | -3000 |
| 4.Interest on outside financing | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | | -3150 |
| 5.Operating costs | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | -7175 | | -147656 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| C.Net cash flow | 2725 | 2740 | 2755 | 2770 | 2785 | 2800 | 2815 | 2830 | 2845 | 2860 | 2875 | 8382 | -6230 |
| D.Cumulative net cash flow | -42687 | -39947 | -37192 | -34422 | -31637 | -28837 | -26022 | -23192 | -20347 | -17487 | -14612 | -6230 | |

Cash Flow table for equity Table 15-12/B

Low quality bauxite autoclave digestion Exchange rate RLS 200 per USD million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -8527 | -26883 | -12281 | -6020 | -8093 | -8078 | -8063 | -8758 | -8743 | -8728 | -8713 | -8698 | -8683 |
| 1.Total equity | -8527 | -26883 | -12281 | -1596 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -710 | -710 | -710 | -710 | -710 | -710 |
| 3.Repayment of outside financing | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Interest on outside financing | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| 5.Operating costs | 0 | 0 | 0 | -4424 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -8527 | -26883 | -12281 | -420 | 3107 | 3122 | 3137 | 2442 | 2457 | 2472 | 2487 | 2502 | 2517 |
| D.Cumulative net cash flow | -8527 | -35410 | -47691 | -48111 | -45004 | -41882 | -38745 | -36303 | -33846 | -31374 | -28887 | -26385 | -23868 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 229600 |
| 1.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | | 229600 |
| B.Cash outflow | -8668 | -8653 | -8638 | -8623 | -8608 | -8593 | -8578 | -8563 | -8548 | -8533 | -8518 | 6302 | -216489 |
| 1.Total equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6302 | -42985 |
| 2.Replacement | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | -710 | | -12070 |
| 3.Repayment of outside financing | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | | -3000 |
| 4.Interest on outside financing | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 | | -3150 |
| 5.Operating costs | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | -7643 | | -157284 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| C.Net cash flow | 2532 | 2547 | 2562 | 2577 | 2592 | 2607 | 2622 | 2637 | 2652 | 2667 | 2682 | 6302 | 11111 |
| D.Cumulative net cash flow | -21336 | -18789 | -16227 | -13650 | -11058 | -8451 | -5829 | -3192 | -540 | 2127 | 4809 | 11111 | |

Cash Flow table for equity Table 15-12/C

Low quality bauxite tube digestion Exchange rate RLS 200 per US$ million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -8473 | -26655 | -12173 | -5907 | -7970 | -7955 | -7940 | -8643 | -8628 | -8613 | -8598 | -8583 | -8568 |
| 1.Total equity | -8473 | -26655 | -12173 | -1567 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -718 | -718 | -718 | -718 | -718 | -718 |
| 3.Repayment of outside financing | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Interest on outside financing | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| 5.Operating costs | 0 | 0 | 0 | -4340 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -8473 | -26655 | -12173 | -307 | 3230 | 3245 | 3260 | 2557 | 2572 | 2587 | 2602 | 2617 | 2632 |
| D.Cumulative net cash flow | -8473 | -35128 | -47301 | -47608 | -44378 | -41133 | -37873 | -35316 | -32744 | -30157 | -27555 | -24938 | -22306 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 229600 |
| 1.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |  | 229600 |
| B.Cash outflow | -8553 | -8538 | -8523 | -8508 | -8493 | -8478 | -8463 | -8448 | -8433 | -8418 | -8403 | 6363 | -215601 |
| 1.Total equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6363 | -42505 |
| 2.Replacement | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 | -718 |  | -12206 |
| 3.Repayment of outside financing | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Interest on outside financing | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| 5.Operating costs | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 | -7520 |  | -154740 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Net cash flow | 2647 | 2662 | 2677 | 2692 | 2707 | 2722 | 2737 | 2752 | 2767 | 2782 | 2797 | 6363 | 13999 |
| D.Cumulative net cash flow | -19659 | -16997 | -14320 | -11628 | -8921 | -6199 | -3462 | -710 | 2057 | 4839 | 7636 | 13999 |  |

Cash Flow table for equity

Table 15-12/B

High quality bauxite autoclave digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -7838 | -24707 | -11196 | -4422 | -5631 | -5616 | -5601 | -6231 | -6216 | -6201 | -6186 | -6171 | -6156 |
| 1.Total equity | -7838 | -24707 | -11196 | -1390 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -645 | -645 | -645 | -645 | -645 | -645 |
| 3.Repayment of outside financing | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Interest on outside financing | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| 5.Operating costs | 0 | 0 | 0 | -3032 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -7838 | -24707 | -11196 | 1178 | 5569 | 5584 | 5599 | 4969 | 4984 | 4999 | 5014 | 5029 | 5044 |
| D.Cumulative net cash flow | -7838 | -32545 | -43741 | -42563 | -36994 | -31410 | -25811 | -20842 | -15858 | -10859 | -5845 | -816 | 4228 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 229600 |
| 1.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |  | 229600 |
| B.Cash outflow | -6141 | -6126 | -6111 | -6096 | -6081 | -6066 | -6051 | -6036 | -6021 | -6006 | -5991 | 5630 | -163268 |
| 1.Total equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5630 | -39501 |
| 2.Replacement | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 | -645 |  | -10965 |
| 3.Repayment of outside financing | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Interest on outside financing | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| 5.Operating costs | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 | -5181 |  | -106652 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Net cash flow | 5059 | 5074 | 5089 | 5104 | 5119 | 5134 | 5149 | 5164 | 5179 | 5194 | 5209 | 5630 | 66332 |
| D.Cumulative net cash flow | 9287 | 14361 | 19450 | 24554 | 29673 | 34807 | 39956 | 45120 | 50299 | 55493 | 60702 | 66332 |  |

Cash Flow table for equity

Table 15-12/E

High quality bauxite tube digestion

Exchange rate RLS 200 per USD

million of Rls

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| 1.Sales revenue | 0 | 0 | 0 | 5600 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |
| B.Cash outflow | -7549 | -23640 | -10721 | -4324 | -5550 | -5535 | -5520 | -6145 | -6130 | -6115 | -6100 | -6085 | -6070 |
| 1.Total equity | -7549 | -23640 | -10721 | -1347 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.Replacement | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -640 | -640 | -640 | -640 | -640 | -640 |
| 3.Repayment of outside financing | 0 | 0 | 0 | 0 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |
| 4.Interest on outside financing | 0 | 0 | 0 | 0 | -300 | -285 | -270 | -255 | -240 | -225 | -210 | -195 | -180 |
| 5.Operating costs | 0 | 0 | 0 | -2977 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C.Net cash flow | -7549 | -23640 | -10721 | 1276 | 5650 | 5665 | 5680 | 5055 | 5070 | 5085 | 5100 | 5115 | 5130 |
| D.Cumulative net cash flow | -7549 | -31189 | -41910 | -40634 | -34984 | -29319 | -23639 | -18584 | -13514 | -8429 | -3329 | 1786 | 6916 |

| Year | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Salv.val. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.Cash inflow | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 0 | 229600 |
| 1.Sales revenue | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 | 11200 |  | 229600 |
| B.Cash outflow | -6055 | -6040 | -6025 | -6010 | -5995 | -5980 | -5965 | -5950 | -5935 | -5920 | -5905 | 5573 | -159691 |
| 1.Total equity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5573 | -37684 |
| 2.Replacement | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 | -640 |  | -10880 |
| 3.Repayment of outside financing | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 | -150 |  | -3000 |
| 4.Interest on outside financing | -165 | -150 | -135 | -120 | -105 | -90 | -75 | -60 | -45 | -30 | -15 |  | -3150 |
| 5.Operating costs | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 | -5100 |  | -104977 |
| 6.Corporate tax | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  | 0 |
| C.Net cash flow | 5145 | 5160 | 5175 | 5190 | 5205 | 5220 | 5235 | 5250 | 5265 | 5280 | 5295 | 5573 | 69909 |
| D.Cumulative net cash flow | 12061 | 17221 | 22396 | 27586 | 32791 | 38011 | 43246 | 48496 | 53761 | 59041 | 64336 | 69909 |  |

# 16. ENVIRONMENT CONTROL

## 16. ENVIRONMENT CONTROL

To the region of Jajarm the bauxite mining has no dangerous side-effects.

Contrary to this the "red-mud" as a side-product in the process of alumina production represents a considerable danger to that underground-water resources which supply drinking and irrigation water to regions of considerable extension - if it can filter into the loose sedimentary rocks on the surface or close to it.

To avoid the hazards of red-mud disposal in ponds it is highly recommended to choose topographical depressions ("closed valleys" preferably) in impermeable rocks to dispose the mud. Terrains formed by the lower parts of the Shemshak-Formation or volcanic rocks like basalt and its tuffs are suitable to this purpose. Anyhow, a thorough geological, hydrogeological and soil-engineering research is to be done in order to select the proper site.

However, contamination of underground waters by the caustic can be prevented by using the technology of "dry-red-mud" disposal. This technology is used in one Hungarian alumina plant (Magyaróvár Alumina Plant), and it is used in some other alumina plants as well. For the Bayer process variants the "dry-red-mud" disposal is envisaged.

# 17. EFFECT OF CHANGES IN BAUXITE QUALITY ON THE SPECIFIC CONSUMPTIONS AND PRODUCTION COSTS AS WELL AS THE TOTAL INVESTMENT COSTS IN THE FUNCTION OF THE PLANT CAPACITY

# 17. EFFECT OF CHANGES IN BAUXITE QUALITY ON THE SPECIFIC CONSUMPTIONS AND PRODUCTION COSTS AS WELL AS THE TOTAL INVESTMENT COSTS IN THE FUNCTION OF THE PLANT CAPACITY

At the present phase of the bauxite prospecting - as it was stated before - the average composition of the bauxite to be processed and the adequate plant capacity can not be determined yet. The selected plant capacity (200,000 tons per year) may be less and the expected bauxite quality to be processed may vary between the studied values (modulus 3.77 and 6.89) in the next phase of the project realization (Feasibility Study phase).

In order to facilitate the decision making we have made some informative calculations on the investment and production costs in the function of the plant capacity (from 75,000 t/y to 200,000 t/y) and that of the bauxite modulus (between 3.77 and 6.89).

In the calculations the following bauxite qualities were taken into consideration.

| | ICS-2 | ICS-3 | (calculated values) |
|---|---|---|---|
| $Al_2O_3$ | 52.4 | 44.2 | 48.3 |
| $SiO_2$ | 7.6 | 11.7 | 9.6 |
| Modul, $Al_2O_3/SiO_2$ | 6.89 | 3.77 | 5.0 |

It is important to point out that with the increasing modulus the $Al_2O_3$ content is increasing significantly, too while the $SiO_2$ content is decreasing.

It should be emphasized that in these cases (when the $Al_2O_3$ content is changing significantly) the modulus of the bauxite ($Al_2O_3$ to $SiO_2$ ratio) is not sufficient to characterize the bauxite quality. From technological point of view one of the best characteristic index for the bauxite quality is the available $Al_2O_3$ content which is approximately the difference of the $Al_2O_3$ and $SiO_2$ contents.

In this interpretation the following available alumina contents ($Al_2O_3$-$SiO_2$) belong to the above considered bauxite modulus:

| Modulus | Available alumina, %<br>($Al_2O_3$ % - $SiO_2$ %) |
|---|---|
| 3.77 | 32.5 |
| 5.0 | 38.7 |
| 6.89 | 44.8 |

The investigation of the effect of the bauxite quality on the investment and production costs was studied in the function of the available alumina content ($Al_2O_3$ %-$SiO_2$ %) of the bauxite. (The bauxite modulus values are also indicated in the figures.) In case of the sintering process all calculated values were extrapolated based on the data given by VAMI, for the following one bauxite composition only: $Al_2O_3$: 47.4 %. $SiO_2$ 11.6 % (modulus: 4.1), the specific bauxite consumption: 2.573 t/t (in dry weight). $Na_2CO_3$ consumption 220 kg/t, fuel consumption for bauxite sintering only (without calcination) 0.583 kg/t. The $Al_2O_3$ yield was found as high as 81.8 % related to the alumina content of the bauxite.

In the sintering process the $Al_2O_3$ yield is not changing significantly by the bauxite quality, therefore the specific bauxite consumption is influenced by the $Al_2O_3$ content of the bauxite only.

The specific bauxite consumption in the function of the bauxite quality is shown in Fig. 17-1/A for the sintering process and in Fig. 17-1/B for the Bayer process.

In the specific consumption figures the tendency of the imported soda ash consumption has a special importance. Figs. 17-1/A and 17-1/B show that the sintering process has a lower specific consumption if the modulus of the processed bauxite is less than 4.5. If the $Al_2O_3$ to $SiO_2$ ratio is higher than 4.5, the Bayer process has the lower specific consumption.

In case of the Bayer process the total fuel oil consumption (0.553 t/t) even if the processed bauxite has an $Al_2O_3$ to $SiO_2$ ratio of 3.77, is less than the requirement of sintering only (0.594 t/t) at the sintering process.

Fig. 17-2 shows the total investment costs in function of the bauxite quality and Fig. 17-4 the total investment costs in function of the plant capacity for both processes.

The investment costs of the sintering process at the capacity of 200 kt/year and in a bauxite modulus range from 3.77 to 6.0 are 35-40 % higher than in the case of the Bayer process (tube digestion variant) (Fig. 17-2). The investment costs of the Bayer process at each examined production capacity show significantly better values than those for sintering process (Figs. 17-4).

In Fig. 17-3 the total investment costs of the Bayer tube digestion process is plotted in the function of the bauxite quality in the range of 75,000-200,000 tpy plant capacity.

The expected production costs can be seen in Fig. 17-5 and 17-6. Fig. 17-5 shows the comparison of the production costs of the Bayer tube digestion and sintering process in the function of the bauxite quality, in Fig. 17-6 the production costs of the Bayer tube digestion process are plotted at different plant capacities.

The bauxite quality has a greater influence on the production costs at the Bayer process than at the Sintering one (Fig. 17-25). However, the production costs of the Bayer process, even if processed bauxite with a modulus of 3.77 is less by about 2000 Rls/t than those of the Sintering process. At a modulus of 5 the difference is more than 6000 Rls/t.

On the basis of the above statements the following conclusions can be drawn:

- above the bauxite modulus value of 4 the Bayer process is more advantageous in all respects than the sintering one,
- the quality of the product alumina manufactured by the Bayer process is much better and less contaminated than the alumina produced by the Sintering process.

As the present bauxite explorations indicate a better bauxite quality than that considered for the low quality bauxite during the elaboration of the variants, the selection of the Bayer process can be rather more justified.

# SPECIFIC CONSUMPTIONS IN THE FUNCTION OF BAUXITE QUALITY

## SINTERING PROCESS

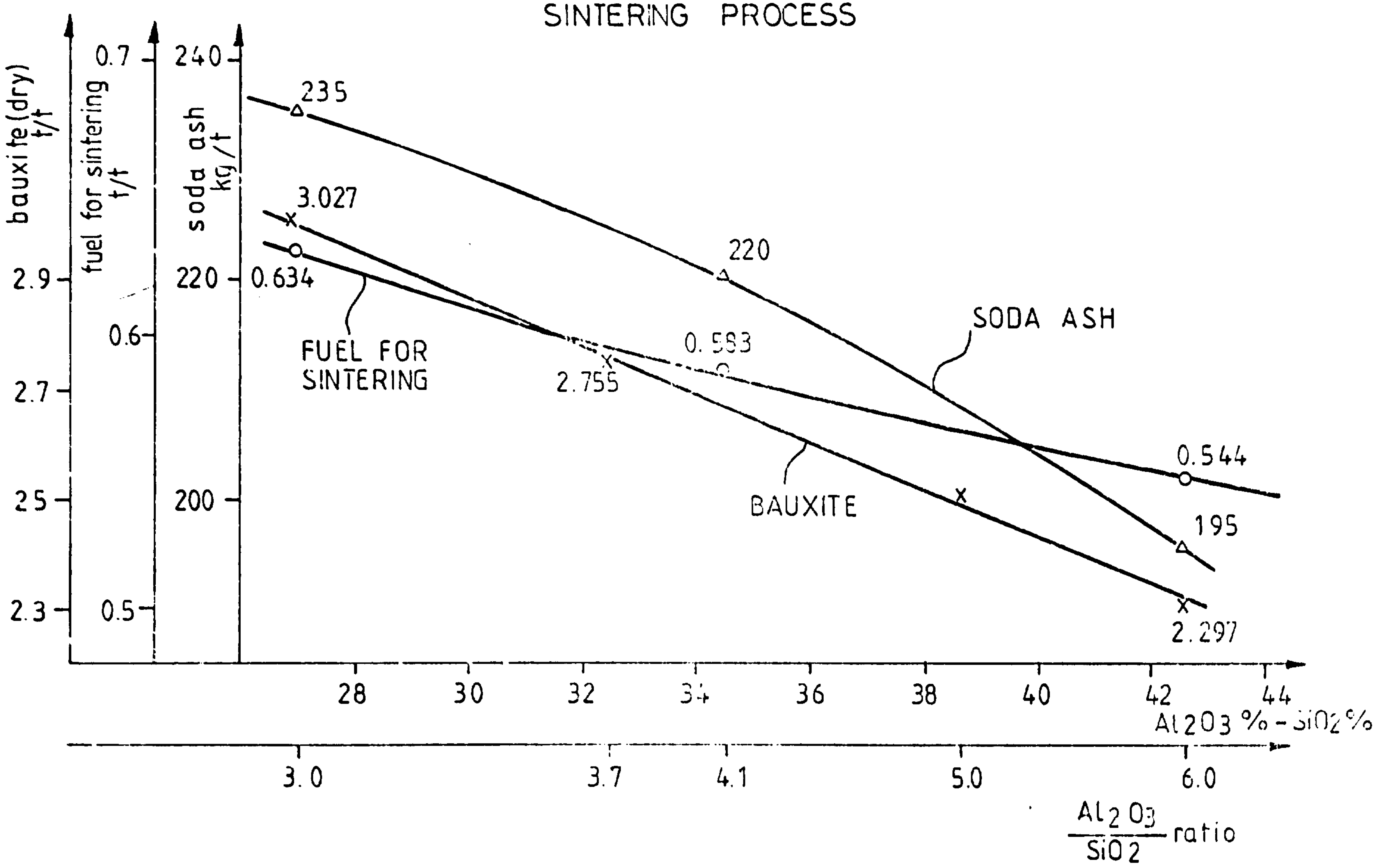


Fig.17-1/1

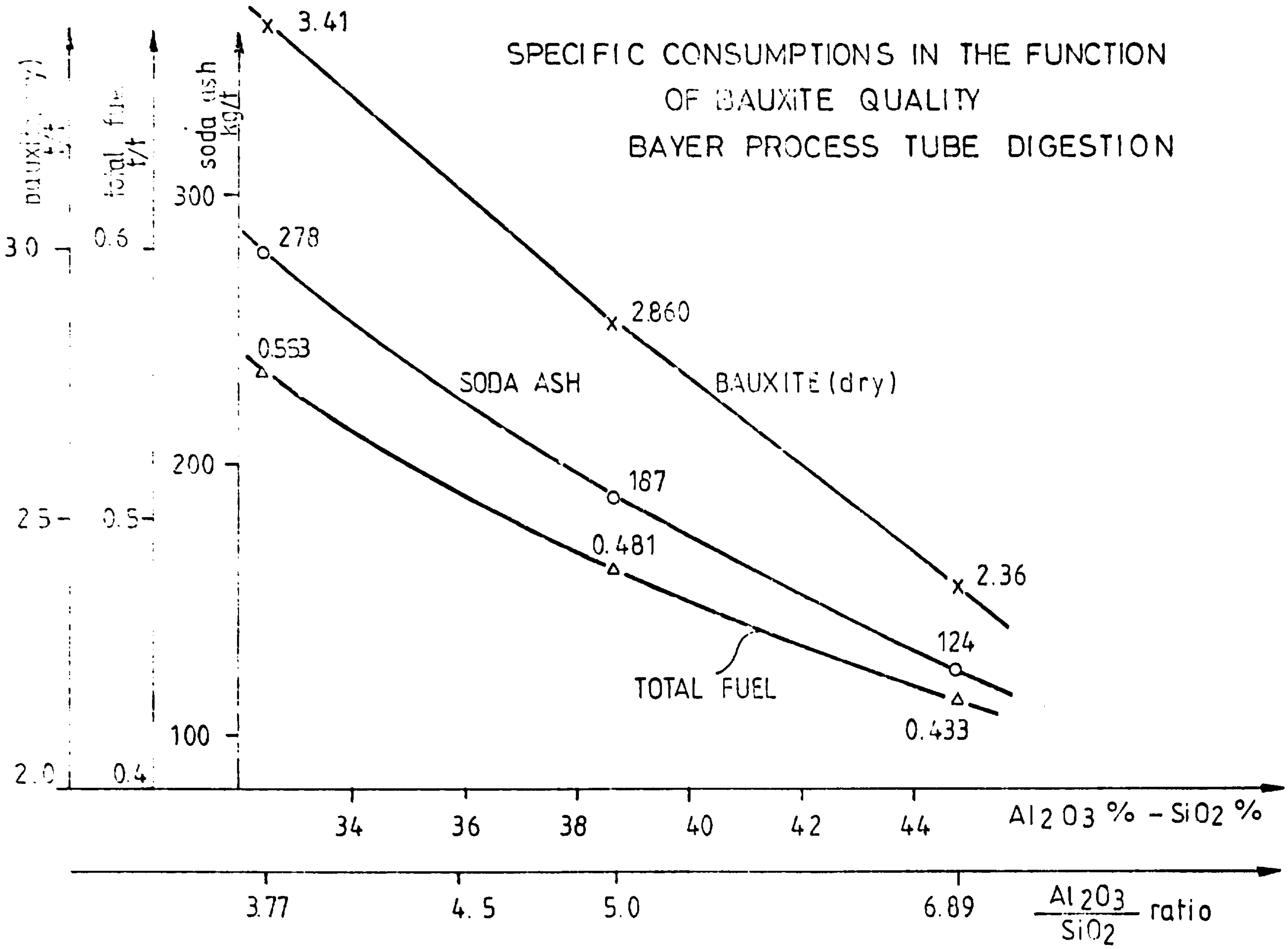

SPECIFIC CONSUMPTIONS IN THE FUNCTION
OF BAUXITE QUALITY
BAYER PROCESS TUBE DIGESTION
bauxite t/t
total fuel t/t
soda ash kg/t
3.0
2.5
2.0
0.6
0.5
0.4
300
200
100
3.41
2.860
2.36
278
187
124
0.553
0.481
0.433
SODA ASH
BAUXITE (dry)
TOTAL FUEL
34
36
38
40
42
44
Al2 03 % – Si02 %
3.77
4.5
5.0
6.89
Al2O3 / SiO2 ratio

