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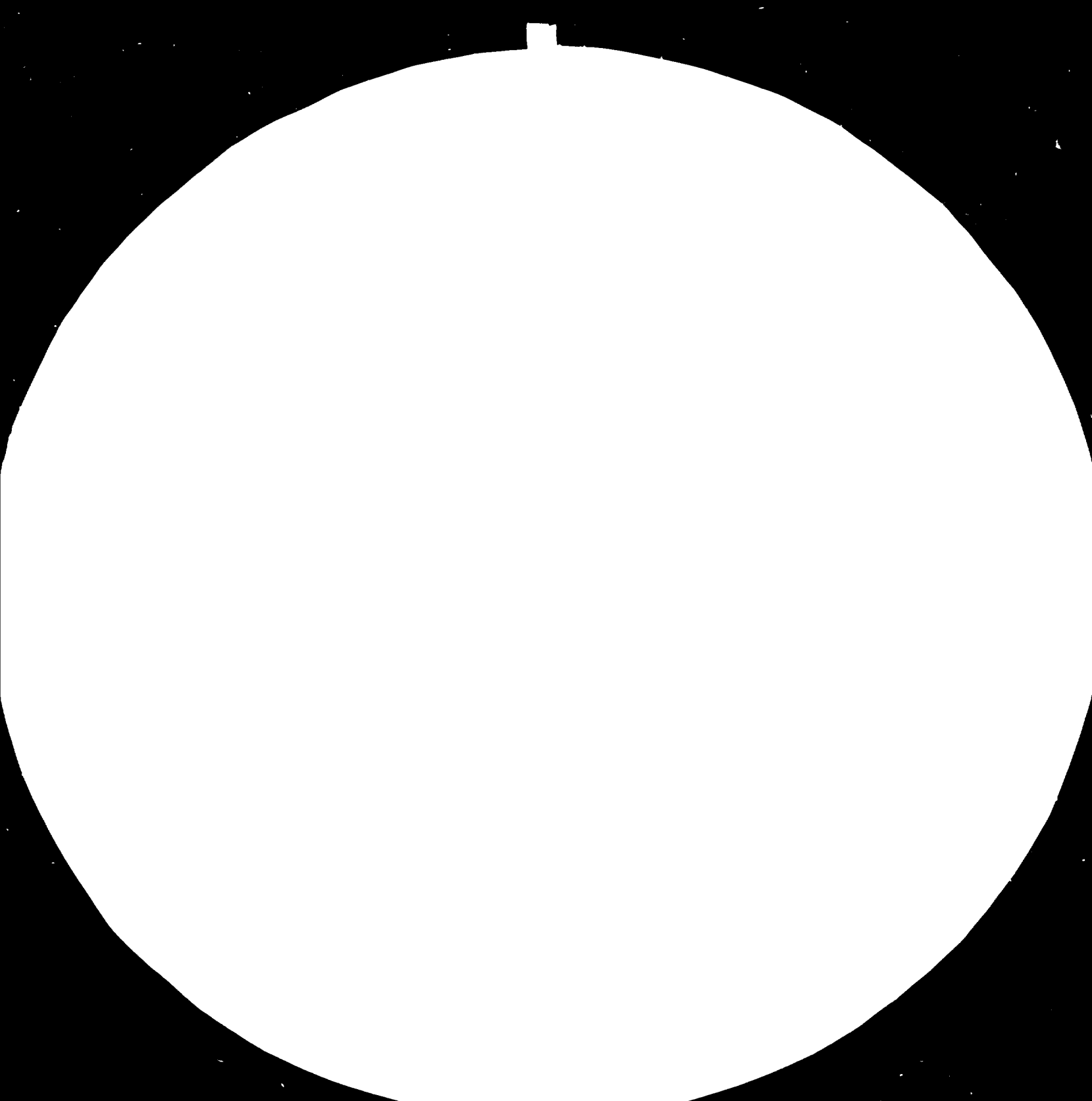
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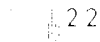
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1.5



Resolution Test Chart
1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5

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REPORT
ON AN ALUMINA PLANT TO BE ESTABLISHED IN
GREECE
FOR THE HELLENIC INDUSTRIAL AND DEVELOPMENT
BANK S.A. ATHENS

TF/GRE/83/001

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Budapest Oct. 1983.