Fig.17-1/B

## TOTAL INVESTMENT COSTS IN THE FUNCTION OF BAUXITE QUALITY
200,000 tons alumina/year

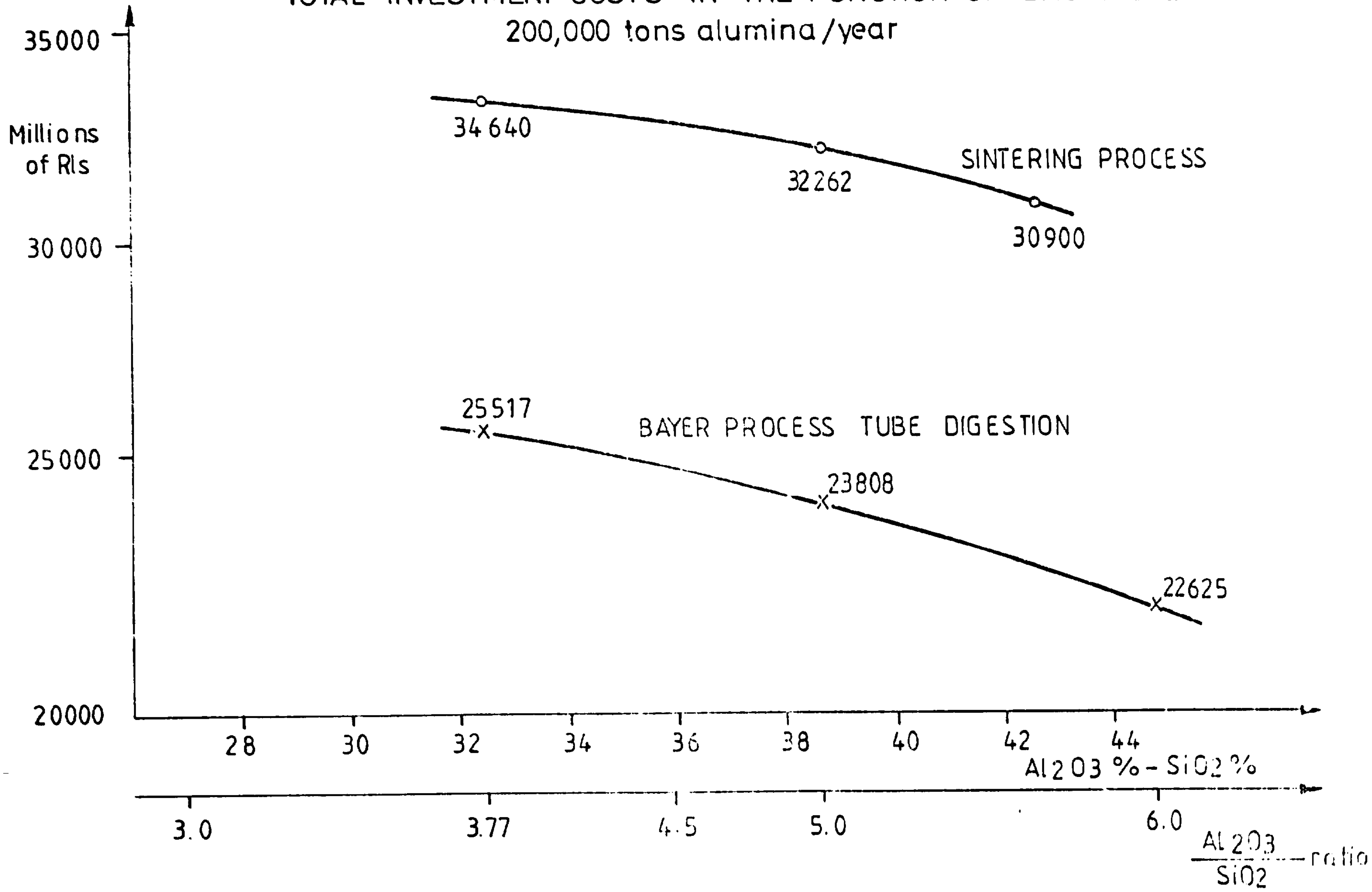


Fig. 17 - 2

Fig. 17-3

# TOTAL INVESTMENT COSTS IN THE FUNCTION OF BAUXITE QUALITY BAYER PROCESS TUBE DIGESTION

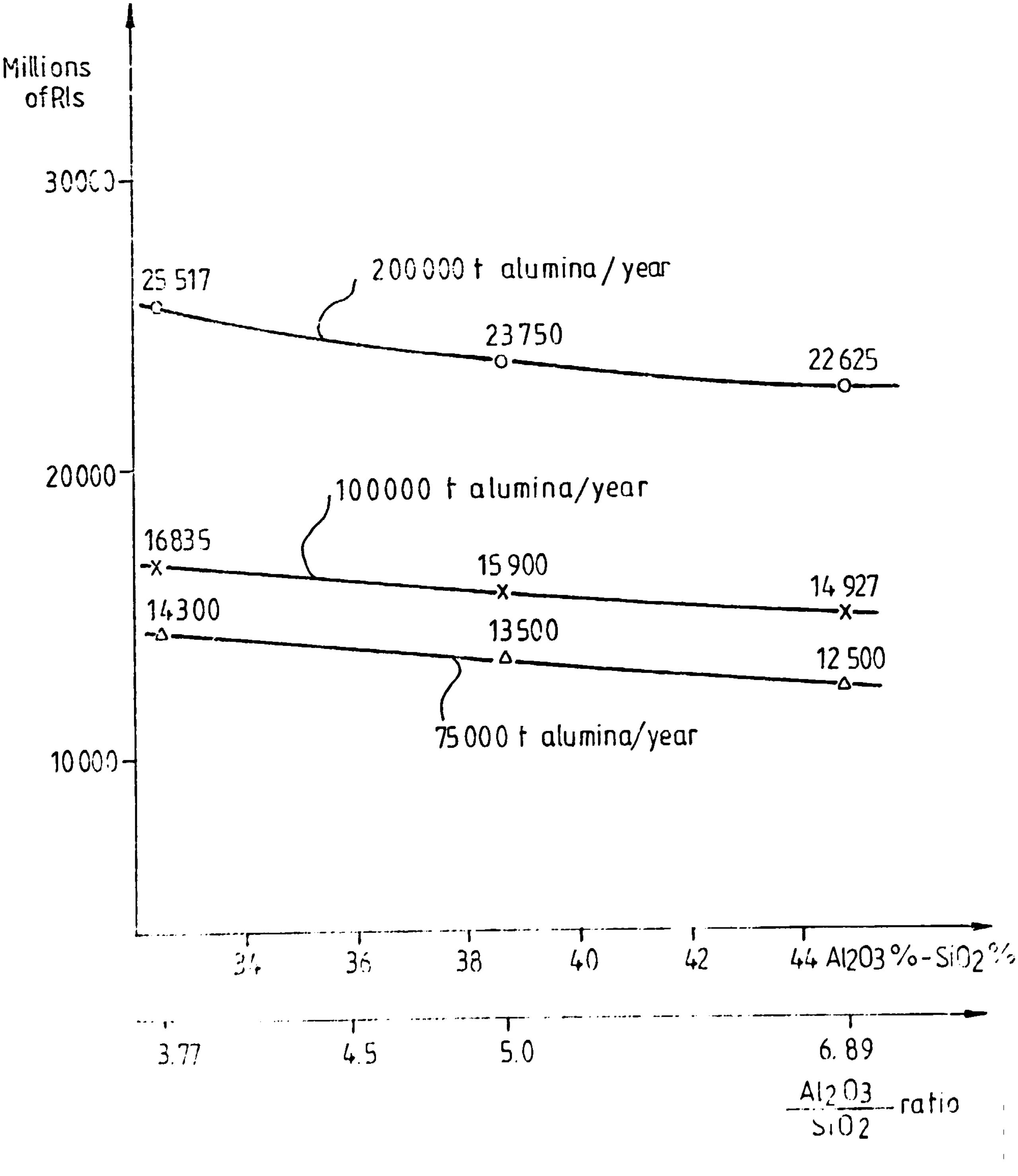
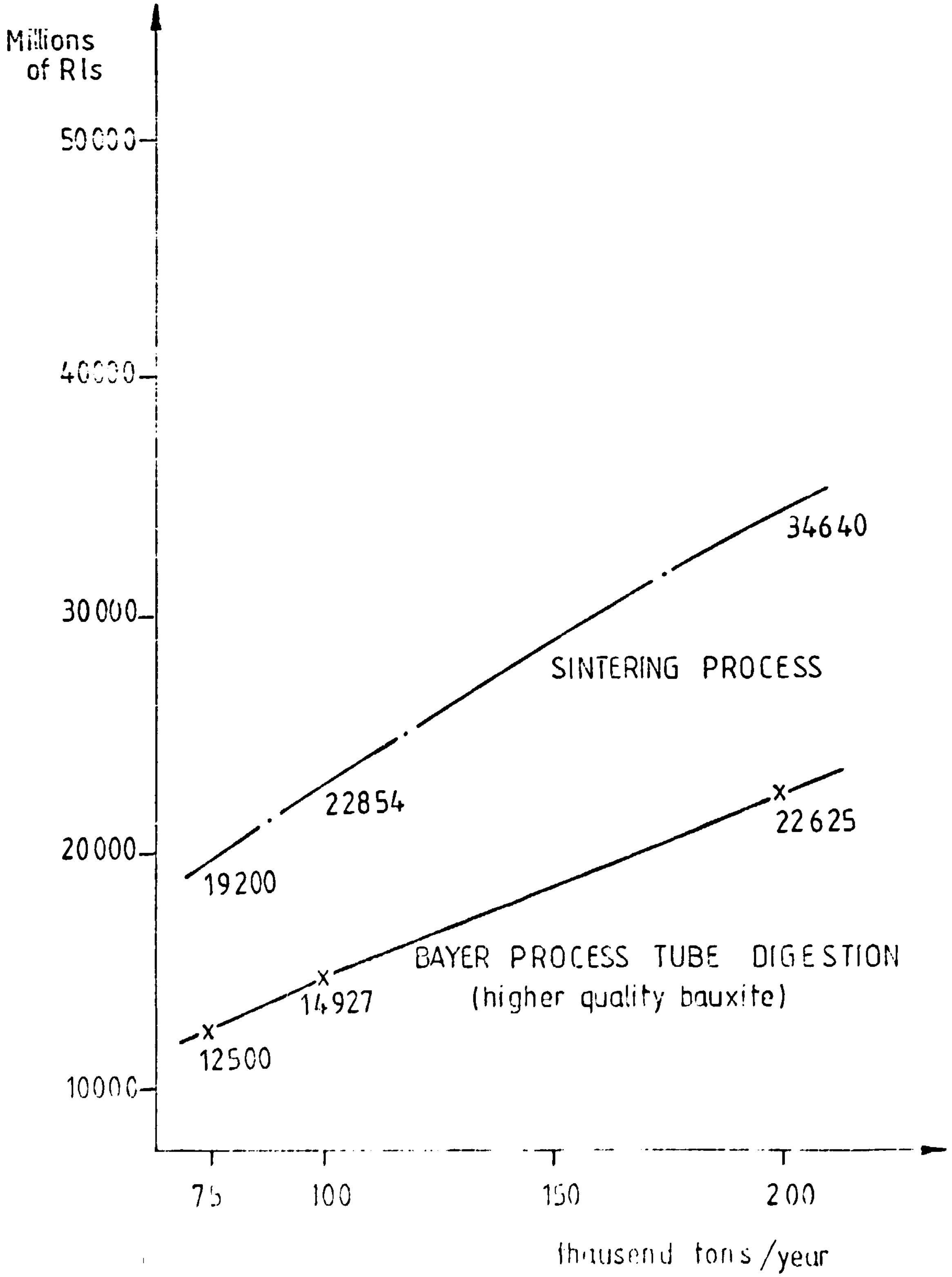
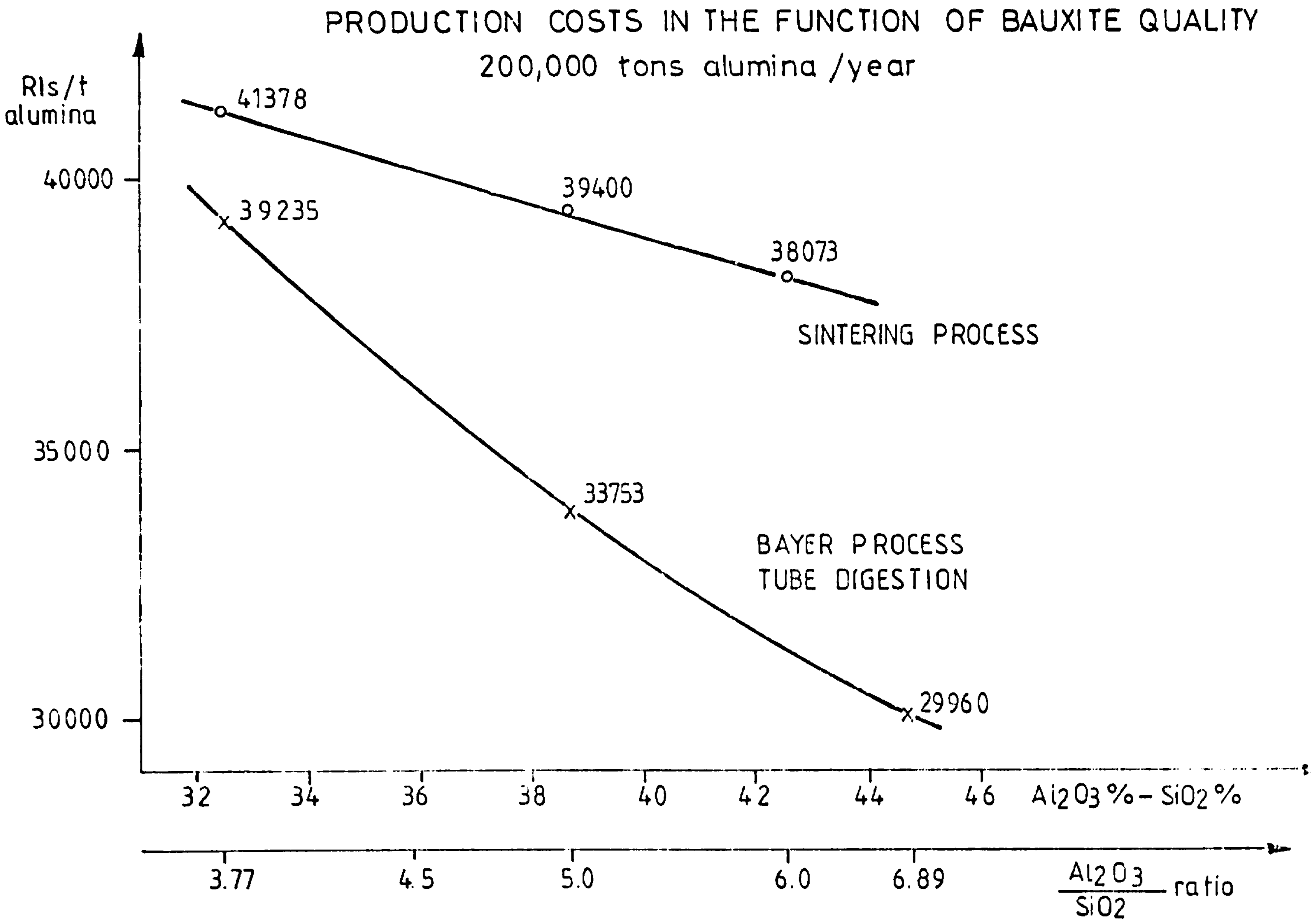


Fig.17-4

## TOTAL INVESTMENT COSTS IN THE FUNCTION OF THE PLANT CAPACITY





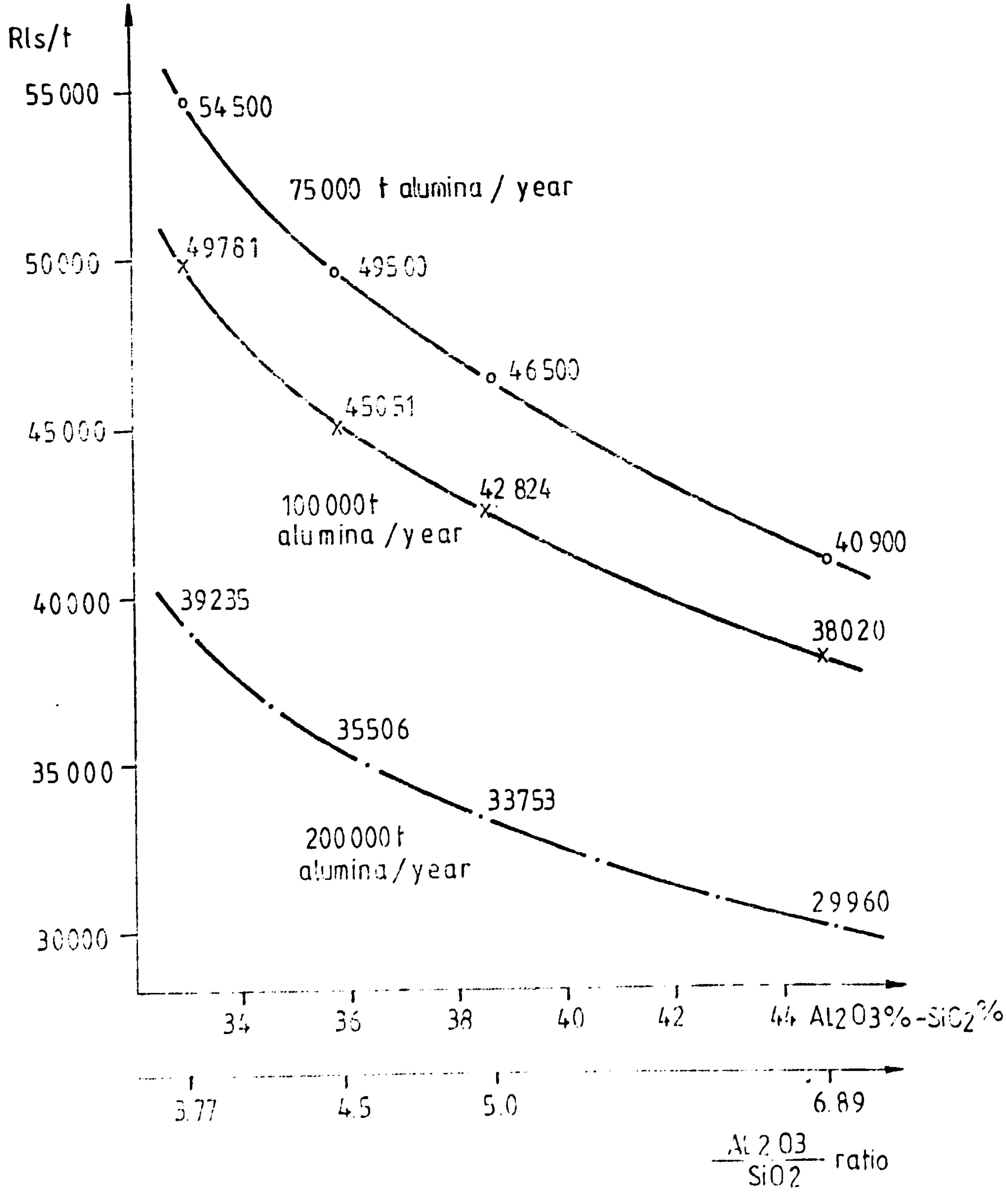
PRODUCTION COSTS IN THE FUNCTION OF BAUXITE QUALITY
200,000 tons alumina /year

Fig.17-5

Fig.17-6

# PRODUCTION COSTS IN THE FUNCTION OF THE BAUXITE QUALITY

## BAYER PROCESS TUBE DIGESTION



UNIDO Contract No.87/42
Project No.DP/IRA/85/003

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

## FINAL REPORT
## ATTACHMENTS

Aluterv-FKI , Budapest , December, 1988

## ATTACHMENTS

| | |
|---|---|
| General description of the Bayer process | Attachment 1 |
| Bench scale tests | Attachment 2 |
| Material and heat balance as well as water balance | Attachment 3 |
| Main equipment list | Attachment 4 |
| Price list of the main equipment | Attachment 5 |
| Conceptional plant lay-out drawings | Attachment 6 |

# LIST OF FIGURES

## LIST OF TABLES

Attachment 1

# General Description of the Bayer process for alumina production

Attachment A1

# 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 manufacturing 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 day 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 flowsheet 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 dischareded.

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.

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.

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)

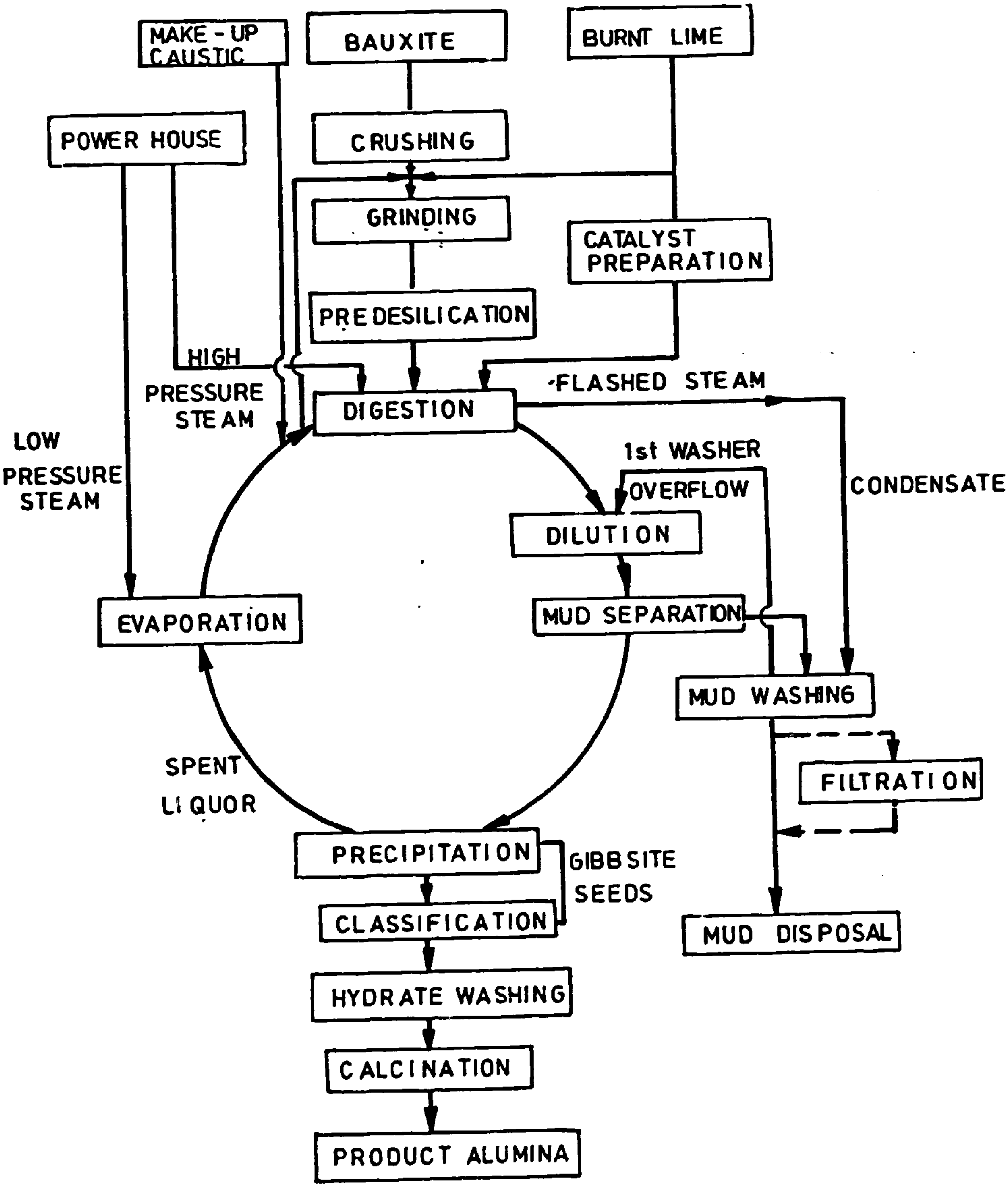


Fig. A2

BAYER PROCESS SCHEMATIC FLOWSHEET

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 | % |
| $SO_3$ | 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 | 0.5-10 $m^2/g$ | 40-45 $m^2/g$ |
| alfa $Al_2O_3$ | 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 micron) | 0.1 % | 2-8 % |
| - 325 Mesh (44 micron) | 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 Austrialia (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.

Table A3

ANALYSIS OF CHARACTERISTIC BAUXITE ORES

| | France | Ghana | Guyana | Jamaica | Weipa | Gove | Guinee |
|---|---|---|---|---|---|---|---|
| $SiO_2$ combined, % | 5.0 | 1.2 | 3.0 | 2.5 | 3.0 | 2.6 | 1.8 |
| $SiO_2$ quartz, % | - | - | 1.5 | - | 2.0 | 0.4 | 0.8 |
| $Al_2O_3$, % | 54.0 | 54.0 | 59.0 | 50.0 | 59.0 | 50.0 | 45.0 |
| $Fe_2O_3$, % | 25.0 | 16.0 | 3.0 | 19.0 | 7.0 | 19.5 | 24.1 |
| $TiO_2$, % | 3.0 | 1.8 | 3.0 | 2.5 | 2.5 | 3.2 | 2.2 |
| L.O.I., % | 11.5 | 27.5 | 29.5 | 25.0 | 26.0 | 24.0 | 25.0 |
| Ratio | | | | | | | |
| $Al_2O_3$/comb. $SiO_2$ | 10.8 | 45.0 | 19.6 | 20.0 | 19.6 | 19.2 | 37.0 |
| comb. $SiO_2$ | | | | | | | |
| Moles $H_2O/Al_2O_3$ | 1.13 | 2.9 | 2.9 | 2.8 | 2.55 | 2.76 | 3.1 |

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 tc form an insoluble sodium-aluminium-hydrosilicate of approximate composition $3/Na_2O.Al_2O_3.2SiO_2.(1-2)H_2O/Na_2X$, 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 virtually 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 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 | $Al_4Si_4O_{10}(OH)_3$ or<br>$Al_2O_3.2SiO_2.2H_2O$ |
| (kaolinite, nakrite, dickite, metahalloysite) | |
| Halloysite | $Al_4\ Si_4\ O_{10}(OH)_8\ (H_2O)_4$ |
| 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 | $(Fe^{2+},Fe^{3+},MgAl)_6(Si_2Al_2O_{10})(OH)_3$ |
| Illite, hydromuscovite | $(K,H_2O)Al_2/(H_2O,OH)_2AlSi_3O_{10}/$ |
| Lithiophorite | $(Al,Li)(MnO_2)(OH)_2$ |
| Lithiophorite | $(Al_3Li)(MnO_2)(OH)_2,F)_2$ |
| Muscovite | $KAl_2(AlSi_3O_{10})(OH_5F)_2$ |
| Siderite | $FeCO_3$ |
| Pirite, Marcas | $FeS_2$ |
| Ilmenite | $FeTiO_3$ |
| Zircon | $ZrSiO_4$ |
| Hausmannite | $MnO.Mn_2O_3$ |

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 precipitation 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 per 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 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.

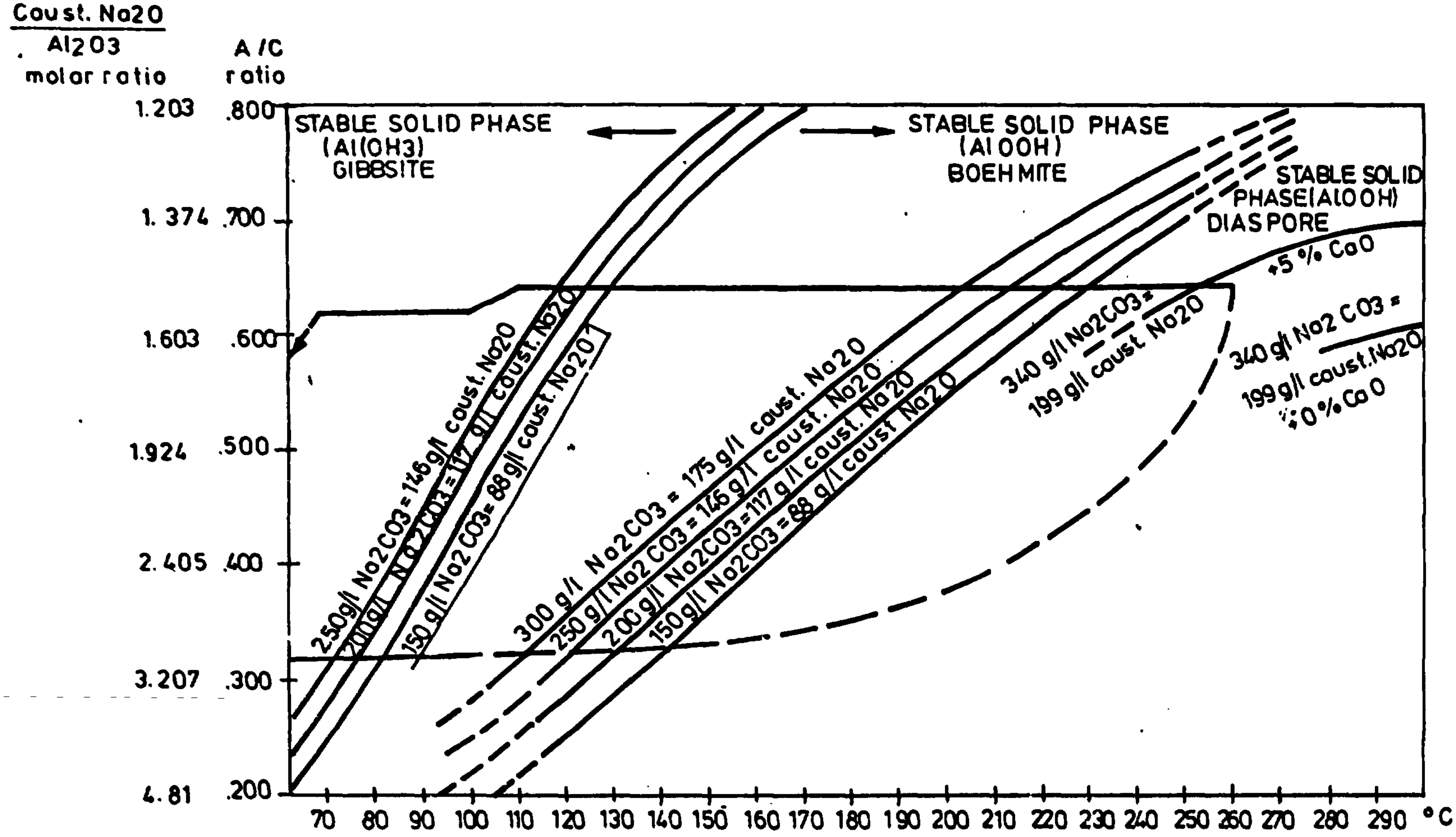


Fig. A3

EQUILIBRIUM A/C RATIOS IN SYNTHETIC LIQUORS FOR GIBBSITE, BOEHMITE AND DIASPORE IN THE FUNCTION OF THE TEMPERATURE AND CAUSTIC CONCENTRATIONS

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 disturbs 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.

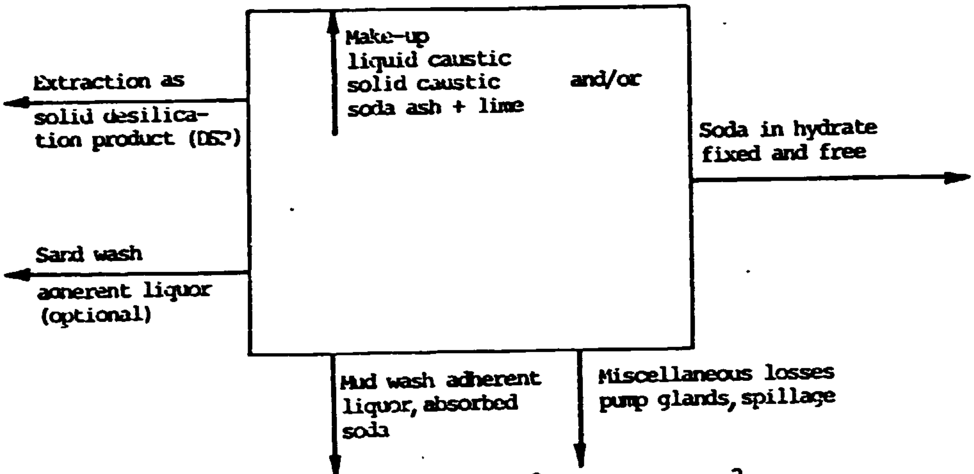
The main loss of soda from the liquor circuit is the chemical loss at the extraction plant, due to reaction with the combined silica in the ore to form the almost insoluble triple zeolitic type of compound. This, ultimately, goes out of the system with the red mud residue.

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 causticizing 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 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.



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

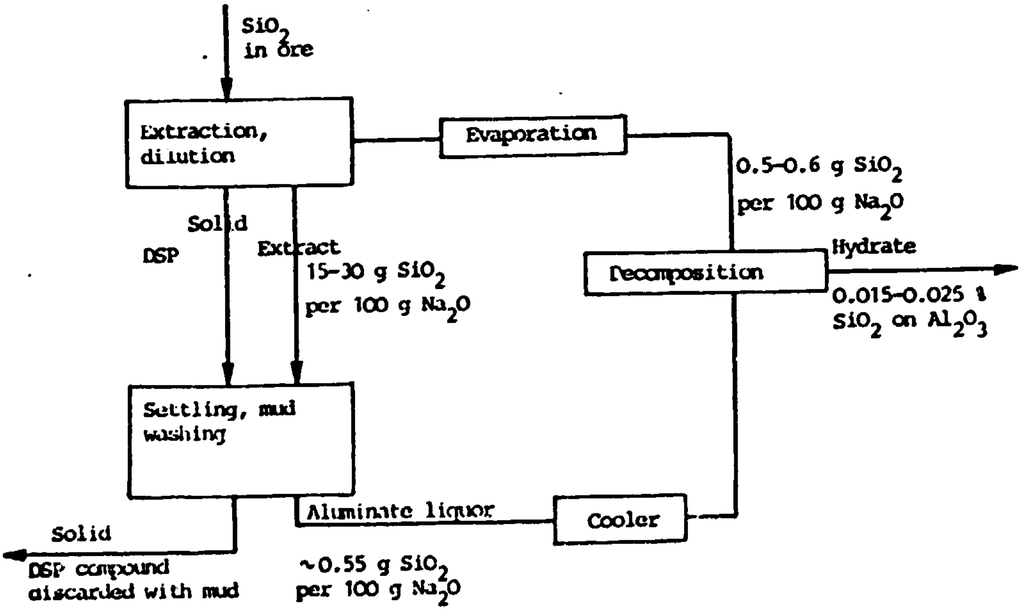


Fig. A5
SILICA CYCLE

## 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 $3/Na_2O.Al_2O_3.2SiO_2.(1-2)H_2O/.Na_2X$, were: $X:CO_3^{2-}$, $2OH^-$, $2AlO_2^-$, $SO_4^{2-}$, 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 quality 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 micron) 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 hydrocylones 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 drainage 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 contribution 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 free to trail along the bottom. Mud offtake can be either at the centre or from side outlets, and it 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 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 evaporation rate and the type of evaporator is determined in connention with the heat economy of the process.

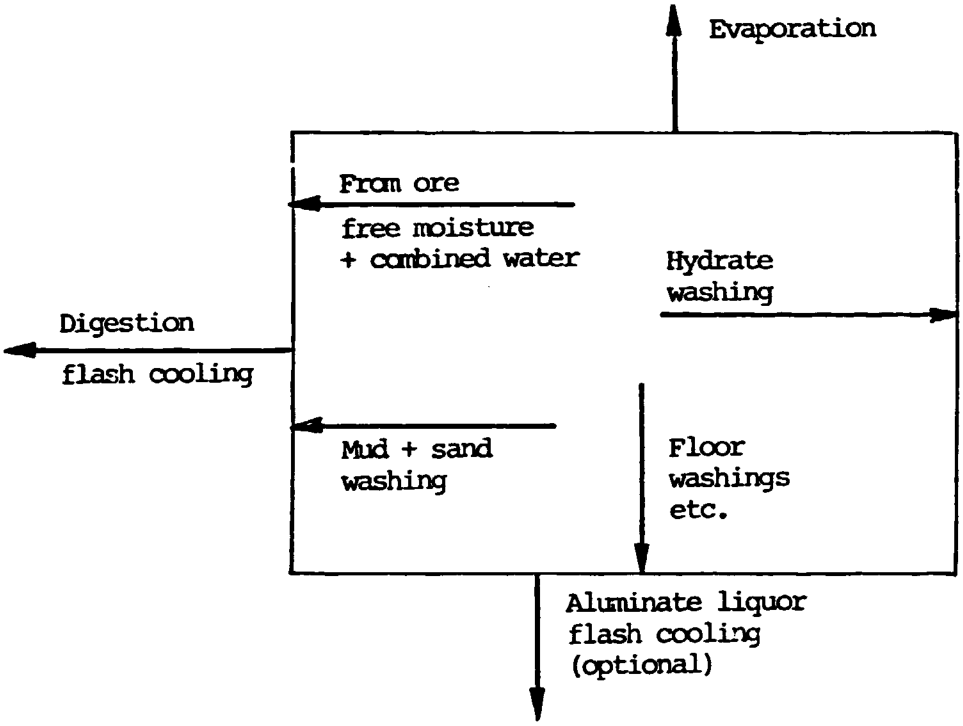


Fig. A6

WATER CYCLE

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 reaction 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 ore 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 /um 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 /um 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 /um 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

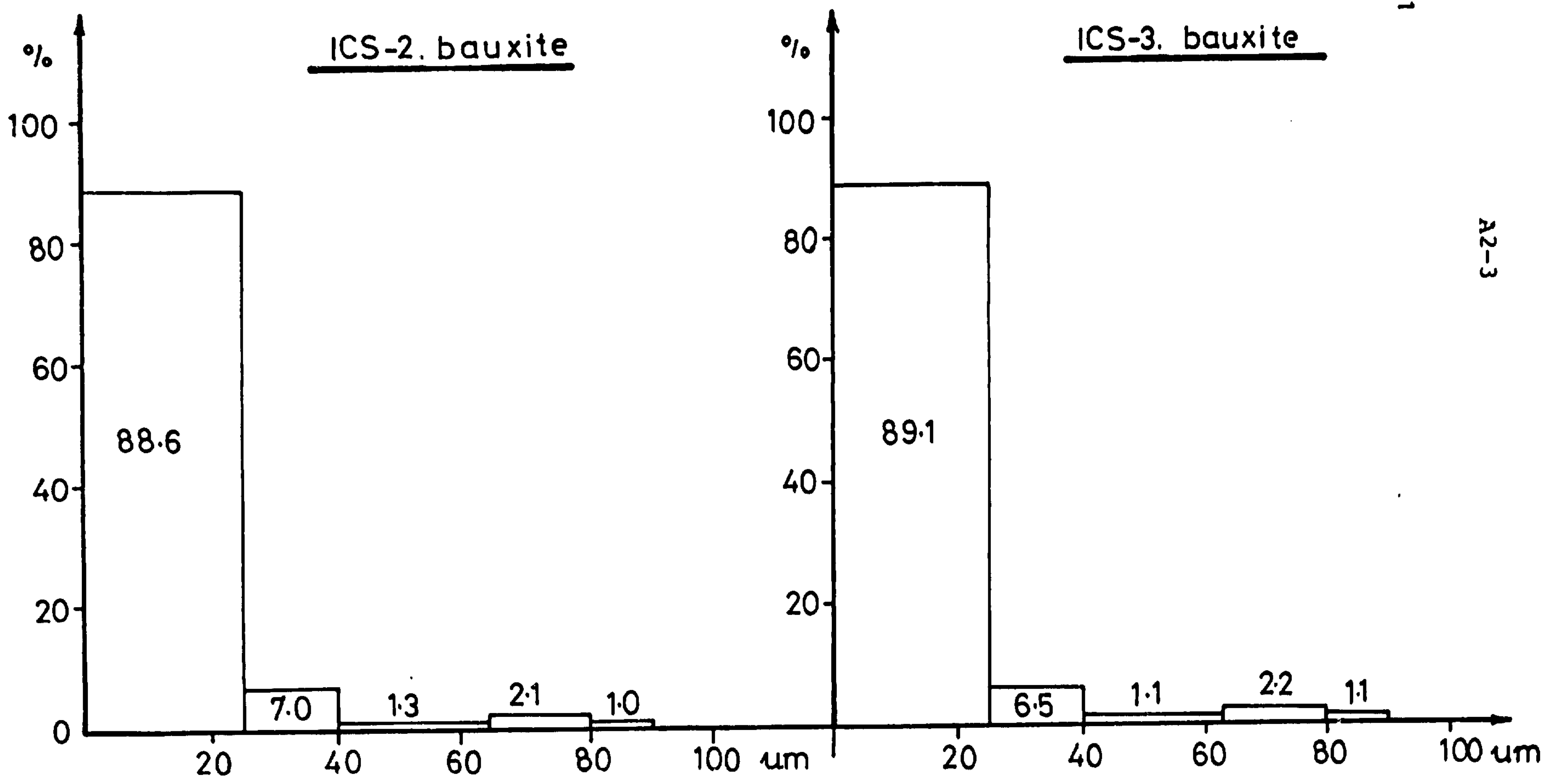


Table A2-2

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 fea[illegible] 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 on 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 of 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 imposing 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 greater 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 $\mu$m 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 /um 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 bauxite/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 /um

| 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, /um | Ground to 63 /um | Ground to 100 /um | Ground to 163 /um |
|---|---|---|---|
| 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 A2-8

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 in 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 /um 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 /um, 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 /um is represented in Table A2-1 and Fig. A2-1; about 89 % of the samples are of grain size less

than 25 $\mu$m,
- from the point of view of both the desilication and digestion the grinding fineness/minus 90 $\mu$m/ 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 $Al_2O_3/SiO_2$ratio of 5.5. Later on more detailed tests were perfected by a representative sample marked "ICS3" composited and sent to Institute VAHI 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 samples

| 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 °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 °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 A2-10

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 $\alpha'$-$C_2S$ (i.e. alpha'-dicalcium-silicate) was observed. This $\alpha'$-$C_2S$ 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 $\alpha'$-$C_2S$. The $\alpha'$-$C_2S$ 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 sintering 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

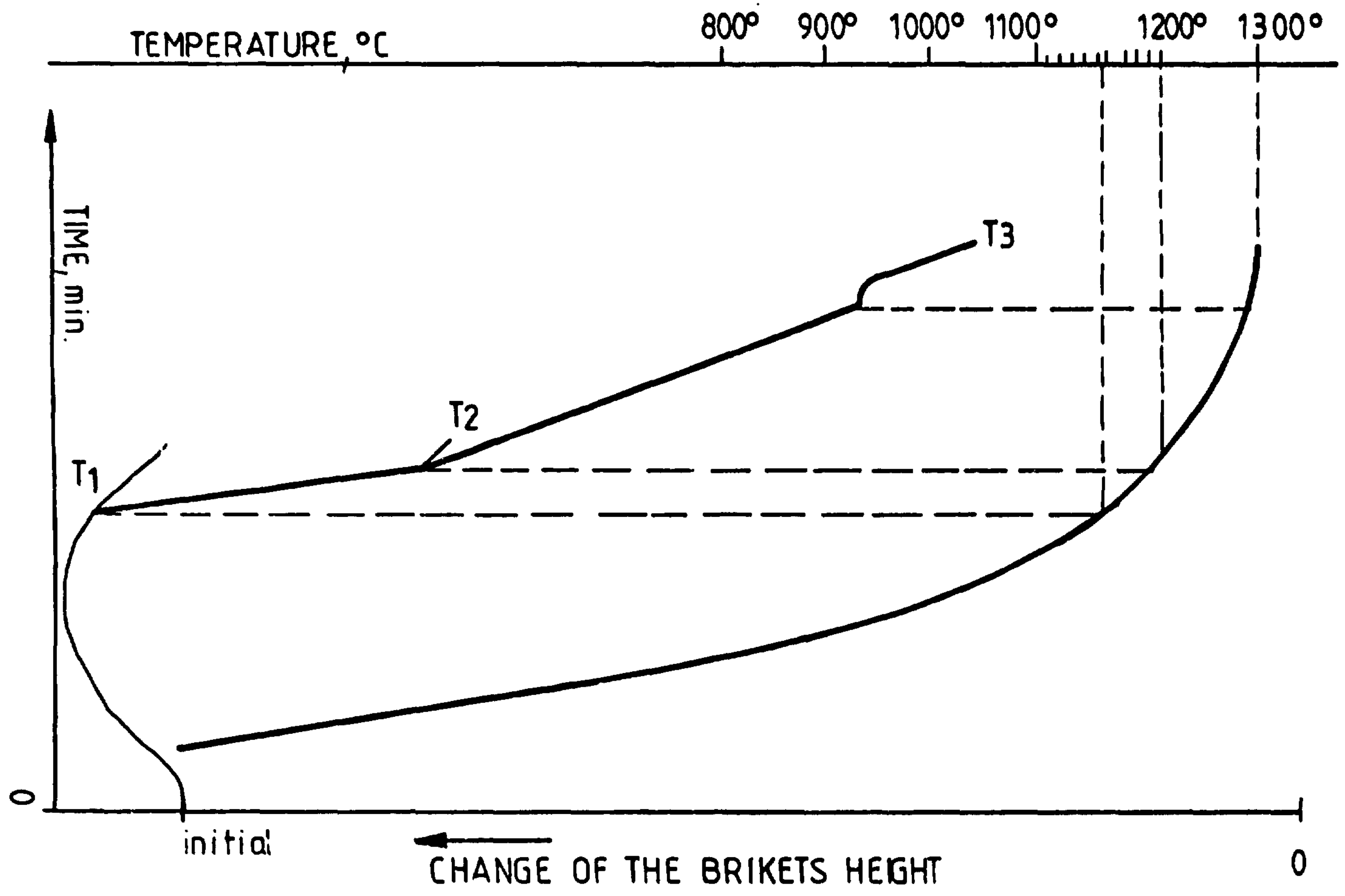


Fig. A 2-2

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) ($T_1$) 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 $T_3-T_1 = 140$ °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 °C with an aim of studying the thermal effects that accompany the heating process. 1000 mg charge and 8-9 °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 °C soda loses its cristalline water (dehydration), at 520 °C diaspore loses its cristalline water, at a temperature of 815 °C soda melts and desintegrates and at 865 °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 A2-12

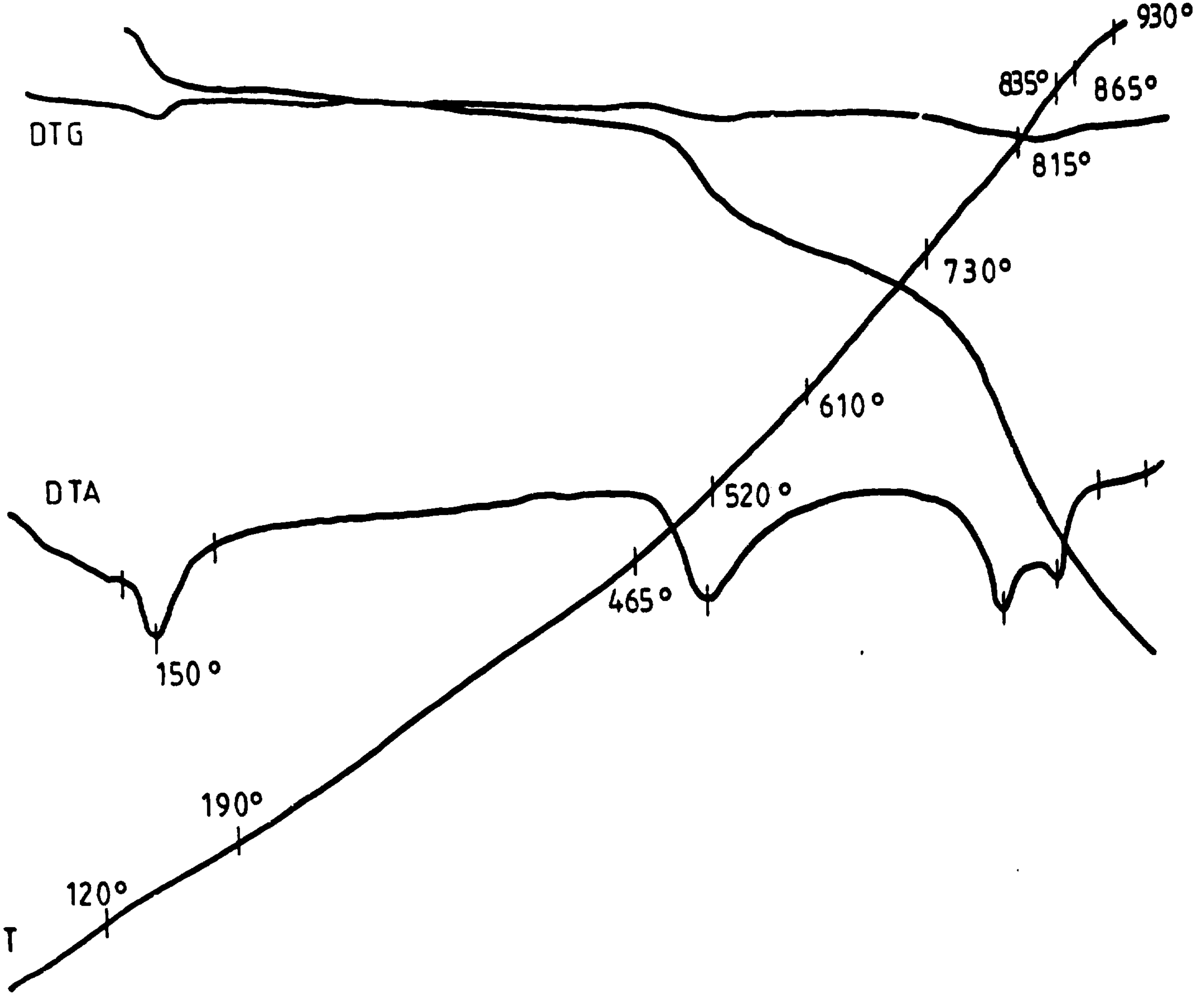
Screen test results

| 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:

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

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 ($\varsigma$) 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 °C. 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.

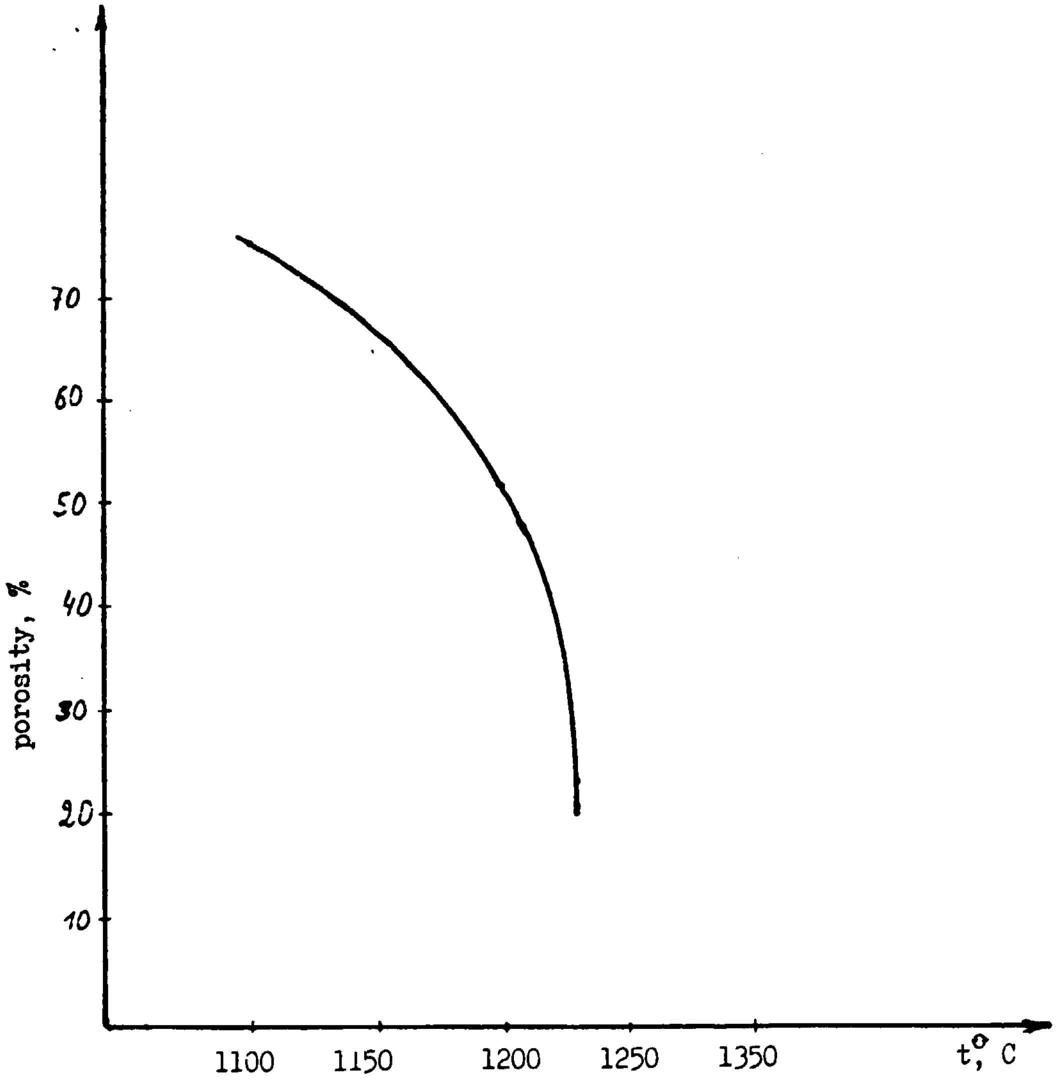
45 grams of sinter was put into a basket that had been placed into the glass. Glass had been filled with aluminate liquor solution previously. Basket was placed into the glass so that some empty volume could get underneath, similar to those of circumstances in large-scale equipment.

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

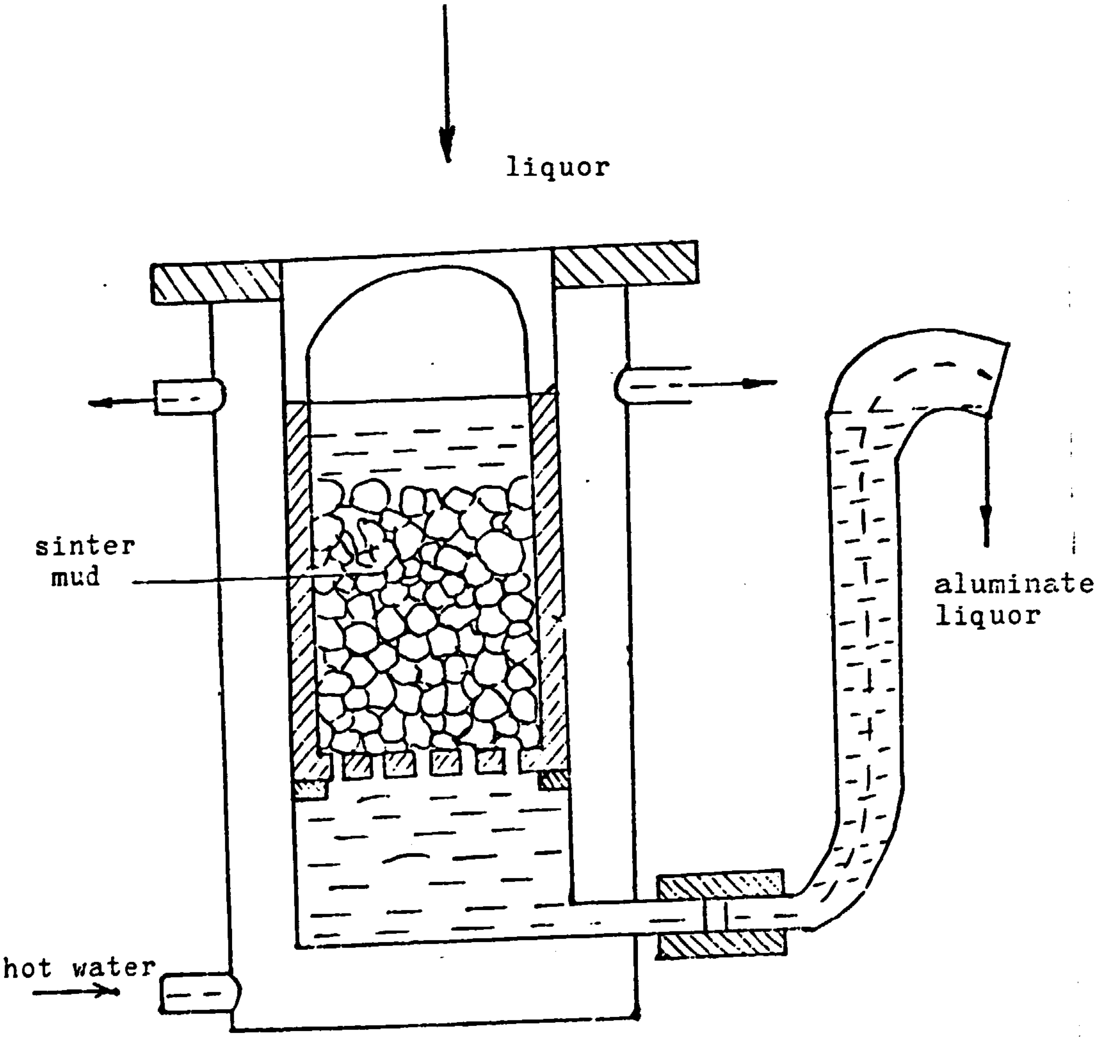


Table A2-14

## 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 | | | | | |
| | | | $Al_2O_3$ | $Na_2O_{caust}$ | caustic molar ratio | $Al_2O_3$ | $Na_2O_{caust}$ | caustic molar ratio | return water $Al_2O_3$ | from mud pond $Na_2O_{caust}$ | Moisture content of mud,% |
| 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: $100^{\circ}$ 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 of 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 % | $Na_2O$ % | $\frac{Na_2O}{SiO_2}$ | Effi-ciency % |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 65.8 |
| 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