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PREFACE

A Feasibility Study about an alumina plant to be established in Greece made by VAMI Institute of the Ministry of Non-Ferrous Metallurgy of the USSR in 5 volumes, 6 books (hereinafter referred to as "Study") has been handed over to us to get acquainted with the plans of the Hellenic Industrial and Development Bank. S.A. Athens (E.T.B.A.). After having read this Study we have visited E.T.B.A. twice and presented our comments on the Study as well as other questions in connection with the alumina plant verbally.

The Study is too detailed in certain relations (e.g. volumes I, II and V) compared to international norms accepted on feasibility studies and this leads to the conclusion, that its calculations, its list of equipment are well based, and the accuracy of investment costs is inside the limits of $\pm 20-30\%$ accepted for feasibility studies. At the same time some of the technological data, e.g. temperatures, heat losses, specific heats, etc. are missing or can be calculated indirectly, therefore, it is difficult to control the integrity of the technology of the heat balance or they can not be controlled at all.

Our general opinion is that it is difficult to handle the Study because of its voluminosity; it seems, that the construction of the volumes does not follow a unified list of contents; each volume is independent, therefore, repetitions are frequent; interdependent data can be recognized only by parallel reading of several volumes.

The present Report is limited to those questions E.T.B.A. wished to have in writing, its contents are in accordance with the head-lines requested by E.T.B.A. during our last meeting. .

1. TECHNICAL QUESTIONS

1.1 Bauxite transport, reception and discharge

Bauxite transport, reception and discharge is projected in one shift, taking into account 5 working days a week. Thus 3.5 times higher capacity is invested as compared to continuous operation. In order to decrease investment costs, I suggest a two shifts per day operation.

1.2 Bauxite storage

Storage of bauxite is foreseen in four prisms, two of them serving as reserve. The suggested mode of storage ensures the homogenisation of bauxite, which is very important especially when bauxite of Elafsina is processed too, which is not suitable alone for processing by Bayer technology.

1.3 Wet grinding

Grinding of bauxite is foreseen in ball mills in closed cycle. The Soviet partner has appropriate knowledge in closed cycle grinding. 4+1 ball mills are foreseen. However, no laboratory tests were performed relative to grinding. Two grinding characteristics could have been determined in laboratory, the Hardgrove-number and the Bound-index, on the basis of which conclusion on the necessary mill capacity and the electric energy consumption of grinding could have been drawn.

In case of hard bauxites difficult to be digested the uniformity of the grain size of ground material is very important. In case the grain size of the ground

material is too coarse, Al_2O_3 recovery is decreasing in digestion, in case it is too fine, sedimentation of red mud is deteriorating. Therefore, before starting the detailed design it is reasonable to have examined by an firm expert in grinding, whether in the interest of uniform grain size and optimum electric energy consumption would it not be reasonable to utilize two-stage grinding e.g. by operating a rod mill in the first stage and a ball mill in the second one.

It is noted here that because of the extraordinary hardness of bauxite a higher maintenance requirement than the average is to be reckoned with in the so called red plant units (wet grinding, digestion, settling-washing). Therefore it is very important, that pumps, pipelines, fittings and valves to be manufactured from suitable, non-abrasive material.

In the enumerated plant units the number of simultaneously and parallelly operated equipment is: 4 ball mills, 2 slurry holding systems, 3 digesting lines, 3 settlers. It would seem reasonable to build in 3+1 parallel lines in each plant unit, which would simplify technological connections and operations.