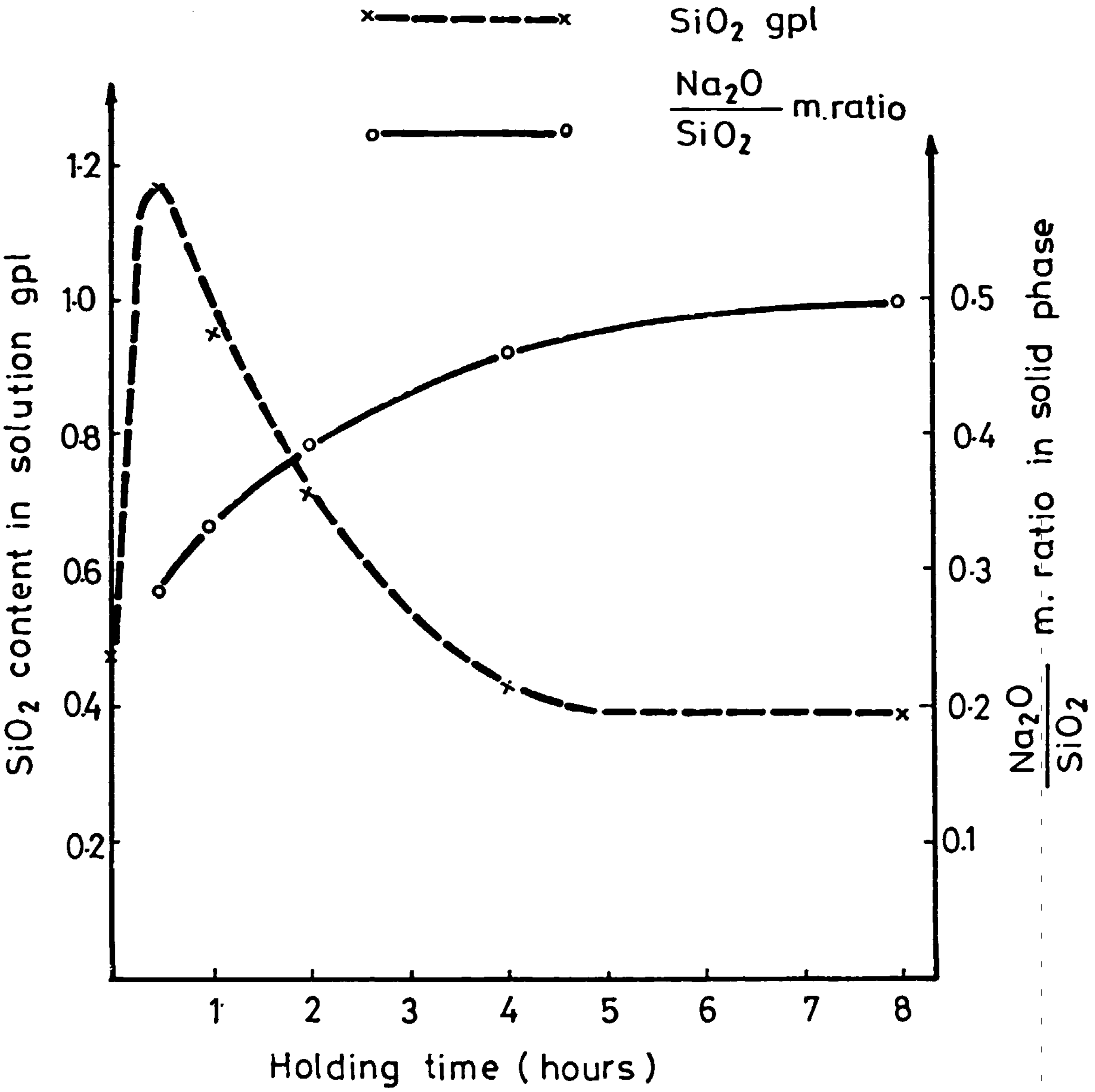
## PREDESILICATION TEST

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 |

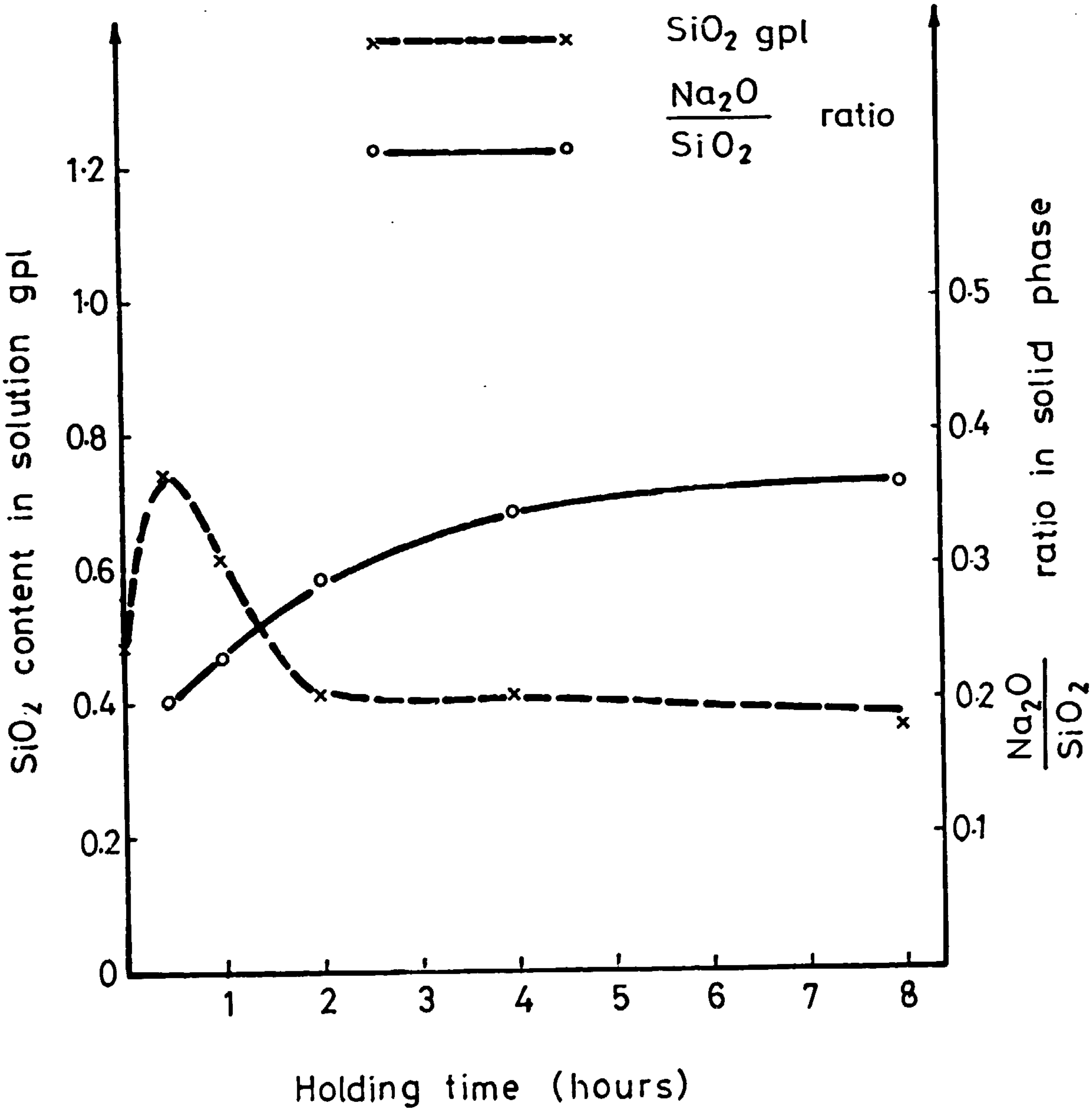
### Chemical composition of the solid phase

|  | $Al_2O_3$ % | $SiO_2$ % | $Fe_2O_3$ % | $TiO_2$ % | LOI. % | CaO % | MgO % | $Na_2O$ % | $\frac{Na_2O}{SiO_2}$ | 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 | 0.5 | 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 $Al_2O_3$-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 |
| LOI % | 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

| | | 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 |
| $Al_2O_3$ % 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 | [illegible] |
| | total | 1.8 | 7.2 | 10.1 | 13.2 | 16.[illegible] |

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 time : 1 hour
Digestion liquor conc.($Na_2O_C$) : 161·6 gpl

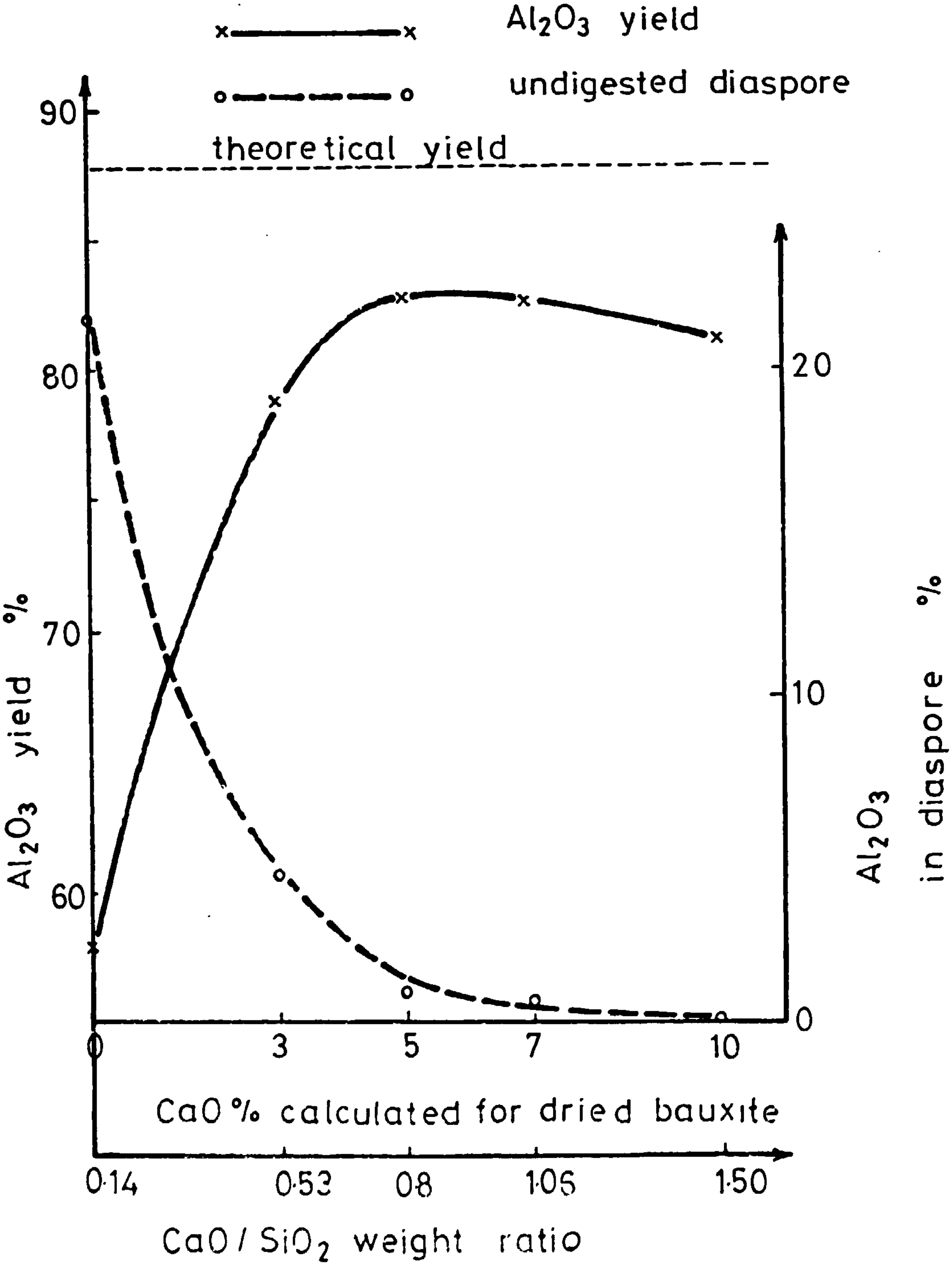
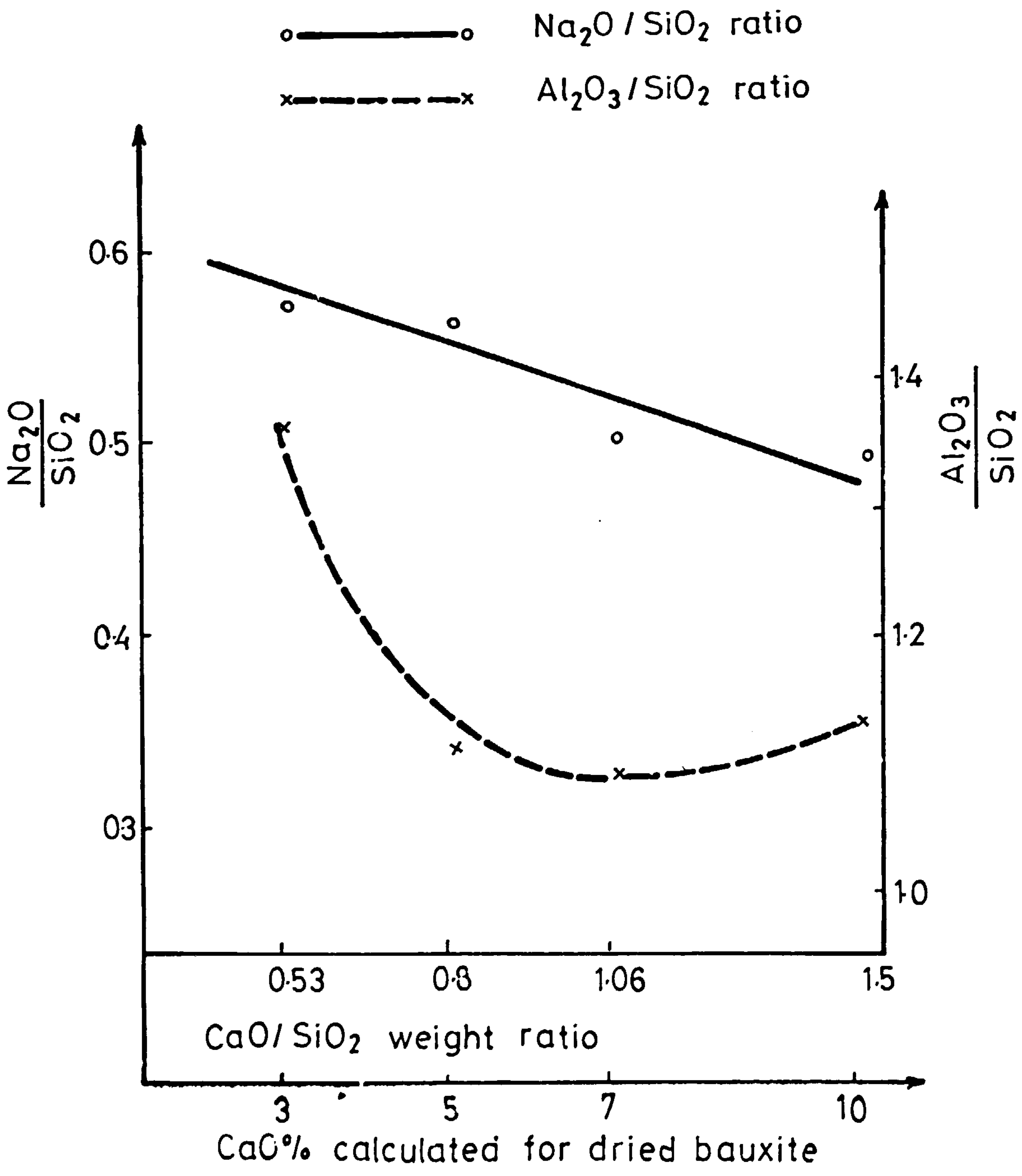


Fig.A2-9

## 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

Modelling 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 | 16.6 |
| | 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

| Sample | | Quantity of lime added % | | | |
|---|---|---|---|---|---|
| | | 3 | 5 | 7 | 10 |
| | | 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 |

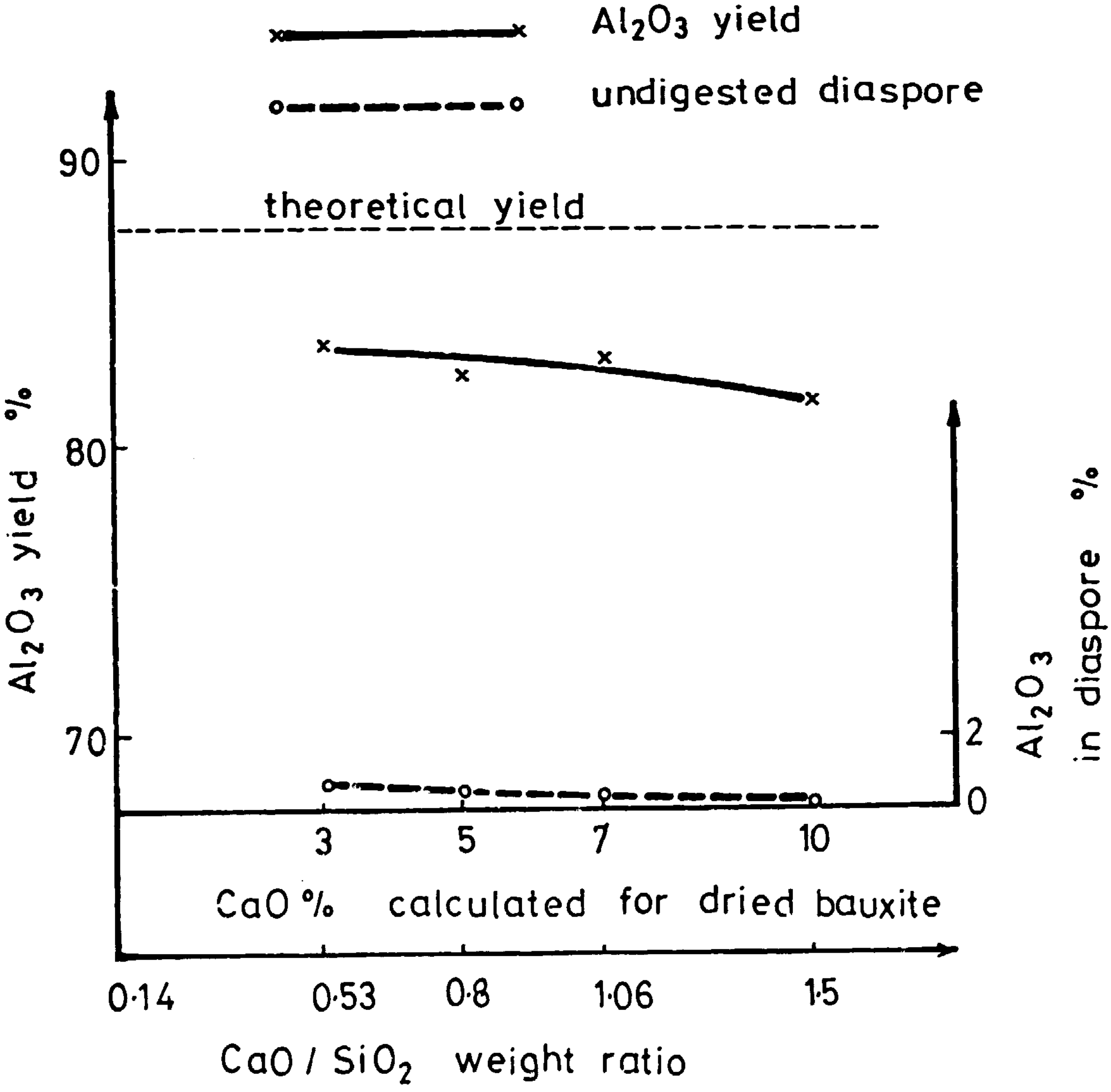
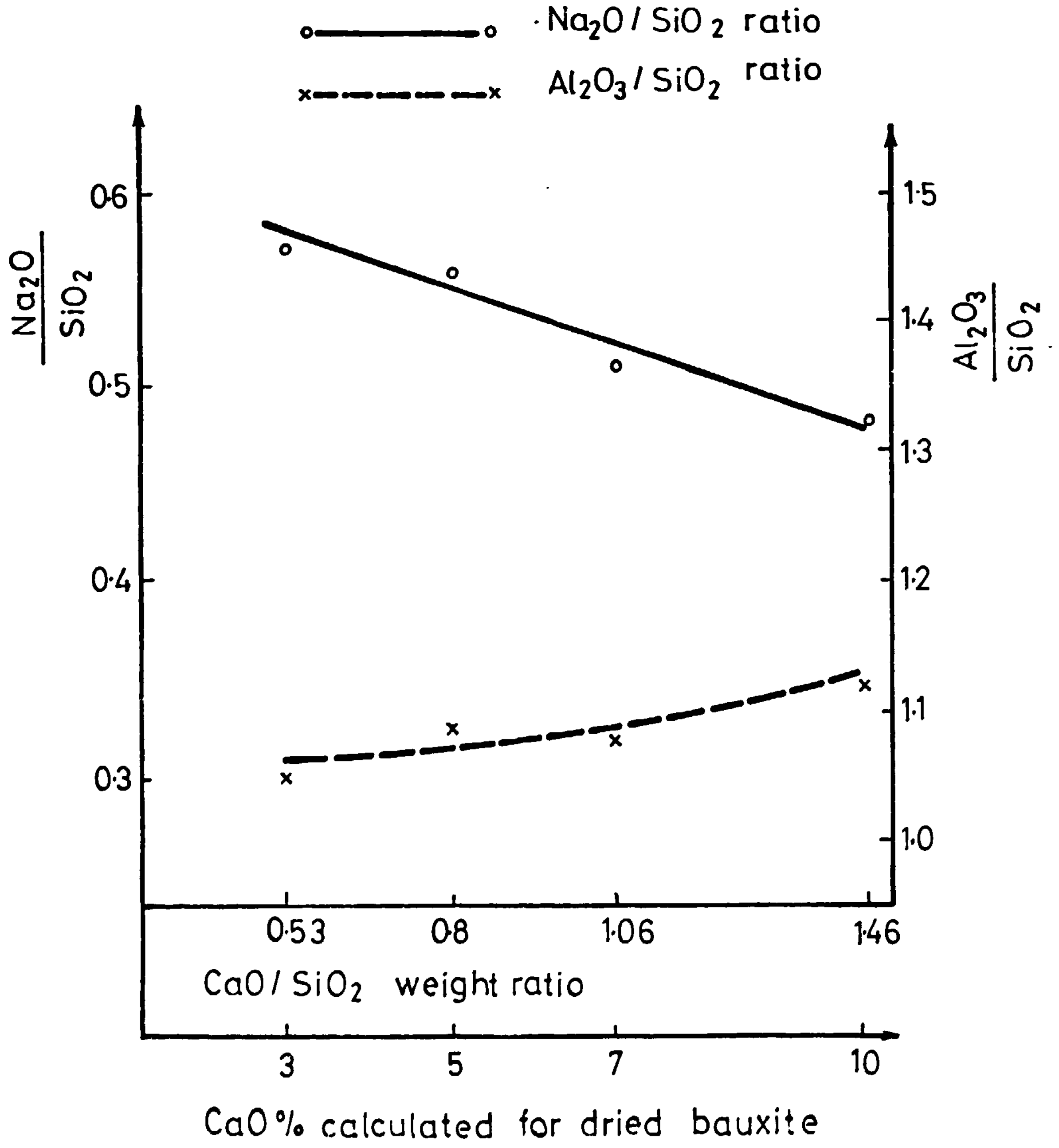


Fig.A2-11

## 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 |



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 /um; ICS-2 <160 /um

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

| | | Grain size of bauxite samples | |
|---|---|---|---|
| Sample | | < 90 /um | <160 /um |
| 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 $< 90\ \mu m$ | ICS-2 $< 160\ \mu m$ |
| $Al_2O_3$ % 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

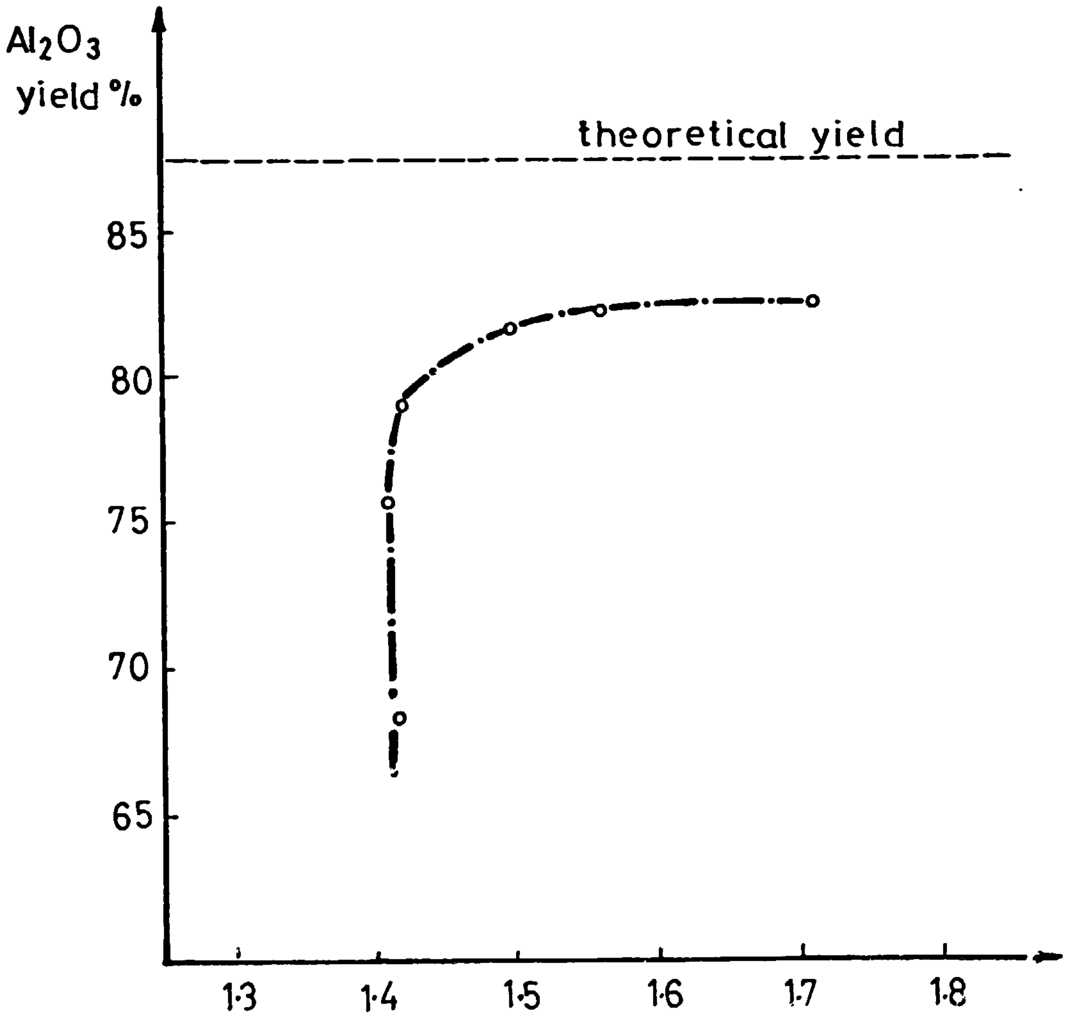
Lime addition: 7 % for dried bauxite

| | 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 /chan./ | 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 /chan./ | 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 /chan./ | 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 | 12.3 |

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



Molar ratio after digestion

### 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 $260^{\circ}$ 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 $Na_2O/SiO_2$ ratio 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 | 134.6 |
| $Al_2O_3$ 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

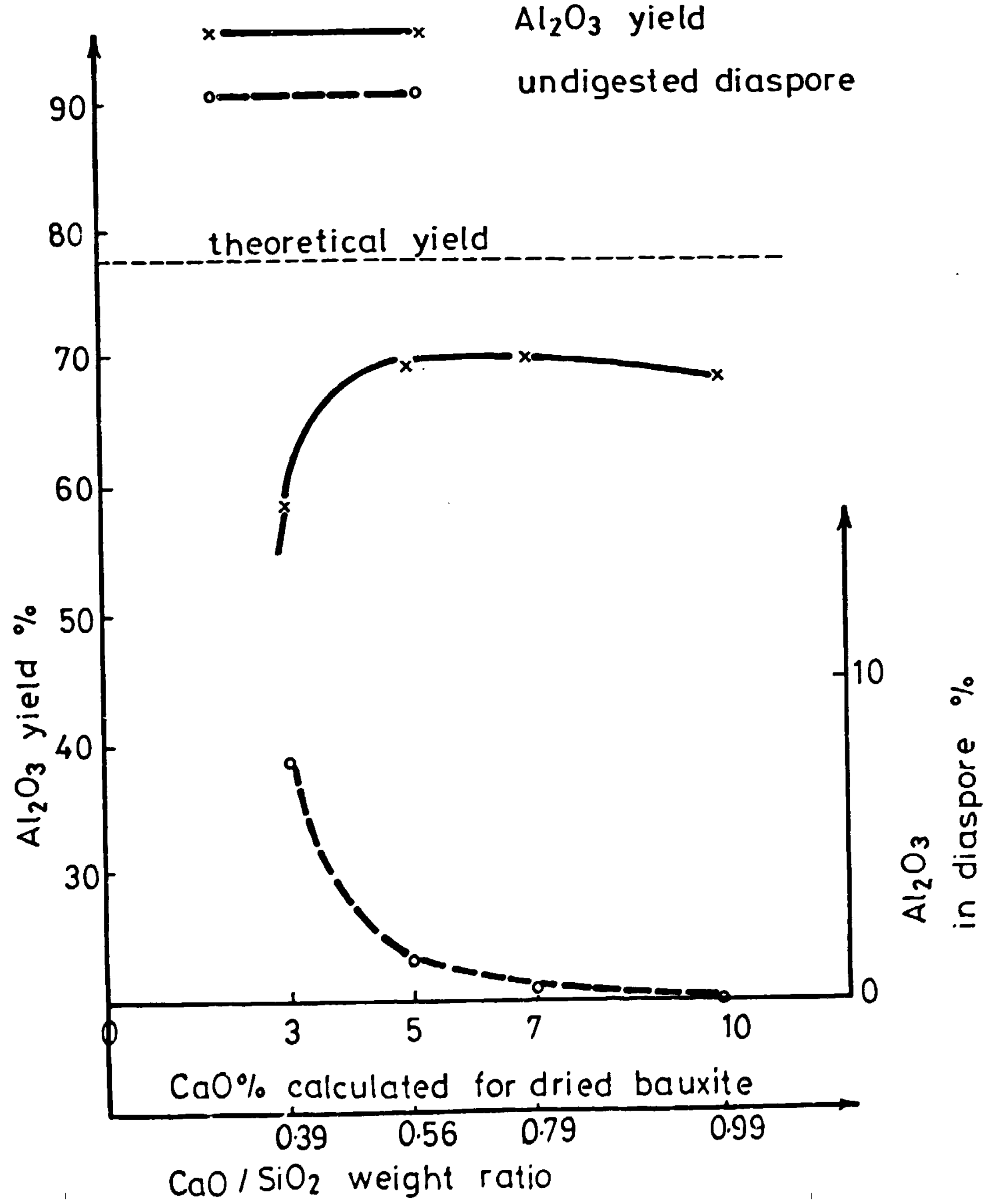


Fig.2-14

## 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 |

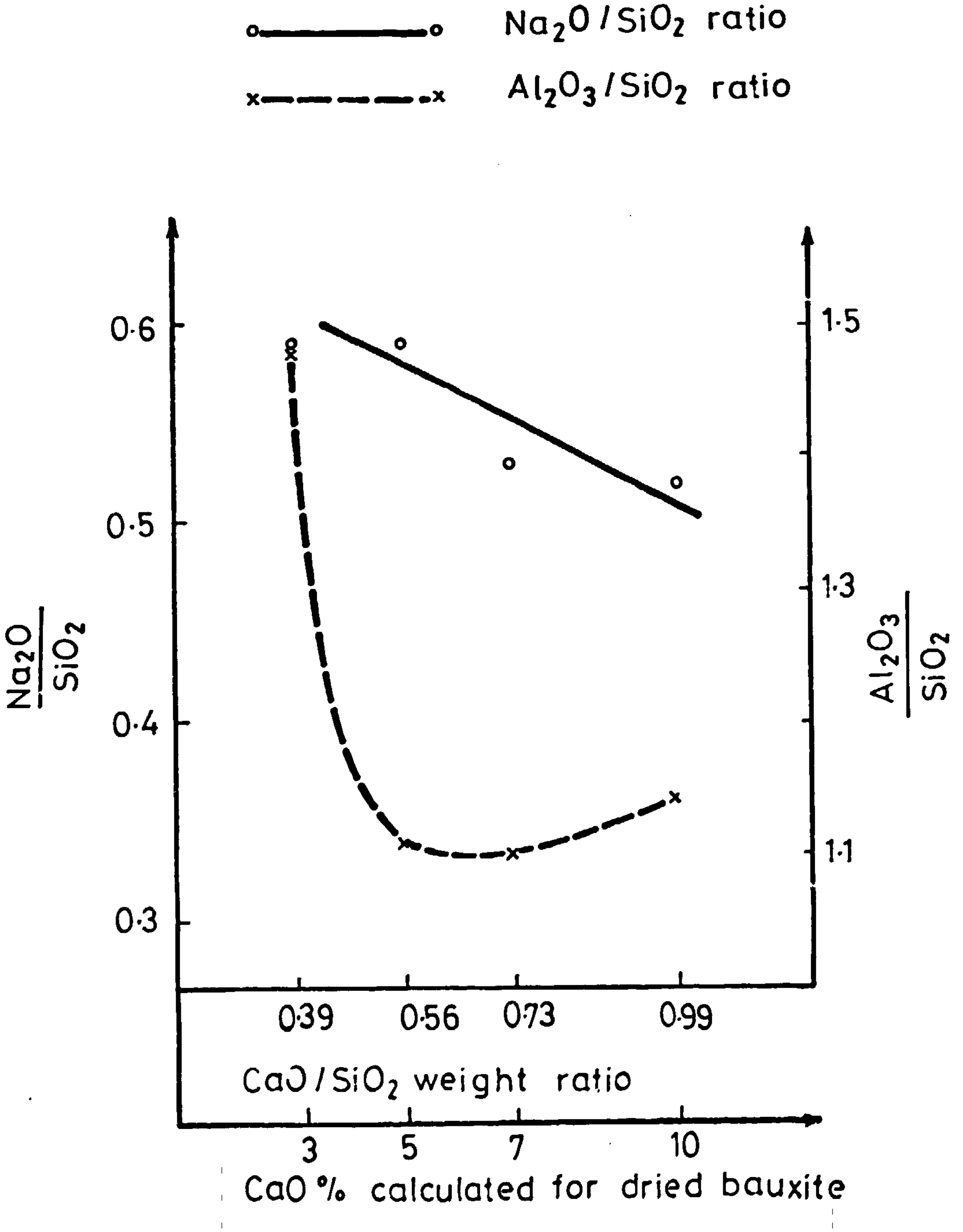


Table A2-32

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<br>M5 | ICS-3<br>M6 | ICS-3<br>M7 | ICS-3<br>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 |

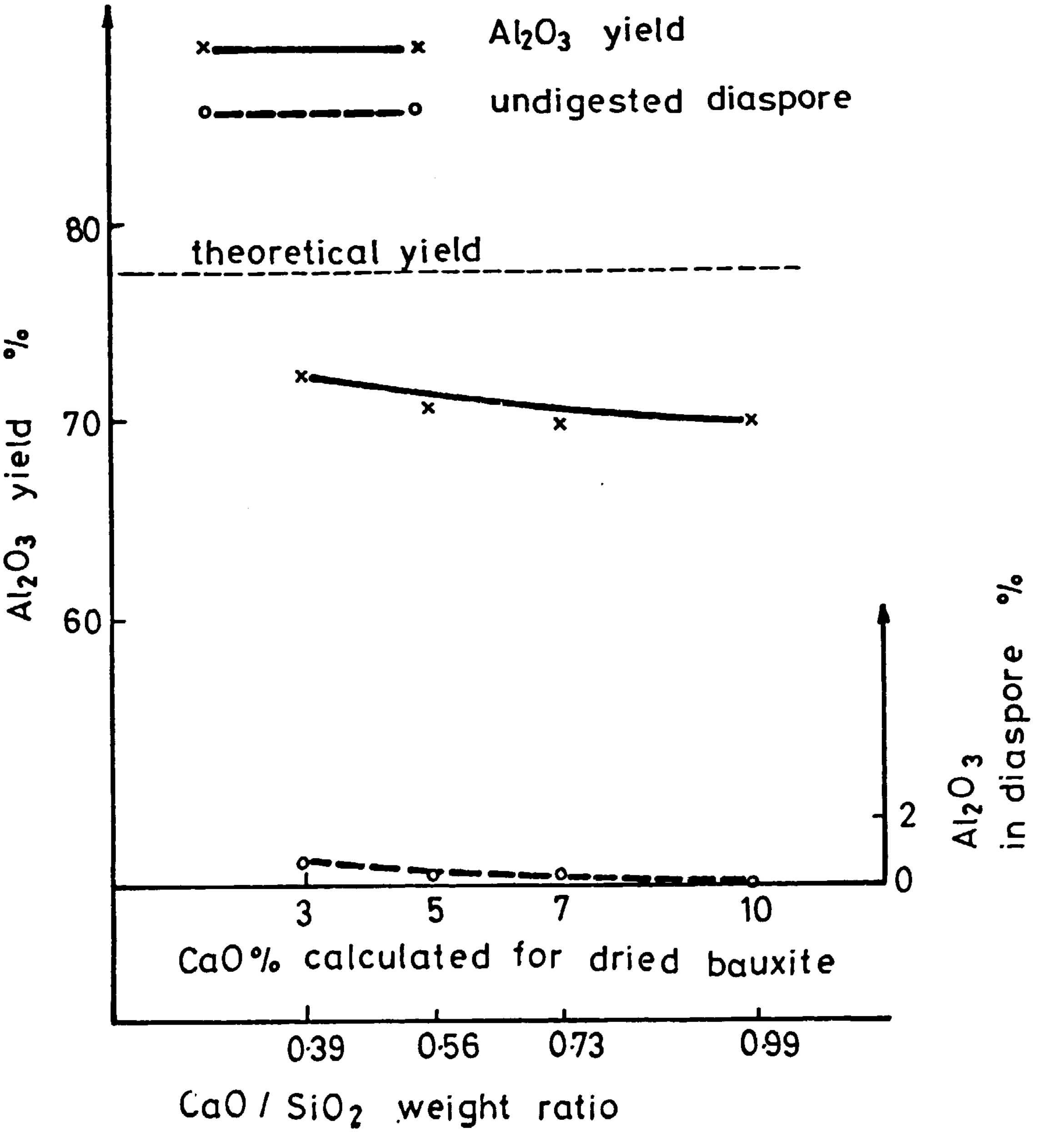
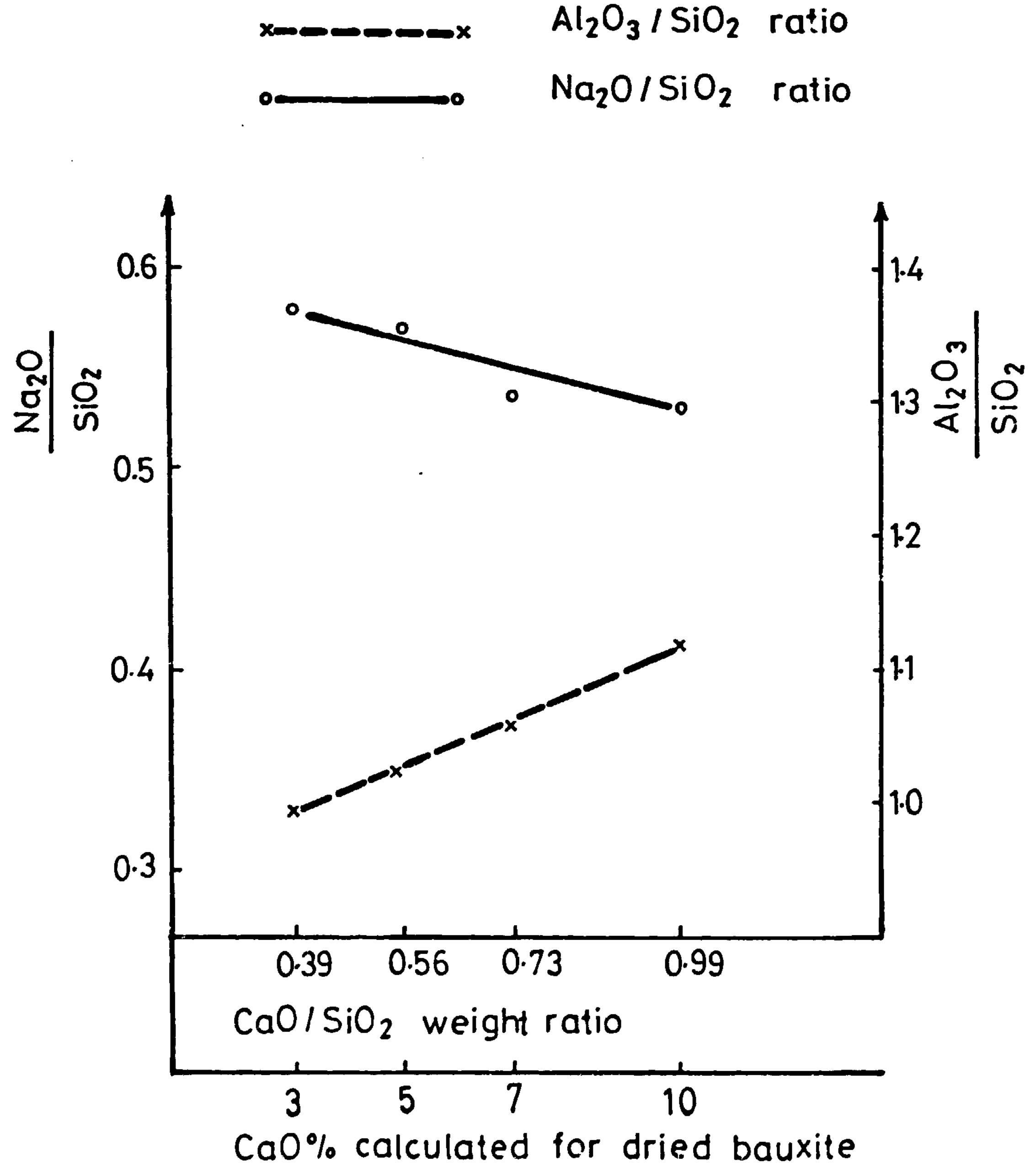


Fig.A2-16

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 /chem./ | 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 /chem./ | 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 /chem./ | 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

| | | Grain size of bauxite | |
|---|---|---|---|
| Sample | | < 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 |
| $Fe_2O_3$ % 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

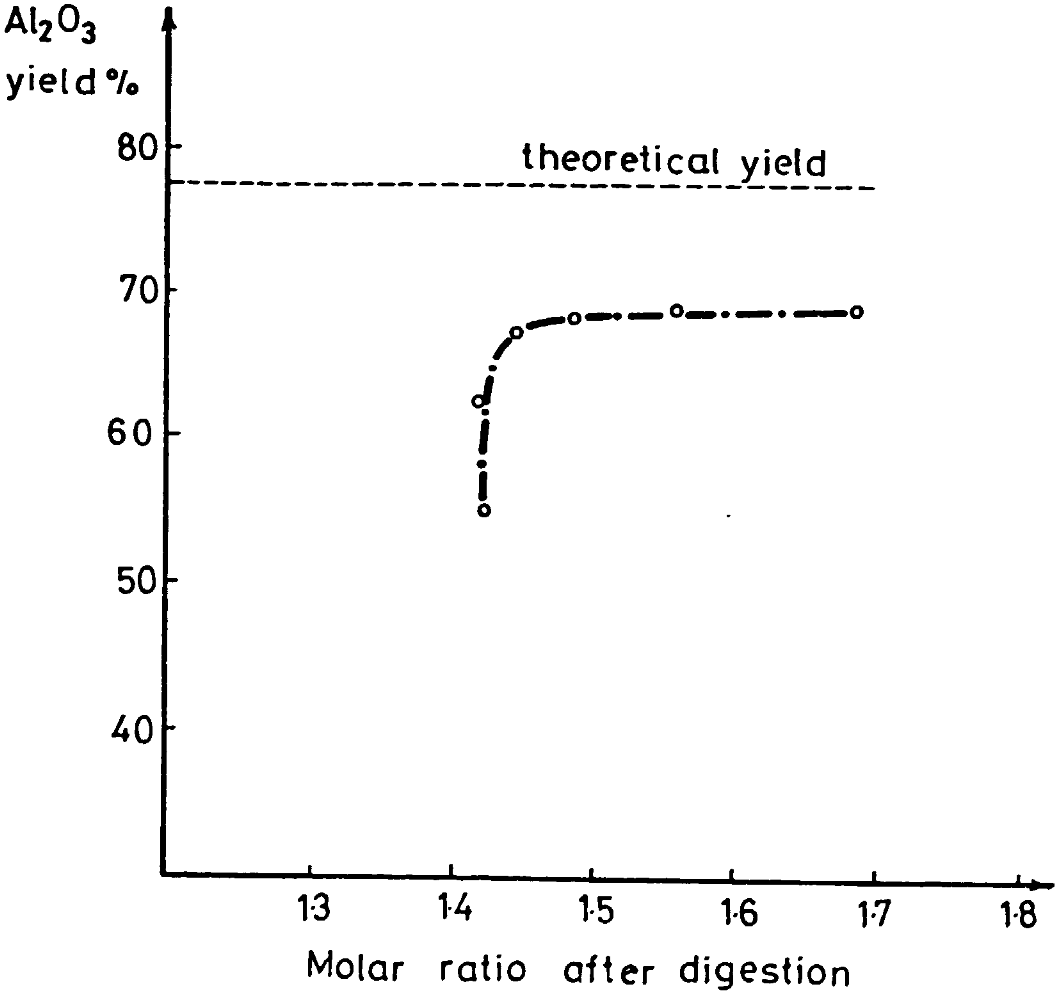
Holding time: 1 hour

| | | 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 | | | |
|---|---|---|---|---|---|
| | | 1o 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 | 13.1 | 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

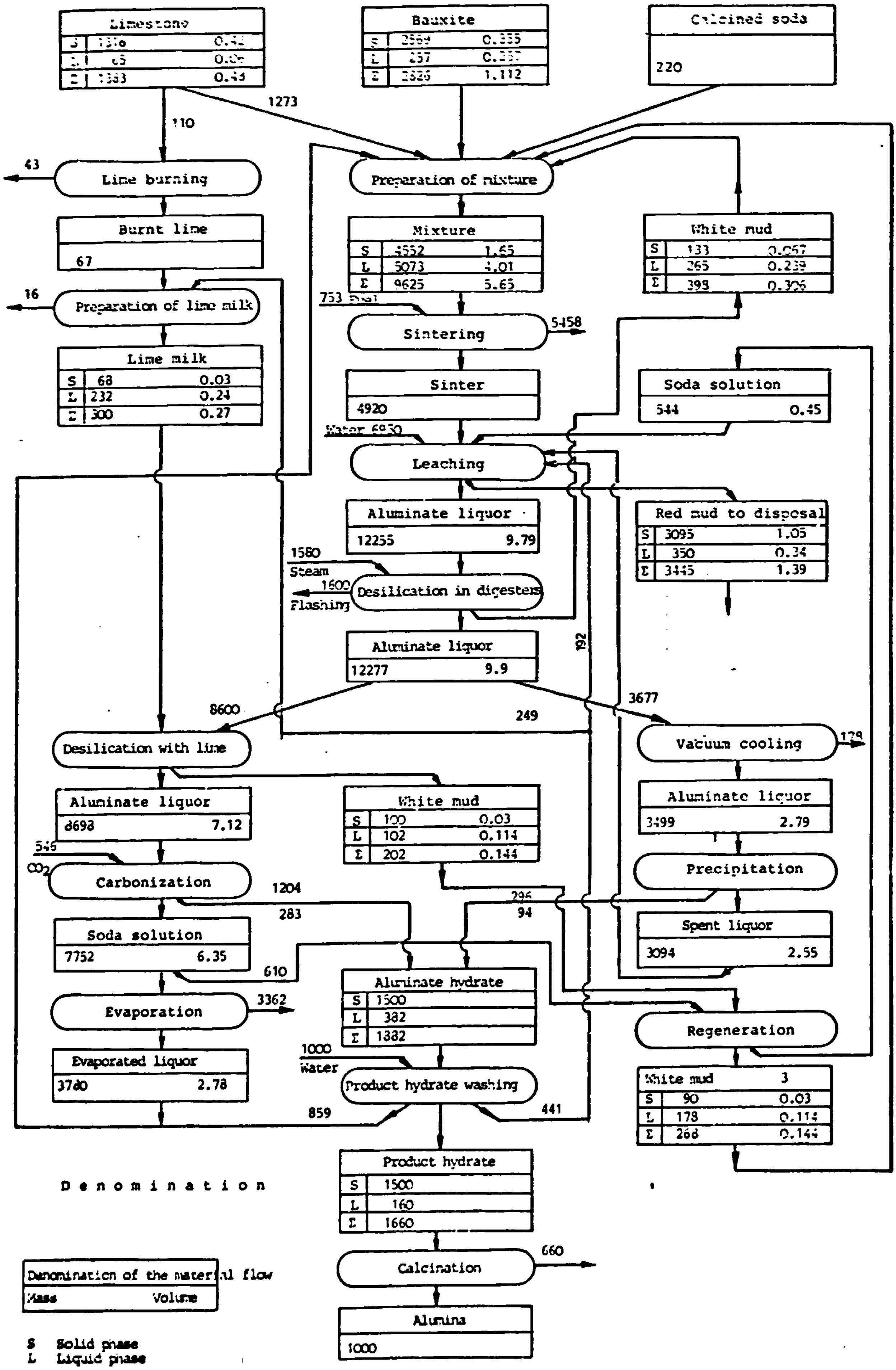


Table A3-2

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

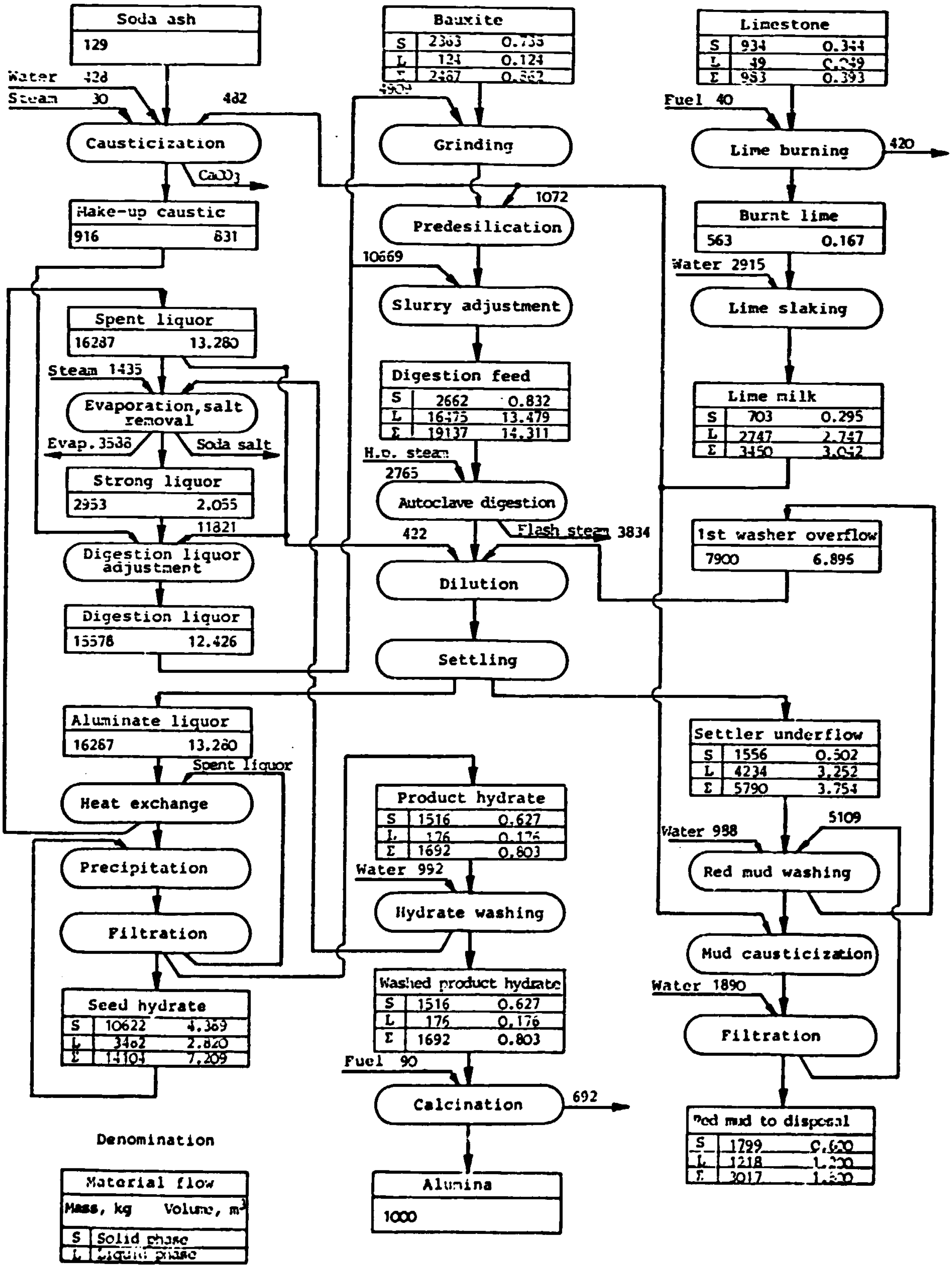


Table A3-3

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

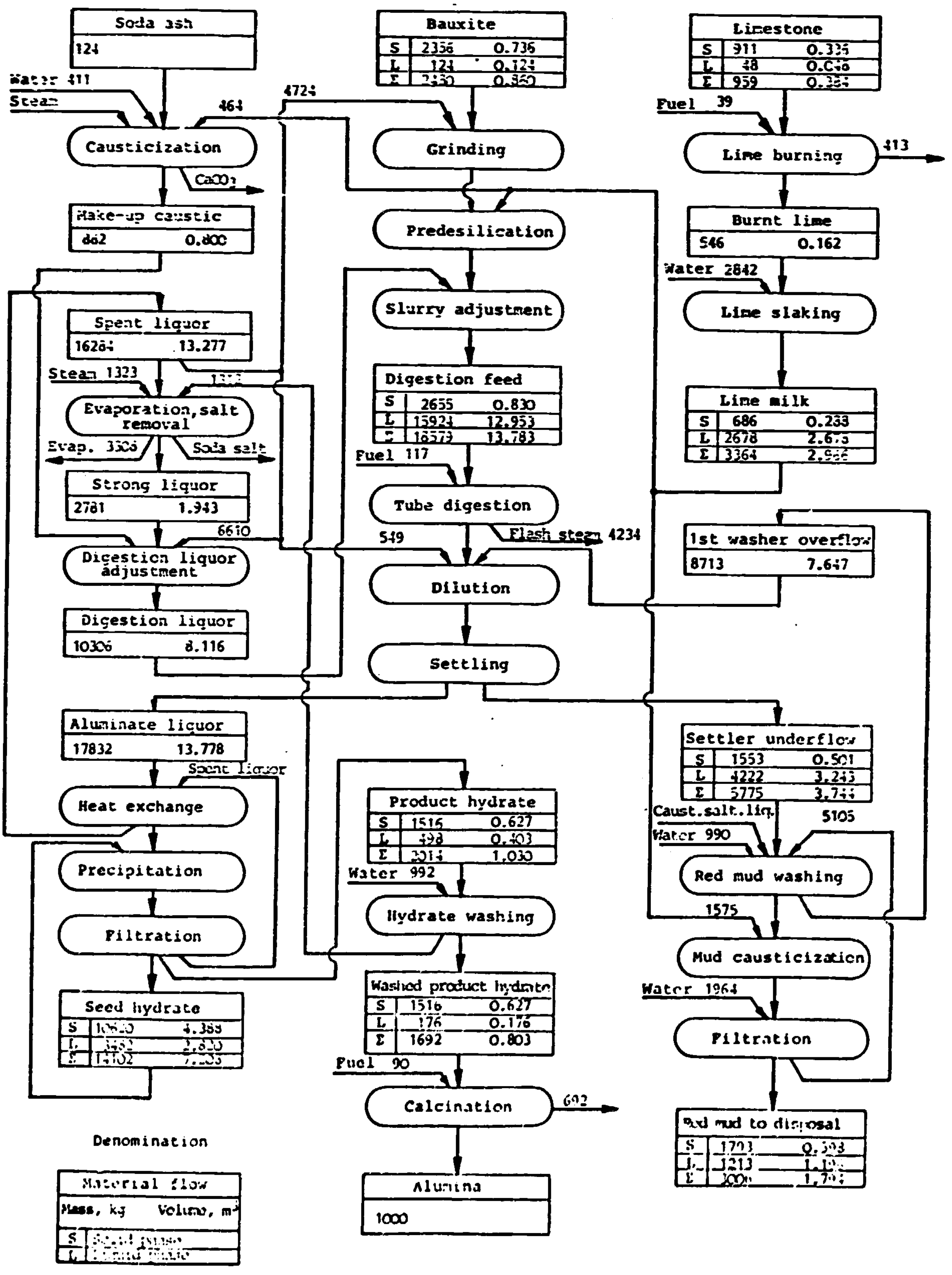


Table A3-4

### 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 caustícization | - | 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 caustisization | - | 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 | |