1.4 Pre-desilication

Before indirectly heated digestion systems pre-desilication is usually built in, in order to transform SiO_2 content of bauxite with 70 to 90 % efficiency in sodium-aluminium silicates hardly soluble in caustic soda solutions. This operation is performed in agitated tanks at about $100^\circ C$, in 8 to 10 hours. By this technological operation formation of sodium-aluminium silicates from silica in the autoclaves provided by heating coils can

be avoided. Thus heating coils can be protected against formation of scaling on them, which would deteriorate rapidly and intensively their heat transfer coefficient. It is not obvious from the Study, whether the 6 tanks, 770 m³ volume each, foreseen between grinding and digestion is serving only holding of the slurry or it is performing predesilication too. It seems, that they are only holding tanks. It is noted that no predesilication tests were performed in the course of laboratory examinations. A probable explanation is that it was supposed that diasporic bauxites can be predesilicated with a low efficiency only. ALUTERV-FKI performed earlier detailed laboratory investigations with Parnassos bauxite and they stated that this bauxite too can be predesilicated with about 80 % efficiency. Therefore I suggest that before starting of detailed design predesilication tests to be performed and optimum parameters determined.

1.5 High pressure slurry pumps

Diaphragm pumps to be purchased from a third country are foreseen for feeding of autoclaves with slurry. 2+1 pumps are foreseen for each digestion line. It is reasonable to examine, whether would it not be more economic from the point of view of investment and operation costs, to foresee 1+1 pumps for each digestion line; or 4+3 pumps in total, when besides one operating pump per digestion line 3 common reserve pumps would be built in. Diaphragm pumps are up-to-date, reliable equipment.

1.6 Digestion

One of the key operations of alumina production is digestion. Digestion can be modelled satisfactorily in

laboratory conditions. The majority of the performed laboratory tests aimed at the determination of optimum digestion parameters. It seems, however, that some fundamental methodical fault was committed in the course of laboratory tests because the results of the laboratory tests are extremely bad. This was noticed by the authors of the Study, too, as they did not accept the results of the laboratory tests and more favourable parameters were considered as basis of design work. In the following table results of laboratory tests performed at 225 g/l caust. Na₂O digestion liquor concentration, 2 hours digestion time and at 255 °C, their calculated average values and the design parameters are summarized.

No of bauxite sample	Lime %	Digestion yield %	Relative to theoretical yield %	Molar ratio	Na ₂ O/SiO ₂
2	3	80.3	88.0	1.68	0.71
5	3	89.8	96.4	1.60	0.71
8	3	70.8	91.4	1.68	0.71
Calculated average of 60:30:10 mixtures	3	82.45	90.84	1.654	0.71
2	5	86.1	94.0	1.65	0.63
5	5	90.6	97.3	1.57	0.63
8	5	74.8	96.5	1.65	0.63
Calculated average of 60:30:10 mixtures	5	86.41	95.21	1.625	0.63
Lab. result of mixture	5	88.0	96.9	1.56	0.61
Basic data of design	3	86.5	96.3	1.54	0.50

It can be seen from the table that data calculated both at 3 and 5 % lime addition are significantly worse, than the data taken into account as basic design data. It can be disapproved that only one single test was performed with mixed bauxite at 5 % lime addition, but these data were not considered as design data either.

It should be noted, that laboratory digestion tests were performed with synthetic liquor not containing any SiO_2 , at the same time, however, significant quantities, 1 to 2 g/l SiO_2 , were found in the liquors after digestion in dissolved form. If plant liquors had been used for digestion, SiO_2 remaining in solution after digestion would have been precipitated too and this would have further diminished actual efficiency by 0.8 to 1 %.

The considerable deviation between laboratory tests and basic design data can not be accepted even if the Soviet partner can guarantee the data taken into account as basis of design work.

It shall be noted, that ALUTERV-FKI too performed very detailed laboratory tests on Parnassos bauxite, and at much lower digestion liquor concentrations (130 to 160 g/l Na_2O), than those taken into account in the Study obtained much better results as regards molar ratio after digestion, Al_2O_3 recovery and $\text{Na}_2\text{O}/\text{SiO}_2$ ratio. Therefore I suggest to repeat laboratory examinations or possibly have them repeated by a third party.