Attachment 4

# Main equipment list

## MAIN EQUIPMENT LIST

Attachment 4

### MECHANICAL EQUIPMENT FOR SINTERING PROCESS

1. Bauxite receiving and crushing
1a Bauxite storage

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 1. Hammer mill with vibrating screen<br>Cap.: 160 t/h | 1 | 1 | 24 |
| 2. Front end loaders<br>Bucket cap.: 1.3 $m^3$ | 3 | 2 | |
| 3. Rubber belt conveyors<br>B = 1000 mm<br>L = 10 m<br>Cap.: 160 t/h | 2 | 2 | 12 |
| 4. Rubber belt conveyor<br>B = 1000 mm<br>L = 150 m<br>Cap.: 160 t/h | 1 | 1 | 30 |
| 5. Rubber belt conveyor with weighing belt<br>B = 1000 mm<br>L = 200 m<br>Cap.: 125 t/h | 1 | 1 | 40 |
| 6. Apron belts with speed control<br>B = 1000 mm<br>L = 8 m<br>Cap.: 160 t/h | 1 | 1 | 15 |

| | Total | Number Operat-ing | Total Weight (t) |
|---|---|---|---|
| 7. Apron belts with speed control<br>B = 800 mm<br>L = 6 m<br>Cap.: 85 t/h | 2 | 1 | 16 |
| 8. Electric hoist<br>Cap.: 5 t | 1 | 1 | 1 |
| 9. Jaw crusher with vibrating screen<br>Cap.: 160 t/h | 1 | 1 | 32 |

## 2. Limestone receiving and crushing

## 2a Limestone storage

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

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

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 3. <u>Lime burning</u><br>3a <u>Lime slaking</u> | | | |
| 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<br>Cap.: 70 t/day (CaO) | 1 | 1 | 300 |
| 2. Lime slaking drum<br>ϕ 1.8 m x 10 m<br>Cap.: 10 $m^3$/h slaked lime | 1 | 1 | 10 |
| 3.*Burnt lime silo with feed and discharge facilities<br>Cap.: 100 t<br>Feed and disch. cap.: 5 t/h | 1 | 1 | 12 |
| 4.*Flat bottom tanks<br>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<br>Cap.: 10 $m^3$/h | 4 | 2 | 2 |

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 4. <u>Soda ash receiving and storage</u> | | | |
| 1.*Soda ash silos with pneumatic feed and discharge facilities<br>ϕ 10 m x 27 m<br>Volume: 2000 $m^3$ | 2 | 2 | 480 |

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

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 6. Adjustment tanks | | | |
| 1.*Tanks with conical bottom<br>∅ 9 m x 20 m<br>Volume: 1000 $m^3$ | 11 | 11 | 770 |

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 6a High pressure pump station | | | |
| 1. Piston slurry pumps with suction and delivery dashpot<br>Cap.: 120 $m^3/h$<br>Head: 30 bar | 6 | 2 | 156 |
| 2. Overhead travelling crane<br>Cap.: 5 t | 1 | 1 | 12 |

## 7. Sintering

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

## 8. Sinter crushing

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 1. Bucket elevators<br>Cap.: 65 t/h | 2 | 1 | 30 |
| 2. Screen classifiers<br>Cap.: 65 t/h | 3 | 2 | 13 |
| 3. Jaw crushers<br>Cap.: 50 t/h | 3 | 2 | 54 |
| 4. Double deck vibrating screens<br>Screening area: 2.5 m x 6 m | 3 | 2 | 36 |
| 5. Cone crushers<br>Dia: 2200 mm<br>Cap.: 70 t/h | 3 | 2 | 255 |
| 6. Rubber belt conveyors<br>B = 800 mm<br>L = 6 m<br>Cap.: 65 t/h | 3 | 2 | 12 |
| 7. Rubber belt conveyors<br>B = 800 mm<br>L = 8 m<br>Cap.: 60 t/h | 3 | 2 | 10 |
| 8. Rubber belt conveyors<br>B = 600 mm<br>L = 10 m<br>Cap.: 15 t/h | 3 | 2 | 9 |

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| **9. Sinter leaching** | | | |
| 1. Leaching belt<br>Cap.: 70 t/h | 2 | 2 | 1740 |
| 2. Filter thickener<br>Surface: 41.5 $m^2$ | 6 | 6 | 120 |
| 3.*Flat bottom tanks<br>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<br>Cap.: 220-300 $m^3$/h | 8 | 4 | 12 |
| 6. Centrifugal pumps for slurry<br>Cap.: 30-100 $m^3$/h | 22 | 13 | 24 |

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 10. Autoclave desilication | | | |
| 1. Autoclaves<br>ϕ 2.5 m x 14 m<br>Volume: 50 $m^3$ | 14 | 14 | 280 |
| 2. Flash tanks<br>ϕ 3.6 m x 5.6 m<br>Volume: 50 $m^3$ | 4 | 4 | 52 |
| 3.*Flat bottom tanks<br>Volume: 6.3-100 $m^3$ | 4 | 4 | 16 |
| 4. Agitators for tanks with gearboxes, couplings and electric motors | 4 | 4 | 7 |
| 5. Centrifugal pumps for slurry with speed control<br>Cap.: 150 $m^3/h$ | 4 | 2 | 4 |
| 6. Centrifugal pumps for slurry<br>Cap.: 30 $m^3/h$ | 2 | 2 | 1 |

## 11. White mud No.1 settling

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 1. Single chamber settler<br>ϕ 20 m x 4 m<br>Volume: 1500 $m^3$ | 1 | 1 | 87 |
| 2. Vacuum drum filters with filtrate receivers<br>Surface: 10 $m^2$ | 2 | 1 | 18 |
| 3.*Flat bottom tanks<br>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<br>Cap.: 200 $m^3/h$ | 2 | 1 | 3 |
| 6. Centrifugal pumps for slurry<br>Cap.: 15-100 $m^3/h$ | 8 | 5 | 6 |
| 7.*Centrifugal pumps for water<br>Cap.: 15 $m^3/h$ | 2 | 1 | 1 |

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 12. <u>Control filtration</u> | | | |
| 1. Pressure filters<br>Surface: 125 $m^2$ | 2 | 1 | 22 |
| 2.*Flat bottom tanks<br>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<br>Cap.: 30-100 $m^3/h$ | 7 | 4 | 5 |
| 5. Centrifugal pumps for liquor<br>Cap.: 60 $m^3/h$ | 2 | 1 | 1.5 |

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| **13. Flash cooling, precipitation** | | | |
| 1. Vacuum flash vessels<br>ϕ 2 m | 3 | 3 | 30 |
| 2. Shell and tube type heat exchangers<br>Surface: 180 $m^2$ | 2 | 2 | 36 |
| 3.*Hydroseparator<br>ϕ 7 m x 19 m<br>Volume: 400 $m^3$ | 1 | 1 | 25 |
| 4. Vacuum disc filters with filtrate receivers<br>Surface: 100 $m^2$ | 2 | 1 | 40 |
| 5. Pressure filters<br>Surface: 125 $m^2$ | 2 | 1 | 22 |
| 6. Vacuum drum filters with filtrate receivers<br>Surface: 10 $m^2$ | 3 | 2 | 24 |
| 7.*Precipitator tanks with conical bottom<br>Volume: 1000 $m^3$ | 7 | 7 | 630 |
| 8.*Flat bottom tanks<br>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<br>Cap.: 15-100 $m^3/h$ | 16 | 11 | 14 |
| 11. Centrifugal pumps for liquor<br>Cap.: 15-100 $m^3/h$ | 8 | 4 | 7 |

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 14. <u>Deep desilication</u> | | | |
| 1. Single chamber settlers<br>ϕ 20 m x 4 m<br>Volume: 1500 $m^3$ | 2 | 2 | 24 |
| 2. Pressure filters<br>Surface: 125 $m^2$ | 3 | 2 | 33 |
| 3. Vacuum drum filters with filtrate recievers<br>Surface: 10 $m^2$ | 4 | 2 | 32 |
| 4.*Flat bottom tanks<br>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<br>Cap.: 230 $m^3/h$ | 6 | 3 | 7 |
| 7. Centrifugal pumps for slurry<br>Cap.: 15-25 $m^3/h$ | 14 | 12 | 10 |
| 8. Centrifugal pumps for liquor<br>Cap.: 15 $m^3/h$ | 4 | 2 | 2 |

## 15. Carbonisation and filtration

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 1. *Hydroseparator<br>Ø 10 m x 28 m<br>Volume: 1000 $m^3$ | 1 | 1 | 40 |
| 2. Vacuum disc filters with filtrate recievers<br>Surface: 100 $m^2$ | 3 | 2 | 60 |
| 3. Vacuum drum filters with filtrate receivers<br>Surface: 20 $m^2$ | 3 | 2 | 36 |
| 4. *Flat bottom tanks<br>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<br>Cap.: 230 $m^3/h$ | 6 | 3 | 7 |
| 7. Centrifugal pumps for slurry<br>Cap.: 30-50 $m^3/h$ | 21 | 13 | 15 |

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 16. <u>Carbonised hydrate filtration</u> | | | |
| 1. Pressure filters<br>Surface: 125 $m^2$ | 3 | 2 | 15 |
| 2.*Flat bottom tanks<br>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<br>Cap.: 200 $m^3$/h | 2 | 1 | 2 |
| 5. Centrfugal pumps for slurry<br>Cap.: 30-100 $m^3$/h | 6 | 4 | 5 |
| 6. Centrifugal pumps for liquor<br>Cap.: 60 $m^3$/h | 2 | 1 | 1.4 |

## 17. Hydrate storage

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 1.*Flat bottom tanks<br>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<br>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<br>Surface: 25 $m^2$ | 2 | 1 | 24 |
| 2. Fluid bed calcining kiln, with cyclons electrostatic dust precipitator, exhaust fan, alumina cooler, oil heating system<br>Cap.: 700 t/day | 1 | 1 | 490 |
| 3. Centrifugal pumps for liquor<br>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<br>Cap.: 65 t/h evaporated water | 2 | 2 | 400 |
| 2.*Flat bottom tanks<br>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<br>Cap.: 65-100 $m^3/h$ | 8 | 5 | 7 |
| 5.*Centrifugal pumps for condensate water<br>Cap.: 60-100 $m^3/h$ | 7 | 4 | 6 |

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

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 21. Compressor station | | | |
| 1. Turbo-compressors<br>Cap.: 15000 Nm$^3$/h<br>Pressure: 5 bar | 3 | 2 | 24 |
| 2. Air tanks<br>Volume: 50 m$^3$/h<br>Pressure: 5 bar | 3 | 3 | 15 |
| 3. Electric overhead travelling crane<br>Cap.: 12.5 t | 1 | 1 | 14 |
| 28. Oil storage | | | |
| 1. Oil storage tanks<br>∅ 18.5 m x 13.5 m<br>Volume: 3000 m$^3$ | 2 | 2 | 150 |
| 2. Oil unloading facilities | 4 | 4 | 2 |
| 3. Gear pumps<br>Cap.: 10-65 m$^3$/h | 6 | 3 | 3 |

MECHNAICAL EQUIPMENT
FOR BAYER PROCESS

1. Bauxite receiving and crushing
1a. Bauxite storage
Low quality bauxite
Autoclave and tube digestion

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

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

## 1. Bauxite receiving and crushing

## 1a. Bauxite storage

High quality bauxite
Autoclave and tube digestion

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

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

| | Total | Number Operat-ing | Total Weight (t) |
|---|---|---|---|
| 2. <u>Limestone receiving and crushing</u><br>2a. <u>Limestone storage</u><br>Low quality bauxite<br>Autoclave and tube digestion | | | |
| 1. Jaw crusher with vibrating screen<br>Cap.: 100 t/h | 1 | 1 | 27 |
| 2. Apron belt with speed control<br>B = 800 mm<br>L = 6 m<br>Cap.: 100 t/h | 1 | 1 | 8.5 |
| 3. Rubber belt conveyor with speed control<br>B = 800 mm<br>L = 220 m<br>Cap.: 100 t/h | 1 | 1 | 45 |
| 4. Apron belts with speed control<br>B = 800 mm<br>L = 6 m<br>Cap.: 80 t/h | 4 | 1 | 28 |
| 5. Rubber belt conveyor with weighing belt<br>B = 800 mm<br>L = 180 m<br>Cap.: 80 t/h | 1 | 1 | 31 |
| 6.* Dust collecting facility with exhaust fan<br>Cap.: 3500 $m^3/h$ | 1 | 1 | 2.5 |
| 7. Front end loaders<br>Bucket cap.: 1.3 $m^3$ | 2 | 1 | |
| 8. Electric hoist<br>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<br>Cap.: 80 t/h | 1 | 1 | 25 |
| 2. | Apron belt with speed control<br>B = 800 mm<br>L = 6 m<br>Cap.: 80 t/h | 1 | 1 | 8.5 |
| 3. | Rubber belt conveyor with speed control<br>B = 800 mm<br>L = 150 m<br>Cap.: 80 t/h | 1 | 1 | 30 |
| 4. | Apron belts with speed control<br>B = 600 mm<br>L = 6 m<br>Cap.: 40 t/h | 2 | 1 | 12 |
| 5. | Rubber belt conveyor with weighing belt<br>B = 600 mm<br>L = 130 m<br>Cap : 40 t/h | 1 | 1 | 21 |
| 6.* | Dust collecting facility with exhaust fan<br>Cap.: 3500 $m^3/h$ | 1 | 1 | 2.5 |
| 7. | Front end loaders<br>Bucket cap.: 1.3 $m^3$ | 2 | 1 | |
| 8. | Electric hoist<br>Cap.: 5 t | 1 | 1 | 1 |

3. <u>Lime burning</u>

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

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.<br>Cap.: 250 t/day | 3 | 3 | 1200 |
| 2.* | Burnt lime silo with feed and discharge facilities<br>Ø 8.5 m x 12 m s.s. conical bottom<br>Cap.: 750 t<br>Feed and disch.cap.: 16 t/h | 1 | 1 | 45 |
| 3. | Lime settler<br>Ø 20 m x 5 m s.s.<br>1:3 slope bottom | 1 | 1 | 100 |
| 4. | Lime slaking drums<br>Ø 1.8 m x 10 m<br>Cap.: 80 $m^3$/h slaked lime | 2 | 2 | 20 |
| 5. | Rubber belt conveyor with weighing belt<br>B = 600 mm<br>L = 15 m<br>Cap.: 20 t/h | 2 | 2 | 12 |
| 6.* | Flat bottom tanks<br>Volume: 6.3-100 $m^3$ | 4 | 3 | 27 |

| | | Total | Number Operat-ing | Total Weight (t) |
|---|---|---|---|---|
| 7. | Agitators for tanks with gearboxes, couplings and electric motors | 3 | 2 | 6 |
| 8. | Centrifugal pumps for slurry with speed control<br>Cap.: 10-95 $m^3/h$ | 10 | 5 | 6 |
| 9. | Centrifugal pump for slurry<br>Cap.: 30 $m^3/h$ | 1 | 1 | 1 |
| 10.* | Centrifugal pump for water<br>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.<br>Cap.: 175 t/day | 2 | 2 | 700 |
| 2.* | Burnt lime silo with feed and discharge facilities<br>Ø 8 m x 10 m s.s. conical bottom<br>Cap.: 500 t<br>Feed and disch.cap.: 16 t/h | 1 | 1 | 35 |
| 3. | Lime settler<br>Ø 20 m x 5 m s.s.<br>1:3 slope bottom | 1 | 1 | 100 |
| 4. | Lime slaking drum<br>Ø 1.8 m x 10 m<br>Cap.: 80 $m^3$/h slaked lime | 1 | 1 | 10 |
| 5. | Rubber belt conveyor with weighing belt<br>B = 600 mm<br>L = 15 m<br>Cap.: 16 t/h | 1 | 1 | 6 |
| 6.* | Flat bottom tanks<br>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<br>Cap.: 10-65 $m^3/h$ | 10 | 5 | 4.5 |
| 9. | Centrifugal pump for slurry<br>Cap.: 30 $m^3/h$ | 1 | 1 | 1 |
| 10.* | Centrifugal pump for water<br>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<br>ϕ 10 m x 18 m with conical bottom<br>Volume: 1400 m$^3$ | 2 | 2 | 280 |
| 2.* | Day bin with feed and discharge facilities<br>ϕ 4 m x 8 m with conical bottom<br>Volume: 65 m$^3$<br>Feed and disch.cap.: 10 t/h | 1 | 1 | 10 |
| 3. | Pressure belt filter<br>Filtration area 20 m$^2$<br>Cap.: 5 t/h | 1 | 1 | 6.5 |
| 4. | Rubber belt conveyor with weighing belt<br>B = 500 mm<br>L = 5 m<br>Cap.: 10 t/h | 1 | 1 | 1.5 |
| 5.* | Flat bottom tanks<br>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<br>Cap.: 25 m$^3$/h | 2 | 1 | 1.5 |
| 8. | Centrifugal pumps for liquor<br>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<br>Ø 8 m x 14 m with conical bottom<br>Volume: 700 $m^3$ | 2 | 2 | 180 |
| 2.* | Day bin with feed and discharge facilities<br>Ø 3.5 m x 8 m with conical bottom<br>Volume: 50 $m^3$<br>Feed and disch.cap.: 6 t/h | 1 | 1 | 8 |
| 3. | Pressure belt filter<br>Filtration area 20 $m^2$<br>cap.: 5 t/h | 1 | 1 | 6.5 |
| 4. | Rubber belt conveyor with weighing belt<br>B = 500 mm<br>L = 5 m<br>Cap.: 6 t/h | 1 | 1 | 1.5 |
| 5.* | Flat bottom tanks<br>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<br>Cap.: 25 $m^3/h$ | 2 | 1 | 1.5 |
| 8. | Centrifugal pumps for liquor<br>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<br>B = 800 mm<br>L = 50 m<br>Cap.: 50 t/h | 3 | 2 | 6 |
| 2. | Multi-chamber ball mills with conical screens<br>ϕ 2.6 m x 13 m<br>Cap.: 50 t/h | 3 | 2 | 360 |
| 3. | Classifier screens | 9 | 6 | 11 |
| 4.* | Flat bottom tanks<br>Volume: 200 $m^3$ | 2 | 2 | 20 |
| 5.* | Flat bottom tanks<br>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<br>Cap.: 70-200 $m^3/h$ | 8 | 3 | 10 |
| 8. | Centrifugal pumps for slurry<br>Cap.: 30 $m^3/h$ | 2 | 2 | 2 |
| 9.* | Centrifugal pumps for water<br>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<br>B = 800 mm<br>L = 50 m<br>Cap.: 35 t/h | 3 | 2 | 6 |
| 2. | Multi-chamber ball mills with conical screens<br>Ø 2.2 m x 13 m<br>Cap.: 35 t/h | 3 | 2 | 315 |
| 3. | Classifier screens | 9 | 6 | 11 |
| 4.* | Flat bottom tanks<br>Volume: 200 $m^3$ | 2 | 2 | 20 |
| 5.* | Flat bottom tanks<br>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<br>Cap.: 70-140 $m^3/h$ | 8 | 3 | 8 |
| 8. | Centrifugal pumps for slurry<br>Cap.: 30 $m^3/h$ | 2 | 2 | 2 |
| 9.* | Centrifugal pumps for water<br>Cap.: 60 $m^3/h$ | 2 | 1 | 1.5 |

| | | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 6. | <u>Slurry storage and predesilication</u><br>Low quality bauxite<br>Autoclave and tube digestion | | | |
| 1. | Shell and tube type heat exchangers<br>Shell dia: Ø 368 x10 mm<br>Heating tubes: 3 x Ø 108 x 4 mm<br>Surface: 12 $m^2$ | 21 | 14 | 52 |
| 2.* | Flat bottom tanks<br>Volume: 500 $m^3$ | 5 | 4 | 85 |
| 3.* | Flat bottom tanks<br>Volume: 6.3-200 $m^3$ | 3 | 3 | 22 |
| 4. | Agitators for tanks with gearboxes, couplings and electric motors | 8 | 7 | 55 |
| 5. | Centrifugal pumps for slurry with speed control<br>Cap.: 230 $m^3$/h | 3 | 2 | 3.3 |
| 6. | Centrifugal pumps for liquor with speed control<br>Cap.: 170-230 $m^3$ | 4 | 2 | 4.4 |
| 7. | Centrifugal pumps for slurry<br>Cap.: 30 $m^3$/h | 1 | 1 | 0.8 |

| | | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 6. | <u>Slurry storage and predesilication</u><br>High quality bauxite<br>Autoclave and tube digestion | | | |
| 1. | Shell and tube type heat exchangers<br>Shell dia: ∅ 219 x 6.3 mm<br>Heating tubes: 3 x ∅ 76 x 2.9 mm<br>Surface: 10 $m^2$ | 21 | 14 | 52 |
| 2.* | Flat bottom tanks<br>Volume: 500 $m^3$ | 4 | 3 | 68 |
| 3.* | Flat bottom tanks<br>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<br>Cap.: 210 $m^3$/h | 3 | 2 | 3.3 |
| 6. | Centrifugal pumps for liquor with speed control<br>Cap.: 120-250 $m^3$ | 4 | 2 | 4.4 |
| 7. | Centrifugal pumps for slurry<br>Cap.: 30 $m^3$/h | 1 | 1 | 0.8 |

## 7. H.P. pump station

Low and high quality bauxite
Autoclave digestion

| | | Number Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 1. | H.P. diaphragm pumps with speed control, with suction and delivery dashpots<br>Cap.: 230 $m^3/h$<br>Head: 70 bar | 3 | 2 | 165 |
| 2.* | Flat bottom tank<br>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<br>Cap.: 5 t | 1 | 1 | 15 |

7. <u>H.P. pump station</u>
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<br>Cap.: 80-150 $m^3/h$<br>Head: 120 bar | 6 | 4 | 276 |
| 2.* | Flat bottom tank<br>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<br>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<br>ϕ 2.5 m x 14 m<br>p = 60/35 bar<br>Volume: 50 $m^3$ | 22 | 22 | 1496 |
| 2. | Autoclaves for heating bauxite slurry with life steam<br>ϕ 2.5 m x 14 m<br>p = 60/80 bar<br>Volume: 50 $m^3$ | 8 | 8 | 544 |
| 3. | Autoclaves for ensuring the required holding time<br>ϕ 2.5 m x 14 m<br>p = 60 bar<br>Volume: 50 $m^3$ | 4 | 4 | 244 |
| 4. | Flash tanks<br>ϕ 2.8 m x 5 m<br>p = 6-25 bar<br>Volume: 25 $m^3$ | 20 | 20 | 223 |
| 4. | Flash tanks<br>ϕ 2.8 m x 5.5 m<br>P = 6 bar<br>Volume: 30 $m^3$ | 2 | 2 | 18 |
| 5. | Condensate blow-off vessels<br>Volume: 0.22-2,2 $m^3$ | 22 | 22 | 9 |

| | Total | Number Operating | Total Weight (t) |
|---|---|---|---|
| 6. Condensers<br>Volume: 3 $m^3$ | 2 | 2 | 3.7 |
| 7.* Flat bottom tanks<br>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<br>Cap.: 270 $m^3/h$ | 4 | 2 | 4.4 |
| 10. Centrifugal pumps for slurry<br>Cap.: 30 $m^3/h$ | 2 | 2 | 2 |
| 11.* Centrifugal pumps for water<br>Cap.: 60 $m^3/h$ | 4 | 2 | 4 |

## 8. Tube digestion

| | | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 1. | Shell and tube type heat exchangers for heating the bauxite slurry and adjusting liquor using low pressure steam<br>Shell dia: 368 x 14 mm<br>Heating tubes: 3x 0 108 x 8 mm<br>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<br>Shell dia: 368 x 14 mm<br>Heating tubes: 3x0 108 x 8 mm<br>Surface: 14 $m^2$ | 156 | 156 | 493 |
| 3. | Shell and tube type heat exchanger for heating the bauxite slurry with molten salt.<br>Shell dia: 368 x 14 mm<br>Heating tubes: 3x0 108 x 8 mm<br>Surface: 14 $m^2$ | 40 | 40 | 126 |
| 4. | Holding tubes<br>Ø 273x16 mm - 1600 m | 2 | 2 | 435 |
| 5. | Flash tanks<br>Ø 2.8 m x 5 m<br>p= 6-60 bar<br>Volume: 25 $m^3$ | 24 | 24 | 300 |
| 6. | Flash tanks<br>Ø 2.8 m x 5.5 m<br>Volume: 30 $m^3$ | 2 | 2 | 18 |

| | | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 7. | Condensate blow-off vessels<br>Ø 1.6 m x 2.7 m<br>Volume:4.5 $m^2$ | 2 | 2 | 4.8 |
| 8. | Condensers<br>Ø 0.9 m x 4.9 m<br>Volume: 3 $m^3$ | 2 | 2 | 3.7 |
| 9. | Flat bottom tanks<br>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<br>Cap.: 300 $m^3$/h | 8 | 8 | 10 |
| 12. | Centrifugal pumps for slurry<br>Cap.: 30 $m^3$/h | 2 | 2 | 2 |
| 13. | Centrifugal pumps for water<br>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 pumps, instrumentation<br>Cap.: 60 GJ/h<br>Molten salt outlet temp.: 330 °C<br>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<br>ϕ 30 m x 6.6 m<br>1:16 slope bottom<br>Volume: 4300 $m^3$ | 2 | 2 | 270 |
| 2. | Single chamber washers with slope bottom and cable torque rake, equiped with feed tanks<br>ϕ 30 x 6.6 m<br>1:16 slope bottom<br>Volume: 4300 $m^3$ | 6 | 5 | 810 |
| 3.* | Flat bottom tanks<br>ϕ 10 m x 6 m<br>Volume: 500 $m^3$ | 2 | 2 | 50 |
| 4.* | Flat bottom tanks<br>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<br>ϕ 2 m x 6.5 m<br>Volume: 15 $m^3/h$ | 5 | 4 | 20 |

| | | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 7. | Centrifugal pumps for slurry with speed control<br>Cap.: 50-140 $m^3/h$ | 21 | 10 | 26 |
| 8. | Centrifugal pumps for liquor with speed control<br>Cap.: 90-320 $m^3/h$ | 14 | 6 | 16 |
| 9. | Centrifugal pumps for slurry<br>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<br>ϕ 30 m x 6.6 m<br>1:16 slope bottom<br>Volume: 4300 $m^3$ | 2 | 2 | 270 |
| 2. | Single chamber washers with slope bottom and cable torque rake, equiped with feed tanks<br>ϕ 30 x 6.6 m<br>1:16 slope bottom<br>Volume: 4300 $m^3$ | 6 | 5 | 810 |
| 3.* | Flat bottom tanks<br>ϕ 10 m x 6 m<br>Volume: 500 $m^3$ | 2 | 2 | 50 |
| 4.* | Flat bottom tanks<br>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<br>ϕ 2 m x 6.5 m<br>Volume: 15 $m^3$ | 5 | 4 | 20 |

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

| | | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 10. | <u>Additive preparation</u><br>Low quality bauxite<br>Autoclave and tube digestion | | | |
| 1. | Flocculent (starch) preparing equipment complete with feed and discharge facilities, with bins, repulping and control units<br>Cap.: 170 kg/h | 1 | 1 | 7 |
| 2. | Synthetic flocculent (ALCLAR) preparing and charging unit complete with tanks pumps, fittings and control system<br>Cap.: 6 kg/h | 1 | 1 | 2 |
| 3.* | Flat bottom tanks<br>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<br>Cap.: 10 $m^3/h$ | 2 | 1 | 1.2 |

| | | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 10. | <u>Additive preparation</u><br>High quality bauxite<br>Autoclave and tube digestion | | | |
| 1. | Flocculent (starch) preparing equipment complete with feed and discharge facilities, with bins, repulping and control units<br>Cap.: 100 kg/h | 1 | 1 | 4.5 |
| 2. | Synthetic flocculent (ALCLAR) preparing and charging unit complete with tanks pumps, fittings and control system<br>Cap.: 4 kg/h | 1 | 1 | 1.5 |
| 3.* | Flat bottom tanks<br>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<br>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<br>Feed cap.: 75 $m^3/h$ | 6 | 4 | 4.8 |
| 2. | Red mud filters with receivers and with roller discharges<br>Surface: 100 $m^2$ | 14 | 12 | 490 |
| 3. | Screw conveyors<br>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<br>Cap.: 110 $m^3/h$<br>Head: 65 bar | 2 | 1 | 92 |
| 6. | Water ring vacuum pumps<br>Cap.: 9000 $m^3/h$ | 4 | 3 | 18 |
| 7. | Air blowers<br>Cap.: 2400 $m^3/h$ | 2 | 1 | 5 |
| 8. | Condenser with moisture trap<br>$\phi$ 2.2 m x 5 m | 1 | 1 | 8 |
| 9.* | Flat bottom tanks<br>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<br>Cap.: 280 $m^3/h$ | 2 | 1 | 3 |
| 12. | Centrifugal pumps for liquor with speed control<br>Cap.: 260 $m^3/h$ | 2 | 1 | 3 |
| 13. | Centrifugal pumps for slurry<br>Cap.: 50 $m^3/h$ | 6 | 5 | 6 |
| 14.* | Centrifugal pumps for water<br>Cap.: 20-120 $m^3/h$ | 3 | 2 | 3 |
| 15. | Overhead travelling cranes<br>Cap.: 5 t | 3 | 3 | 24 |

| | | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 11. | Mud causticization and red mud filtration<br>High quality bauxite<br>Autoclave and tube digestion | | | |
| 1. | Vibrating screens<br>Feed cap.: 75 $m^3/h$ | 3 | 2 | 2.4 |
| 2. | Red mud filters with receivers and with roller discharges<br>Surface: 100 $m^2$ | 5 | 4 | 175 |
| 3. | Screw conveyors<br>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<br>Cap.: 55 $m^3/h$<br>Head: 65 bar | 2 | 1 | 56 |
| 6. | Water ring vacuum pumps<br>Cap.: 5000 $m^3/h$ | 3 | 2 | 9 |
| 7. | Air blowers<br>Cap.: 1000 $m^3/h$ | 2 | 1 | 3 |
| 8. | Condenser with moisture trap<br>ϕ 2.2 m x 5 m | 1 | 1 | 8 |
| 9.* | Flat bottom tanks<br>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<br>Cap.: 150 $m^3/h$ | 2 | 1 | 2.2 |
| 12. | Centrifugal pumps for liquor with speed control<br>Cap.: 150 $m^3/h$ | 2 | 1 | 2.2 |
| 13. | Centrifugal pumps for slurry<br>Cap.: 50 $m^3/h$ | 6 | 5 | 6 |
| 14.* | Centrifugal pumps for water<br>Cap.: 20-120 $m^3/h$ | 3 | 2 | 3 |
| 15. | Overhead travelling cranes<br>Cap.: 5 t | 3 | 3 | 24 |

| | | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 12. | <u>Control filtration</u><br>Low and high quality bauxite<br>Autoclave and tube digestion | | | |
| 1. | Pressure filters<br>Surface: 125 $m^2$ | 4 | 3 | 44 |
| 2.* | Flat bottom tanks<br>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<br>Cap.: 410 $m^3$/h | 2 | 1 | 4 |
| 5. | Centrifugal pumps for slurry<br>Cap.: 30-150 $m^3$/h | 5 | 3 | 5 |

| | | Total | Operating | Total Weight (t) |
|---|---|---|---|---|
| 13. | <u>Heat interchange</u><br>Low and high quality bauxite<br>Autoclave and tube digestion | | | |
| 1. | Plate heat exchangers<br>Surface: 300 $m^2$ | 3 | 2 | 14.4 |
| 2.* | Flat bottom tanks<br>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<br>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<br>ϕ 10 m x 31.5 m<br>Volume: 2000 $m^3$ | 16 | 15 | 2896 |
| 2. | Wash liquor preheater<br>Surface: 160 $m^2$ | 1 | 1 | 5.1 |
| 3. | Interstage coolers<br>Surface: 150 $m^2$ | 2 | 2 | 40 |
| 4.* | Hydroseparators with 60° cone bottom<br>ϕ 10 m x 18 m s.s. | 2 | 1 | 192 |
| 5.* | Flat bottom tanks<br>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<br>Cap.: 170-600 $m^3/h$ | 4 | 2 | 9 |
| 8. | Centrifugal pumps for slurry<br>Cap.: 160-320 $m^3/h$ | 8 | 5 | 14 |
| 9. | Centrifugal pumps for slurry<br>Cap.: 30-60 $m^3/h$ | 5 | 4 | 5 |

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

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

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

| | | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 16. | <u>Calcination, alumina storage</u><br>Low and high quality bauxite<br>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<br>Cap.: 350 t/day | 2 | 2 | 1390 |
| 2. | Alumina silo feed and discharge units | 2 | 2 | 7 |
| 3. | Waggon feed units | 2 | 2 | 1.6 |

|  |  | Total | Operating | Weight (t) |
|---|---|---|---|---|
| 17. | <u>Evaporation</u><br>Low quality bauxite<br>Autoclave and tube digestion |  |  |  |
| 1. | Five effect counter-current forced circulation evaporators, with flash tanks, preheaters, feed and circulation pumps<br>Cap.: 60 t/h evaporated water | 2 | 2 | 380 |
| 2. | Superconcentrator with feed and cirulation pumps, preheaters and flash tanks<br>Cap.: 15 t/h evaporated water | 1 | 1 | 45 |
| 3. | Strong liquor preheater<br>Surface: 50 $m^2$ | 1 | 1 | 4 |
| 4.* | Flat bottom tanks<br>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<br>Cap.: 30-70 $m^3/h$ | 8 | 5 | 8 |
| 7. | Centrifugal pumps for water with speed control<br>Cap.: 700 $m^3/h$ | 2 | 1 | 4 |
| 8.* | Centrifugal pumps for water<br>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<br>Cap.: 50 t/h evaporated water | 2 | 2 | 360 |
| 2. | Superconcentrator with feed and cirulation pumps, preheaters and flash tanks<br>Cap.: 15 t/h evaporated water | 1 | 1 | 45 |
| 3. | Strong liquor preheater<br>Surface: 50 $m^2$ | 1 | 1 | 4 |
| 4.* | Flat bottom tanks<br>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<br>Cap.: 30-70 $m^3$/h | 8 | 5 | 8 |
| 7. | Centrifugal pumps for water with speed control<br>Cap.: 600 $m^3$/h | 2 | 1 | 4 |
| 8.* | Centrifugal pumps for water<br>Cap.: 25-50 $m^3$/h | 8 | 4 | 5 |

## 18. Salt removal

Low quality bauxite
Autoclave and tube digestion

| | | Total | Number Operating | Total Weight |
|---|---|---|---|---|
| 1. | Pressure filters<br>Surface: 125 $m^2$ | 2 | 1 | 16 |
| 2. | Vacuum drum filter with receiver<br>Surface: 12 $m^2$ | 1 | 1 | 8 |
| 3.* | Flat bottom tanks<br>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<br>Cap.: 10-30 $m^3$/h | 5 | 4 | 3 |
| 6. | Centrifugal pumps for liquor<br>Cap.: 20-100 $m^3$/h | 3 | 2 | 2 |

| | | Total | Number Operating | Total Weight |
|---|---|---|---|---|
| 18. | <u>Salt removal</u><br>High quality bauxite<br>Autoclave and tube digestion | | | |
| 1. | Pressure filters<br>Surface: 80 $m^2$ | 2 | 1 | 16 |
| 2. | Vacuum drum filter with receiver<br>Surface: 12 $m^2$ | 1 | 1 | 8 |
| 3.* | Flat bottom tanks<br>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<br>Cap.: 10-30 $m^3/h$ | 5 | 4 | 3 |
| 6. | Centrifugal pumps for liquor<br>Cap.: 20-50 $m^3/h$ | 3 | 2 | 2 |

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

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

|  |  | Total | Number Operating | Total Weight (t) |
|---|---|---|---|---|
| 21. | Oil storage<br>Low and high quality bauxite<br>Autoclave and tube digestion |  |  |  |
| 1. | Oil storage tanks<br>Ø 18.5 m x 13.5 m<br>Volume: 3000 $m^3$ | 2 | 2 | 150 |
| 2. | Oil unloading facilities | 4 | 4 | 2 |
| 3. | Gear pumps<br>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<br>Cap.: 8 t and 5 t | 2 | 2 |
| 32. | Frame crane<br>Cap.: 12.5 t | 1 | 1 |

| | | Number | |
|---|---|---|---|
| | Total | Operating | Spare |
| <u>Motor vehicles</u> | | | |
| 1. Autocrane<br>Cap.: 40 t | 1 | 1 | - |
| 2. Autocrane<br>Cap.: 10 t | 1 | 1 | - |
| 3. Autocrane<br>Cap.: 6.3 t | 1 | 1 | - |
| 4. Trucks<br>Cap.: 3.5 t | 4 | 4 | - |
| 5. Tilting-platforms trucks<br>Cap.: 6 $m^3$ | 2 | 2 | - |
| 6. Trucks with electric platform<br>Cap.: 3 t | 3 | 3 | - |
| 7. Trucks with electric platform<br>Cap.: 2 t | 3 | 3 | - |
| 8. Trucks with electric forks<br>Cap.: 2 t | 2 | 2 | - |
| 9. Trolley trucks with electric forks<br>Cap.: 2 t | 2 | 2 | - |
| 10. Trailers for trucks<br>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.:160 t/h | 28 |
| | 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 | |
| | ∅ 1.8 m x 10 m | |
| | Cap.: 10 $m^3$/h slaked lime | 8 |
| 5. | Multi-chamber ball mill with vibrating screen | |
| | ∅ 2.6 m x 13 m | |
| | Cap.: 125 t/h | 54 |

| | million of Rls |
|---|---|
| 6. Tank with conical bottom<br>Ø 9 m x 20 m<br>Volume: 1000 m$^3$ | 15 |
| 7. Piston slurry pump with suction and delivery dashpot<br>Cap.: 120 m$^3$/h<br>Head: 30 bar | 32 |
| 8. Rotary kiln with cooler, cyclon, gas purification system and exhaust fan<br>Ø 5 m x 120 m<br>Cap.: 1600 t/day | 998 |
| 9. Double deck vibrating screen<br>Screening area: 2.5 m x 6 m | 7 |
| 10. Cone cruscher<br>Dia: 220 mm<br>Cap.: 70 t/h | 61 |
| 11. Belt extractor<br>Cap.: 70 t/h | 386 |
| 12. Jigging screen<br>Surface: 41.5 m$^2$ | 12 |
| 13. Autoclave<br>Ø 2.5 m x 14 m<br>Volume: 50 m$^3$ | 8 |
| 14. Flash tank<br>Ø 3.6 m x 5.6 m<br>Volume: 50 m$^3$ | 5 |
| 15. Single chamber settler<br>Ø 20 m x 4 m<br>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 $m^2$ | 15 |
| 19. Shell and tube type heat exchanger | |
| Surface: 180 $m^2$ | 16 |
| 20. Hydroseparator | |
| ∅ 7 m x 19 m | |
| Volume: 400 $m^3$ | 7 |
| 21. Hydroseparator | |
| ∅ 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<br>Cap.: 65 t/h evaporated water | 159 |
| 25. Water ring vacuum pumps<br>Cap.: 7500 $m^3/h$ | 22 |
| 26. Turbo-compressor<br>Cap.: 15000 $Nm^3/h$<br>Pressure: 5 bar | 55 |

## 2. Bayer process

| | | million of Rls |
|---|---|---|
| 1. | Jaw crusher with vibrating screen<br>Cap.: 140 t/h | 22 |
| 2. | Hammer mill with vibrating screen<br>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<br>Cap.: 250 t/day | 160 |
| | Cap.: 175 t/day | 140 |
| 4. | Lime settler<br>ϕ 20 m x 5 m s.s.<br>1:3 slope bottom | 17 |
| 5. | Lime slaking drum<br>ϕ 1.8 m x 10 m<br>Cap.: 80 m$^3$/h slaked lime | 8 |
| 6. | Pressure belt filter<br>Filtration area: 20 m$^2$<br>Cap.: 5 t/h | 18 |
| 7. | Multi-chamber ball mill<br>with conical screen<br>ϕ 2.6 m x 13 m<br>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<br>Head: 70 bar | 97 |
| Cap.: 150 $m^3$/h<br>Head: 120 bar | 92 |
| 9. Autoclave for heating bauxite slurry with life steam<br>ϕ 2.5 m x 14 m<br>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<br>Cap.: 65 GJ/h | 98 |
| 11. Single chamber settler with slope bottom and cable torque rake<br>ϕ 30 m x 6.6 m<br>1:16 slope bottom | 22 |
| 12. Vacuum drum filter for filtering red mud with receivers and with roller discharge<br>Surface: 100 $m^2$ | 15 |
| 13. Vacuum drum filter with receivers<br>Surface: 12 m2 | 6 |

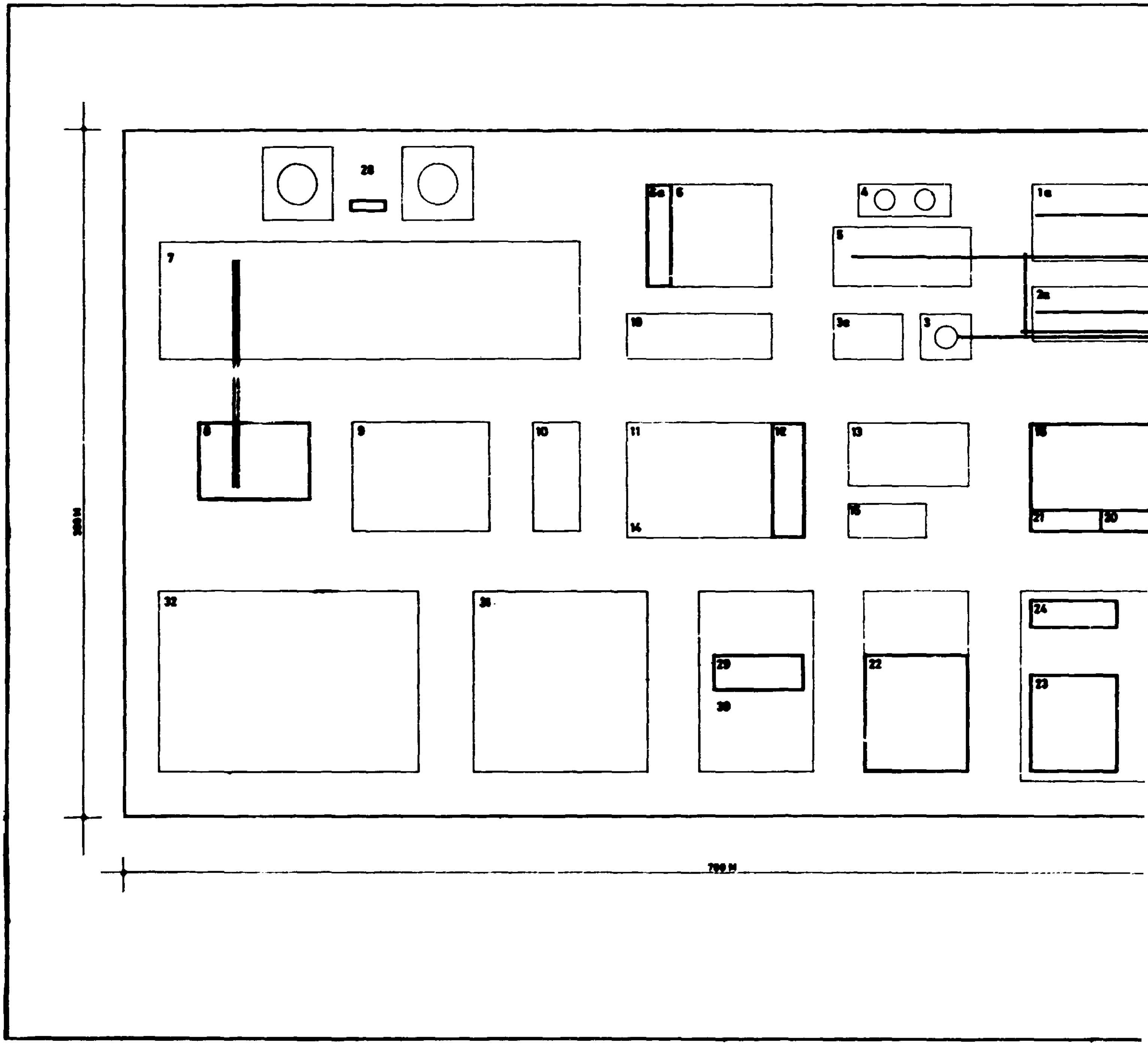
| | | million of Rls |
|---|---|---|
| 14. | Disc filter with receiver<br>Surface: 100 $m^2$ | 15 |
| 15. | Pan filter with receivers, interstage pumps, tanks<br>Surface: 20 $m^2$ | 14 |
| 16. | Pressure filter<br>Surface: 125 $m^2$ | 12 |
| | Surface: 80 $m^2$ | 9 |
| 17. | Precipitator tank with conical bottom, air agitated<br>ϕ 10 m x 31.5 m<br>Volume: 2000 $m^3$ | 29 |
| 18. | Hydroseparator with 60° con. bottom<br>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<br>Cap.: 350 t/day | 311 |
| 20. | Five effect counter-current forced circulation evaporator, with flash tanks, preheaters, feed end circulation pumps<br>Cap.: 60 t/h evaporated water | 151 |
| 21. | Superconcentrator with feed and circulation pumps, preheaters and flash tanks<br>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 |

Attachment 6

# Conceptional plant lay-out drawings

# SECTION 1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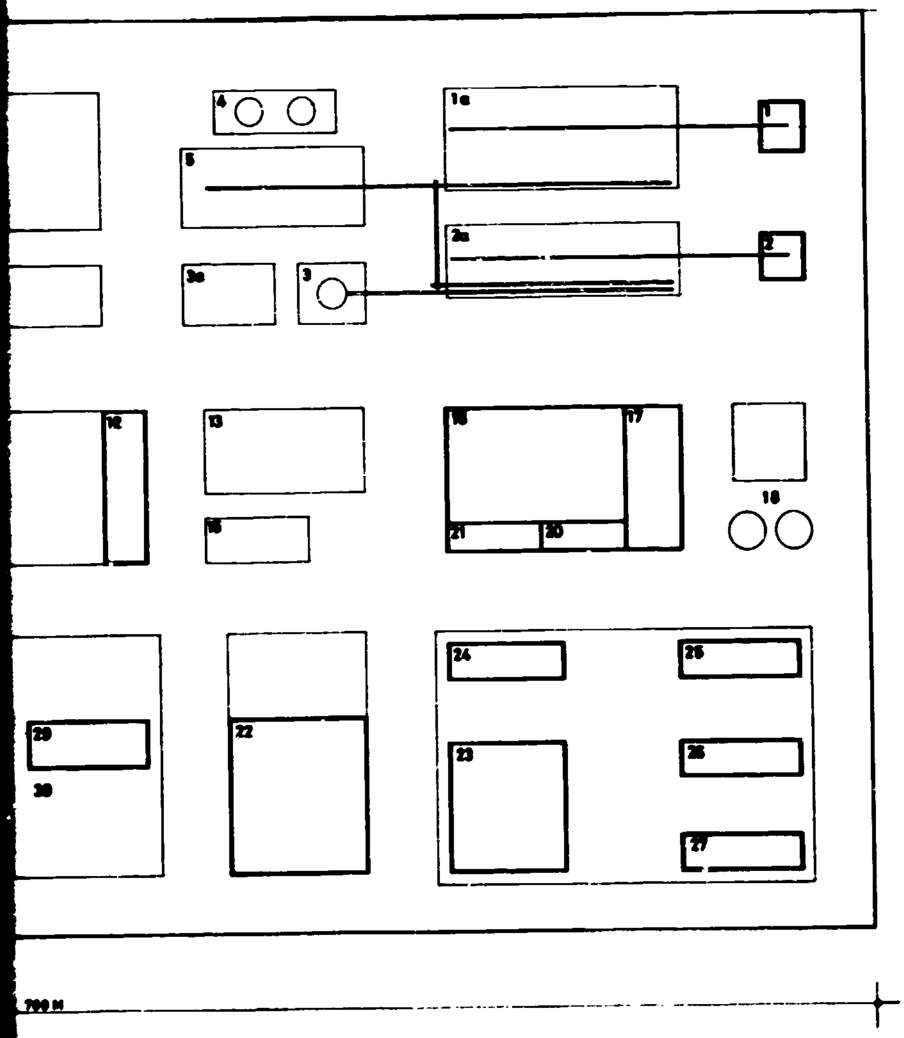
# SECTION 2



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1a BAUXITE STORAGE
2 LIMESTONE RECEIVING AND CRUSHING
2a LIMESTONE STORAGE
3 LIME BURNING
3a LIME SLAKING
4 SODA ASH RECEIVING AND STORAGE
5 WET GRINDING
6 ADJUSTMENT TANKS
6a H.P. PUMP STATION
7 SINTERING
8 SINTER CRUSHING
9 SINTER LEACHING
10 AUTOCLAVE DESILICATION
11 WHITE MUD N°1 SETTLING
12 CONTROL FILTRATION
13 FLASH COOLING, PRECIPITATION
14 DEEP DESILICATION
15 CARBONISATION AND FILTRATION
16 CARBONISED HYDRATE FILTRATION
17 HYDRATE STORAGE
18 CALCINATION, ALUMINA STORAGE
19 EVAPORATION
20 VACUUM STATION
21 COMPRESSOR STATION
22 WORKSHOP AND OPEN AIR STORAGE
23 STORES, GARAGES
24 CENTRAL LABORATORY
25 CHANGE HOUSE
26 CANTEEN
27 MANAGEMENT BUILDING
28 OIL STORAGE
29 CENTRAL ELECTRIC SWITCH HOUSE
30 110/10kV TRANSFORMER STATION
31 POWER PLANT
32 WATER PLANT, COOLING TOWERS

**ALUTERV-FKI**

CPL-1

GOLYAN
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ALUMINA PLANT IN IRAN