The indirectly heated digesters of 100 m³ volume each foreseen for digestion are up-to-date, to my knowledge equipment of higher volume than that are not used in case of indirect heating. The high temperature necessary to digestion and the hard digestibility of bauxite recalls the idea of the use of tube-digestion. Digestion temperatures of 280 to 300 °C can be realized in tube-

digestion equipment, enabling the near 100 % recovery of available Al_2O_3 content of the bauxite and the decrease of the molar ratio after digestion, which leads to economy of energy and provides more favourable conditions for the production of sandy alumina. Investment costs of tube-digestion equipment are about the same as these of autoclave system, advantages appear in about 10 to 20 % decrease of heat energy consumption. VAW and the Hungarian Aluminium Corporation are at present in possession of tube-digestion equipment. Construction of this latter equipment is enabling self-cleaning of the tubes during operation.

1.7 Red mud settling and washing

For the determination of settling characteristics of red mud laboratory tests in settling tubes were performed. This method is out-of-date, it can not be used for supplying basic design data. There are such settling equipment available, based on gamma-ray absorption, whose data can be used as basic design data, therefore it is reasonable to have performed such type of tests.

Flour only was used as settling aid, effect of synthetic flocculants was not examined. Therefore it is expedient in the course of supplementary examinations to determine the optimum of simultaneous application of flour and synthetic flocculants.

For settling and washing of red mud single chamber thickeners of 40 m dia are designed. The thickeners are flat bottomed, with side discharge. It does not appear from the drawings, whether the stirring mechanism is centrally or periferically driven. Up-to-date equipment are centrally driven, their stirring mechanism is suspended on cable and their bottom is slightly conical. The advantage of these equipment compared to the periferically driven ones lies

in their lower weight and the higher solids concentration obtainable in the underflow. As an alternative of the red mud washing it is expedient to examine the filtration of red mud too. Roller discharge vacuum drum filters are used for this purpose, which are built in after 2 to 3 washing stages. The advantage of filtration is that red mud can be washed with less water and this can reduce the investment and energy costs of evaporation. Further on in case of filtration red mud can be stored more economically and in a manner better satisfying the viewpoints of environment protection.

In order to decrease operation costs, paralelly with filtration of red mud it is worth examining its causticization possibility as well.

1.8 Control filtration of aluminate liquor

Control filtration of aluminate liquor decreases Fe_2O_3 content of alumina. LVAZS type filters were foreseen for this purpose, which are half-automatically operated up-to-date equipment. Control filtration is projected on paper layer. This is not a modern solution, as preparation of paper-pulp and its uniform distribution on the surface of the filter is difficult, requiring too much physical work. I suggest to use lime-hydrate, or alumina hydrate as filtering precoat; hydrate can be mixed with some material e.g. perlit, loosening the filtering layer.

1.9 Cooling of aluminate liquor

For cooling of aluminate liquor plate heat exchangers are designed. These are up-to-date equipment, however, equipment of bigger size than the designed ones are available, too. Maintenance requirement of plate heat exchangers is minimum, in case of using appropriate know-how.

1.10 Precipitation, hydrate classification

Precipitation of alumina liquor is designed in continuous system, in conical bottom tanks with air agitation. Very high, 3.5:1 seed ration is designed, and intermediate cooling in the course of precipitation is foreseen. The precipitated slurry is led into hydroseparators, whose underflow contains the production hydrate and overflow the seed. According to information and to alumina specification given in the Study the final product is sandy alumina. The outlined technology reminds me of the technology of Pechiney, whose final product, according to experts, is a coarse grain size, but not typically sandy, alumina. Without going into details of technological and apparative requirements of sandy alumina production I suggest to accept the designed technology, as the Soviet partner will be the Buyer of the alumina; at a later point of time, when the high concentration sandy alumina technology will reach its final development and the requirements of smelters will come to a rest as well, to switch over to a new technology, which, in my opinion, will be realizable with a minimum of supplementary equipment.