CONCEPTIONAL PLANT
LAY-OUT FOR SINTER
PROCESS
LOW QUALITY BAUXITE

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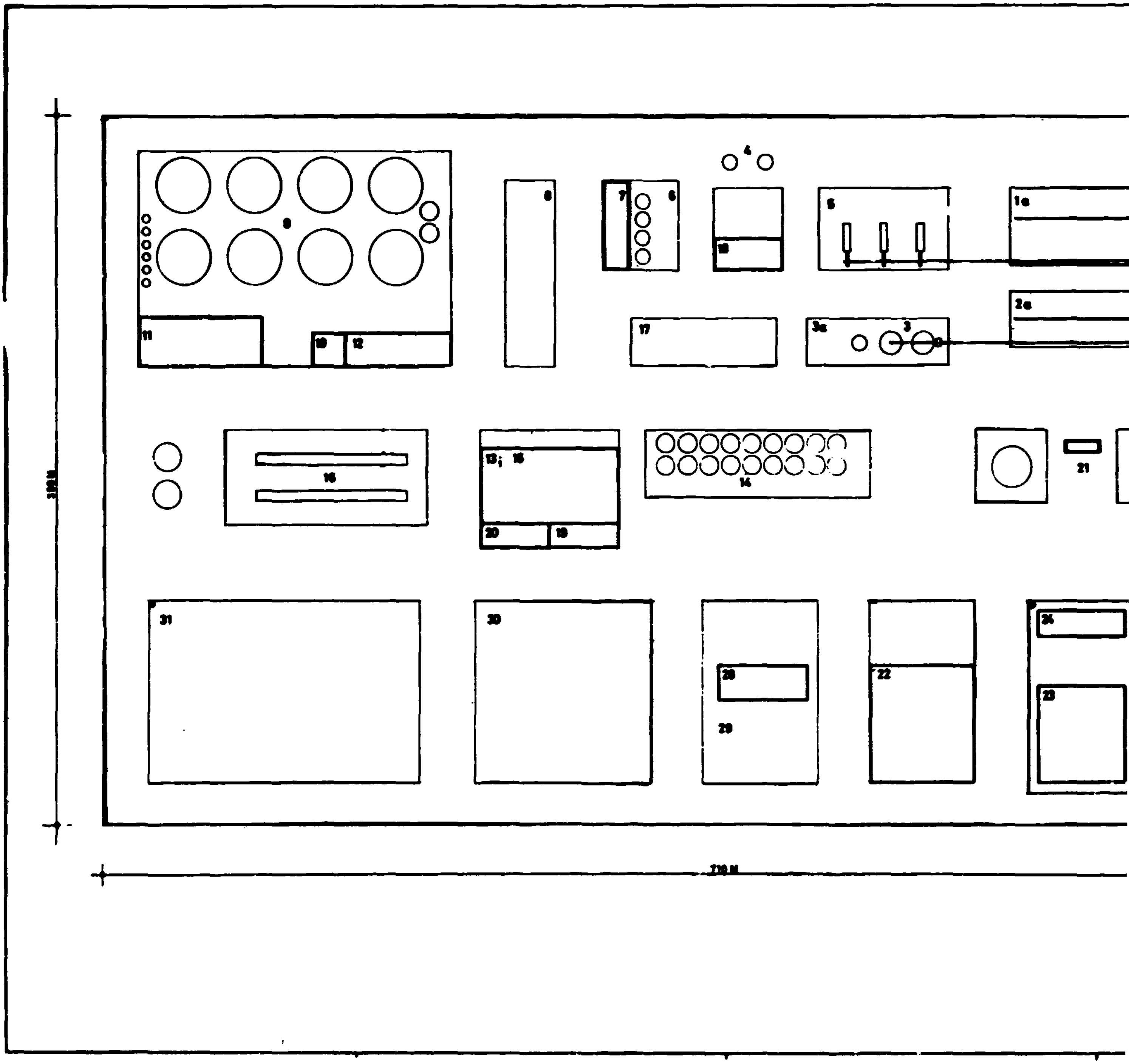
# SECTION 1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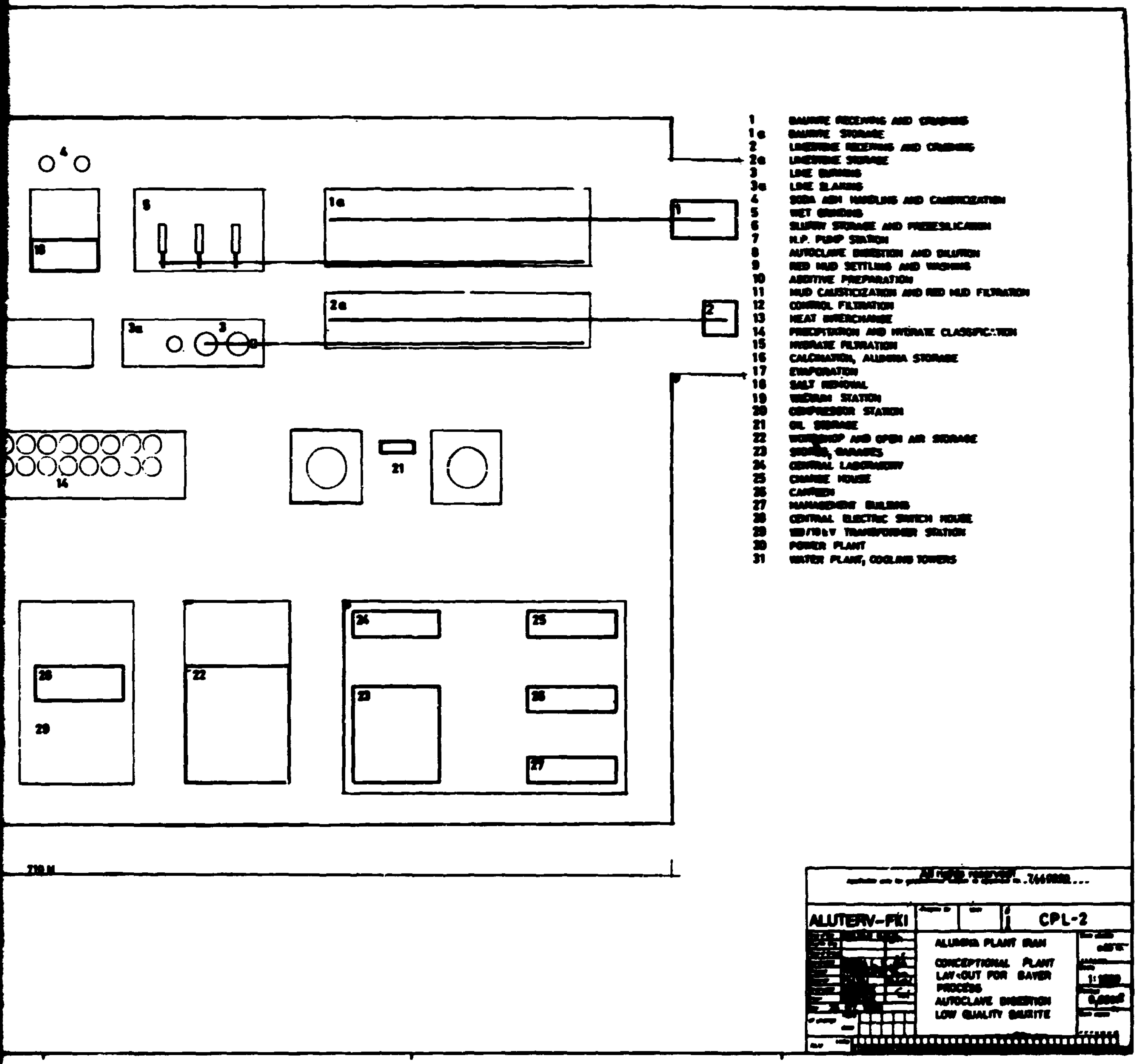
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2 LIMESTONE RECEIVING AND CRUSHING
2a LIMESTONE STORAGE
3 LIME BURNING
3a LIME SLAKING
4 SODA ASH HANDLING AND CAUSTICIZATION
5 WET GRINDING
6 SLURRY STORAGE AND PREDESILICATION
7 H.P. PUMP STATION
8 AUTOCLAVE DIGESTION AND DILUTION
9 RED MUD SETTLING AND WASHING
10 ADDITIVE PREPARATION
11 MUD CAUSTICIZATION AND RED MUD FILTRATION
12 CONTROL FILTRATION
13 HEAT INTERCHANGE
14 PRECIPITATION AND HYDRATE CLASSIFICATION
15 HYDRATE FILTRATION
16 CALCINATION, ALUMINA STORAGE
17 EVAPORATION
18 SALT REMOVAL
19 VACUUM STATION
20 COMPRESSOR STATION
21 OIL STORAGE
22 WORKSHOP AND OPEN AIR STORAGE
23 STORES, GARAGES
24 CENTRAL LABORATORY
25 CHANGE HOUSE
26 CANTEEN
27 MANAGEMENT BUILDING
28 CENTRAL ELECTRIC SWITCH HOUSE
29 [illegible]/10kV TRANSFORMER STATION
30 POWER PLANT
31 WATER PLANT, COOLING TOWERS
All rights reserved
ALUTERV-FKI
CPL-2
ALUMINA PLANT IRAN
CONCEPTIONAL PLANT LAY-OUT FOR BAYER PROCESS AUTOCLAVE DIGESTION LOW QUALITY BAUXITE
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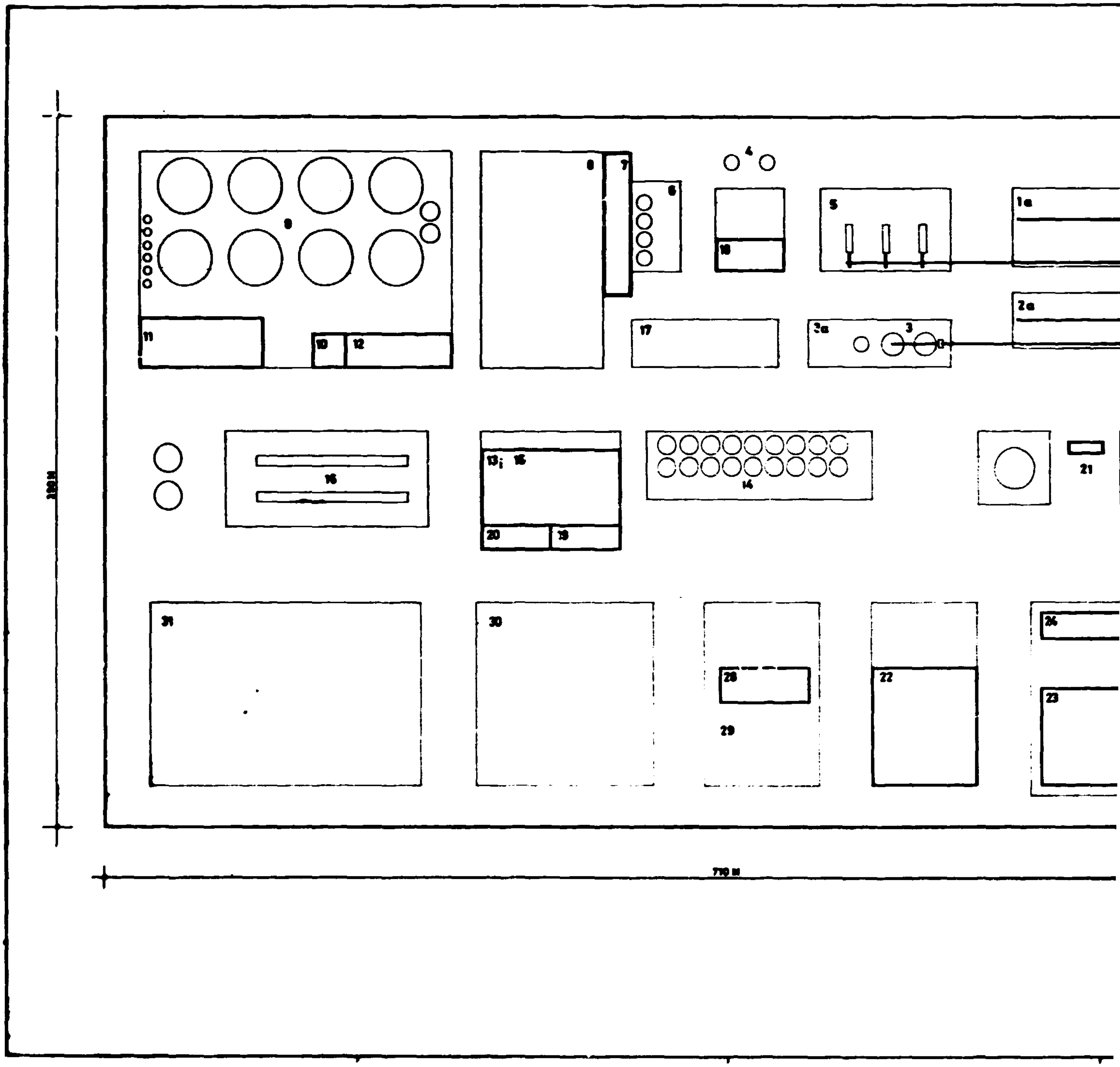
# SECTION 1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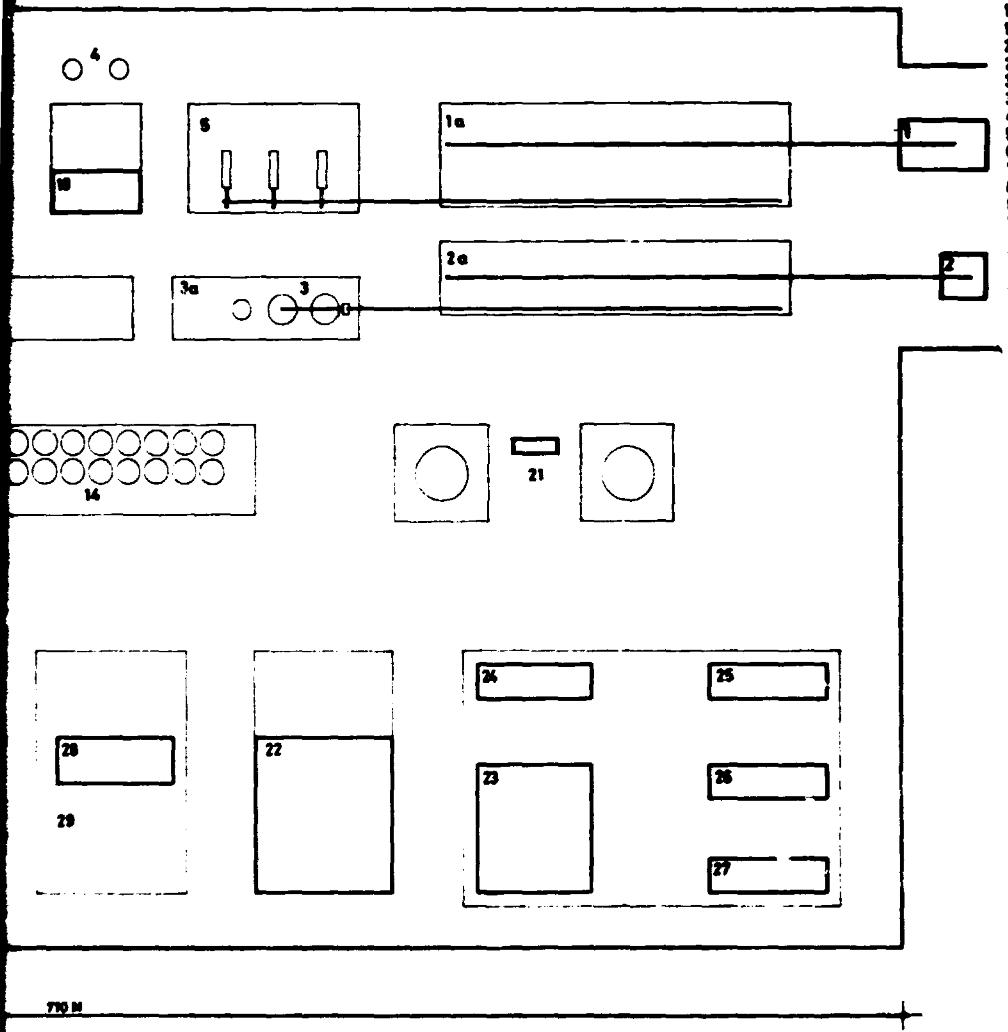
# SECTION 2



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| 1a | BAUXITE STORAGE |
| 2 | LIMESTONE RECEIVING AND CRUSHING |
| 2a | LIMESTONE STORAGE |
| 3 | LIME BURNING |
| 3a | LIME SLAKING |
| 4 | SODA ASH HANDLING AND CAUSTICIZATION |
| 5 | WET GRINDING |
| 6 | SLURRY STORAGE AND PREDESILICATION |
| 7 | H.P. PUMP STATION |
| 8 | TUBE DIGESTION AND DILUTION |
| 9 | RED MUD SETTLING AND WASHING |
| 10 | ADDITIVE PREPARATION |
| 11 | MUD CAUSTICIZATION AND RED MUD FILTRATION |
| 12 | CONTROL FILTRATION |
| 13 | HEAT INTERCHANGE |
| 14 | PRECIPITATION AND HYDRATE CLASSIFICATION |
| 15 | HYDRATE FILTRATION |
| 16 | CALCINATION, ALUMINA STORAGE |
| 17 | EVAPORATION |
| 18 | SALT REMOVAL |
| 19 | VACUUM STATION |
| 20 | COMPRESSOR STATION |
| 21 | OIL STORAGE |
| 22 | WORKSHOP AND OPEN AIR STORAGE |
| 23 | STORES, GARAGES |
| 24 | CENTRAL LABORATORY |
| 25 | CHANGE HOUSE |
| 26 | CANTEEN |
| 27 | MANAGEMENT BUILDING |
| 28 | CENTRAL ELECTRIC SWITCH HOUSE |
| 29 | 100/10 kV TRANSFORMER STATION |
| 30 | POWER PLANT |
| 31 | WATER PLANT, COOLING TOWERS |

ALUTERV-FKI
CPL-3

ALUMINA PLANT IRAN

CONCEPTIONAL PLANT
LAY-OUT FOR BAYER
PROCESS
TUBE DIGESTION
LOW QUALITY BAUXITE

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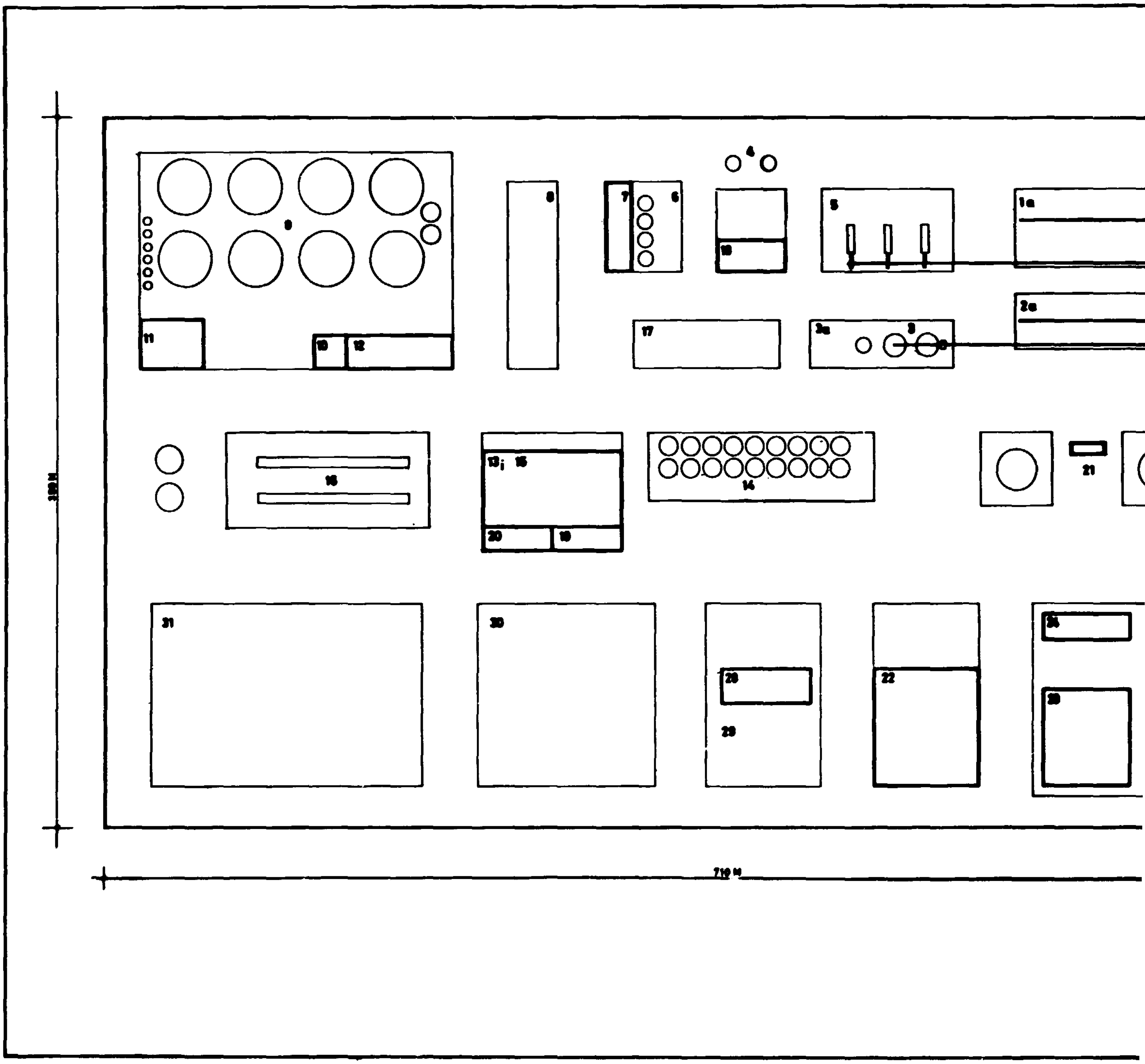
# SECTION 1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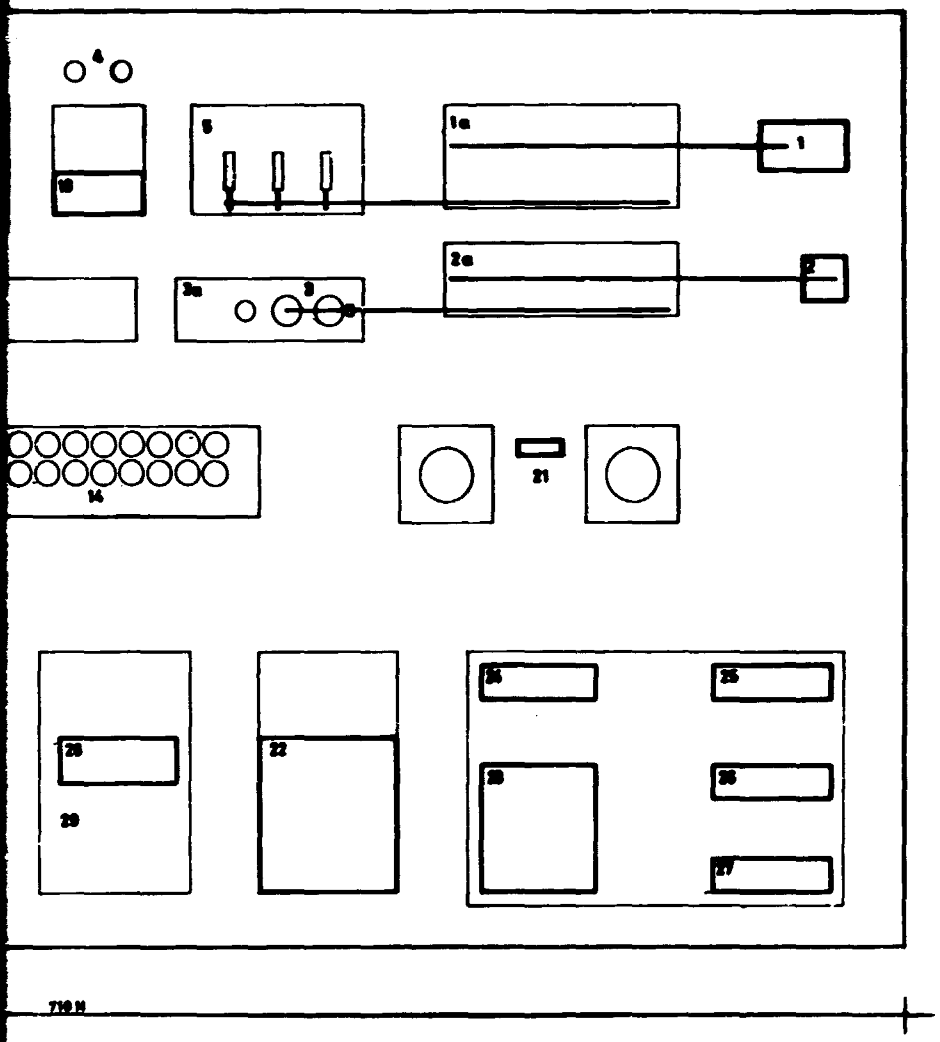
# SECTION 2



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| 1a | BAUXITE STORAGE |
| 2 | LIMESTONE RECEIVING AND CRUSHING |
| 2a | LIMESTONE STORAGE |
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| 3a | LIME SLAKING |
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| 5 | WET GRINDING |
| 6 | SLURRY STORAGE AND PREDESILICATION |
| 7 | H.P. PUMP STATION |
| 8 | AUTOCLAVE DIGESTION AND DILUTION |
| 9 | RED MUD SETTLING AND WASHING |
| 10 | ADDITIVE PREPARATION |
| 11 | MUD CAUSTICIZATION AND RED MUD FILTRATION |
| 12 | CONTROL FILTRATION |
| 13 | HEAT INTERCHANGE |
| 14 | PRECIPITATION AND HYDRATE CLASSIFICATION |
| 15 | HYDRATE FILTRATION |
| 16 | CALCINATION, ALUMINA STORAGE |
| 17 | EVAPORATION |
| 18 | SALT REMOVAL |
| 19 | VACUUM STATION |
| 20 | COMPRESSOR STATION |
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| 22 | WORKSHOP AND OPEN AIR STORAGE |
| 23 | STORES, GARAGES |
| 24 | CENTRAL LABORATORY |
| 25 | CHANGE HOUSE |
| 26 | CANTEEN |
| 27 | MANAGEMENT BUILDING |
| 28 | CENTRAL ELECTRIC SWITCH HOUSE |
| 29 | 120/10 kV TRANSFORMER STATION |
| 30 | POWER PLANT |
| 31 | WATER PLANT, COOLING TOWERS |

ALUTERV-FKI

CPL-4

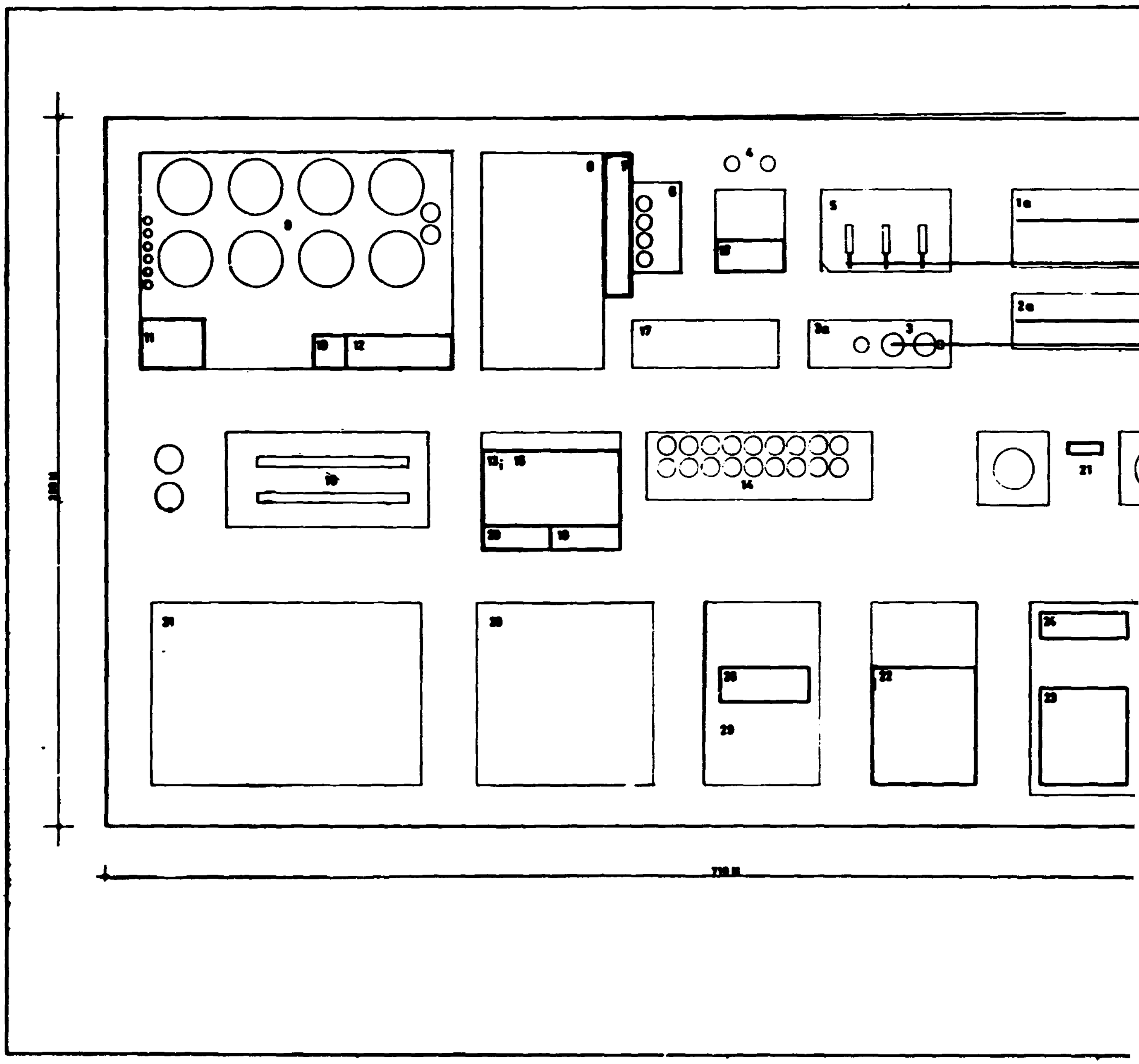
ALUMINA PLANT IRAN

CONCEPTIONAL PLANT
LAY-OUT FOR BAYER
PROCESS
AUTOCLAVE DIGESTION
HIGH QUALITY BAUXITE

1 1000

0,63 M²

# SECTION 1



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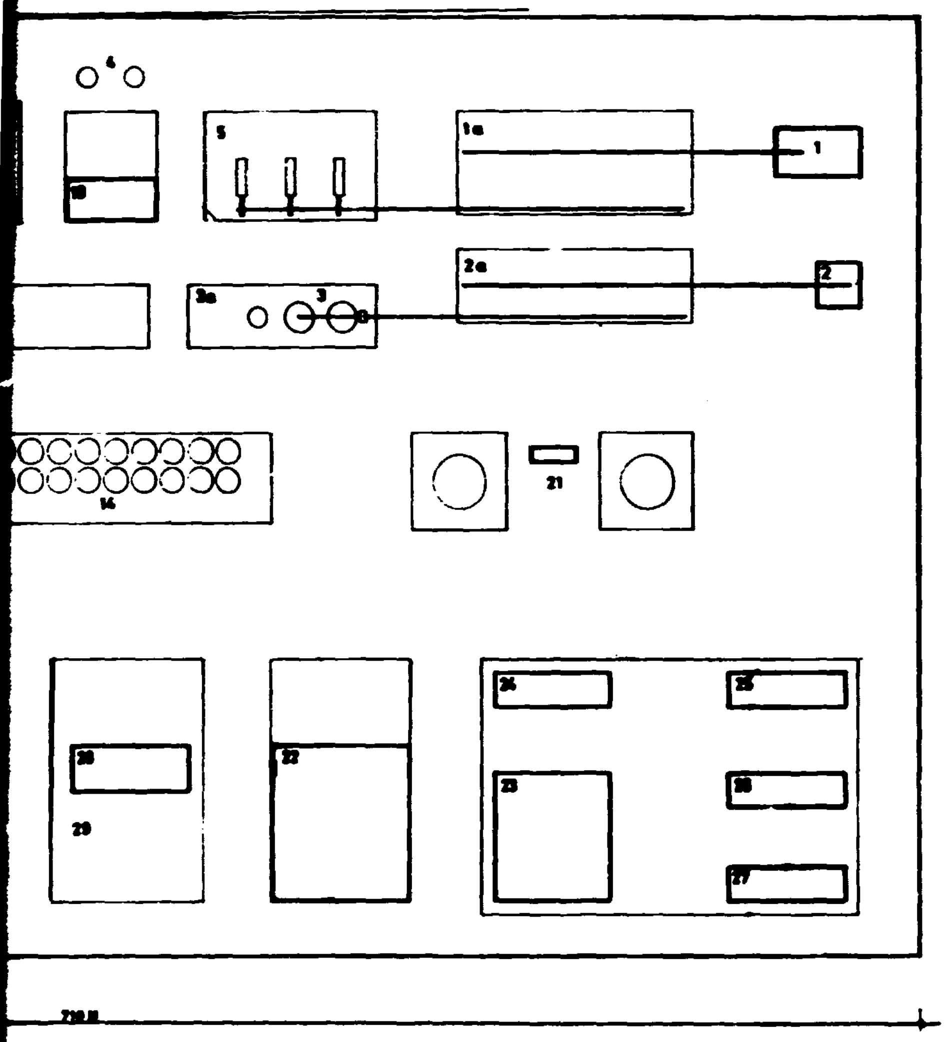

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| 1a | BAUXITE STORAGE |
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| 5 | WET GRINDING |
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| 7 | H.P. PUMP STATION |
| 8 | TUBE DIGESTION AND DILUTION |
| 9 | RED MUD SETTLING AND WASHING |
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| 30 | POWER PLANT |
| 31 | WATER PLANT, COOLING TOWERS |

ALUTERV-FKI

CPL-8

ALUMINA PLANT IRAN

CONCEPTUAL PLANT
LAY-OUT FOR BAYER
PROCESS
TUBE DIGESTION
HIGH QUALITY BAUXITE