The precipitators of 3000 m³ volume designed for precipitation are up-to-date. As regards air and mechanical agitation resp., there is a differenc of opinion among experts. In my opinion energy consumption of air agitated tanks, in case of appropriate design of the air-lift tube, is equal to, or even more favourable, than that of mechanically agitated ones. Investment costs of flattbottom, mechanically agitated tanks may be somewhat lower. The effect on breaking up of grains is nearly equal, however, firms producing tipical sandy alumina consider mechanical agitation more varourable.

1.11 Filtration of product hydrate and of seed

Filtration of product hydrate is designed on drum filters in several stages. In case of production of coarse grain size or sandy alumina it is not usual to filter it on drum filters. Use of pan filters or belt filters is increasing and these are placed above the feeding hole of calcining kilns. Disc filters designed for seed filtration are up-to-date, high performance equipment, requiring little maintenance.

1.12 Calcination

Fluid calcining kilns designed for calcination of alumina are of the most modern type known at present. Oil consumption corresponds to that of up-to-date kilns.

1.13 Evaporation, salt separation

Three evaporators are designed, supplemented by a double-pass crystallizing evaporator each, in order to ensure the low carbonate soda content of the liquor necessary to the production of sandy alumina. Evaporated water is nearly 5 t per ton of alumina, a very high value, which results from the fact, that in the course of laboratory investigation 225 g/l caust. Na_2O concentration was found to be suitable as digestion liquor concentration. In case when repeating laboratory tests it will come to light that digestion liquor concentration may be decreased, evaporator capacity built in can be decreased, too. Evaporators are of relatively low performance. Kestner, and eventually other firms too, are manufacturing such equipment, which can evaporate the necessary quantity of water in one single equipment only.

1.14 Instrumentation, automation

On the basis of equipment list the conclusion can be drawn that instrumentation and automation do not meet modern requirements. Before detailed design all those places have to be determined, where conditions are given for the application of microprocessors, microcomputers and from the viewpoints of economy of energy those processes have to be considered, where application of pumps with revolution control instead of control valves is expedient. At the same time those equipment have to be determined, whose starting and stoppage is expedient to be done from local or central control rooms by remote control.

1.15 Typization of equipment, standby units

In order to decrease operation costs and storehouse stocks typization of some equipment (pumps, motors, gear-boxes, fittings and valves, etc.) is expedient. In order to decrease investment costs, it is expedient to examine, whether standby units have to be built in in each case, or they have to be taken into account as storehouse spare-parts only. In case reserves may be taken into account as storehouse stocks, costs connected to building in of standby units (foundation, automation, supply of energy, valving etc.) can be avoided.

1.16 Transport and storage of alumina

Different territories were taken into account for siting the alumina plant. During consultations on the spot experts of ETBA informed us that the site taken into account at present is at 1000 to 1500 m distance from the seashore. There is a hill of about 150 m high extending between the seashore and the site. Alumina is exported by

ships. As regards alumina storage I suggest to build a silo suitable for the storage of 1 to 2 days of alumina production inside the alumina plant and to design storage of alumina in a bigger silo situated on the seashore, capacity of which depends on the movement of ships and their capacity. Transport of the alumina to the silo situated in the seashore may be realized pneumatically or by belt conveyors. Because of the higher energy requirement of the pneumatic transport, its unfavourable effect on diminution of grains, and because of excess work necessary in case of clogging I would suggest transport of alumina on covered belt conveyors. Naturally exact knowledge of the site is necessary to final decision of the mode of transport.

1.17 Maintenance

Because of the hardness of bauxite equipment of red plant (from bauxite reception to discharge of red mud inclusive) require increased maintenance compared to the average alumina plant conditions. In case of normal bauxite 2 to 3 % of investment costs of equipment are taken into account as maintenance costs. In case of red plant units mentioned above, taking into account of 3 to 5 % maintenance costs is justified. Because of abrasive effect of bauxite it is necessary to use good quality, abrasion resistant constructional material. In course of design work facilitation of physical work has to be considered; e.g. in case of 100 m³ volume digesters special tools, platforms for cleaning and appropriate know-how have to be designed; in case of red mud settling and washing equipment such manholes have to be designed, which make possible discharge of slate by means of special machines.

1.18 Quality of alumina

Production of sandy alumina was foreseen during design work. From the point of view of sandy alumina production technology it is advantageous, that bauxite contains minimum quantity of organic matter, however, its high carbonate content is unfavourable. In order to keep carbonate content of the liquor on a favourable level, intensive salt separation is designed.

Molar ratio of aluminate liquor before precipitation has to be kept on the lowest value. Therefore - in spite of laboratory tests - such molar ratio after digestion was selected, which ensures the 1.6 molar ratio value still acceptable for the liquor going to precipitation. It should be proved by laboratory tests, whether this value can be reached, or not. Data given for chemical and physical properties of alumina correspond to the characteristic parameters of sandy alumina, the 10 % quantity of -325 mesh fraction is on the higher side of the limit acceptable for sandy alumina. In big western factories SiO_2 content of the alumina is 0.015 to 0.020 %, its Fe_2O_3 content 0.010 to 0.020 % and ZnO content 0.010 to 0.015. These values are somewhat better, than those given in the specification.

Besides characteristics given in the specification an important index is the breaking up tendency of the alumina. This, however, can not be determined on an alumina sample produced in laboratory. It follows from the technology given for the precipitation, that coarse grain size hydrate is produced first of all by growth of the grain size and not by agglomeration and from this it can be deduced to some extent, that the structure of the produced hydrate will be loose and it will have a certain tendency to break up.

1.19 Specific material consumption, material balance

Specific material and energy consumptions are calculated on the basis of bauxite composition and designed technological parameters. Alteration of specific consumptions, first of all their reduction is possible either by amelioration of bauxite quality - e.g. by putting aside the worst quality - or by fundamental change of the technology, e.g. by decrease of digestion liquor concentration and by this, decrease of evaporation requirement. For the realization of this latter change, basic laboratory tests are necessary.

By putting aside the worst quality bauxite, specific bauxite consumption would decrease by 70 kg/t, caustic soda consumption by 13 kg/t. This would result in about 5 \$/t reduction in costs of production. As regards price of bauxite it should be noted, that it was taken into account with a 26 and 28 \$/t price resp., regardless of its quality. According to Hungarian practice in determining bauxite price its alumina content is diminished by the major components (SiO_2 , CaO and MgO) causing alumina and soda losses, using different factors and the difference, multiplied by a determined value, gives the price of bauxite. With an informative character I calculated that if one would like to avoid production costs increasing effect of the worst bauxite - taken into account in 10 % quantity - this bauxite should be taken into account with 8 \$/t instead of 28 \$/t value.

Decrease of concentration of digestion liquor can suggested only, if this is supported by laboratory tests. In this case, operating tube digestion with a higher temperature than the designed one, total heat consumption could be decreased by about 10 to 20 %. In totality it can be considered that by optimization of the technology and amelioration of bauxite quality projected costs of production can be decreased by about 10 %.

The energy balance is not detailed enough to allow drawing of unambiguous conclusions on its basis. Several important temperature data are missing; data relative to heat consumption can be collected only with high uncertainty from several volumes and different tables. It would be expedient to prepare such material and heat balances, which contain material- and heat-flows for each plant unit and technological operation, indicating heat losses occurring at each individual operation.

I would like to mention, that in designing alumina plants, independent from the fact, whether stand-by units have been taken into account, or not, material and heat balances are calculated normally for 8000 working hours a year. From the material balance it seems, that in digestion they calculate with $660 \text{ m}^3/\text{h}$ slurry which, taken into account the specific slurry quantity of $9.38 \text{ m}^3/\text{t}$, corresponds to 70.36 t/h alumina production, as against average 68.5 t/h . This gives a 97.35 % utilization of operating time, i.e. 8257 operating hours per year. This high value can not be accepted as basis of design work, even in case if stand-by units would be built in in each section.

1.20 Guarantee

In case of alumina plants guarantees are given for machinery and equipment, quantity, quality of alumina and specific consumptions. Guarantee of machinery and equipment refers to its operating ability and performance. Guarantees are accepted by the Seller for 18 months calculated from the supply of machinery or 12 months from the putting on stream. If possible, it is expedient to calculate the guarantee from putting on stream. Fulfilment of mechanical guarantee or its non-fulfilment can be decided

easily, however, fulfilment of technological and performance guarantees of individual machinery and equipment is difficult to be decided. Generally conditions are missing for measuring the parameters of individual machinery and equipment after putting on stream. Usually it is a matter of dispute who undertakes technological guarantee. The machine factory generally undertakes only the mechanical guarantee and tries to shift the technological guarantee on the prime contractor.

In my opinion in case of certain equipment, as filters, mills, high pressure pumps, heat exchangers, calcining kilns, evaporators etc. one has to insist on stipulation of technological guarantee and on realization of measuring possibilities during design work and start up.

Quantitative, qualitative and specific consumptions guarantees are provided by the Seller usually in one month operation time. As the time point of guarantee is chosen usually by the Seller, generally in a point of time, when the equipment are in a good condition, it is expedient in case of quantitative guarantee to stipulate the quantity serving as basis of design. In practice quantitative guarantee tests are accepted as fulfilled if the Seller produces 96 to 97 % of the maximum quantity, which can be produced in one month.

As regards quality guarantee can be accepted as fulfilled if monthly averages of physical and chemical quality parameters are inside the maximum and minimum values given in the specification.

For specific material and energy consumptions it is expedient to stipulate a basket value, besides giving a +5 to 10 % tolerance for the individual specific consumptions. The basket value, which is the sum of the products of specific consumptions and prices taken into account by

the guarantee, can be accepted with a +3 to +5 % tolerance. This means that in case some specific consumptions are exceeded by 5 to 10 %, other specific consumptions have to be fulfilled with a more favourable value in order to keep exceeding of basket value below 3 to 5 %. In case of unsuccessful tests the Seller has to assure repetition of the guarantee test and in case even this repeated guarantee test is unsuccessful, it has to be determined whether the Seller will pay a liquidation of damages, or undertakes realization of conditions necessary for fulfilment of guarantee.

1.21 Summary of recommendations

1. In the interest of optimization of technology detailed digestion and red mud settling and washing tests and examinations have to be performed.

2. The following alternatives have to be examined: tube digestion, red mud filtration, red mud causticization, storage of dry red mud, use of synthetic flocculants, control filtration of aluminate liquor on lime, or alumina-hydrate precoat.

3. Performance of some machinery and equipment does not meet the requirements of an up-to-date, 600,000 t/year capacity alumina plant. Such equipment are: high pressure slurry pumps, plate heat exchangers, evaporators. Taking into account credit conditions, possibility of their purchase from a third country has to be examined. As regards information given on instrumentation and automation, this suggests too, that their purchase from a third country would be expedient.

4. In order to improve economy it is expedient to analyse the possibility of utilization of part of the

capacity for the production of special aluminas as well as of processing part of red mud for production of high quality roof and wall tiles, and bricks (on the basis of a Hungarian patent).

The aim of my observations enumerated in the expert opinion was the foundation of the technology, optimization of a 600,000 t/year capacity alumina plant.

Beside the enumerated insufficiencies and observations the Feasibility Study meets the requirements; it is considering carefully the connections of individual plant units in the lay-out, and has taken into account further expansion possibilities too. The number of staff proves that the productivity corresponds to that of up-to-date plants.

I am sure that careful analysis of my suggestions may promote decrease of production costs.

2. ECONOMIC AND COMMERCIAL QUESTIONS

2.1 Comments on costs

The costs of the alumina plant are estimated in Vol. I of the Study. These estimations include both investment as well as operations costs. They have been worked out in sufficient detail for the study but there are certain criticism to be given as well as some interconnections to be enlightened.

The costs were worked out in Drachmas on the basis of 1 USD = 57.18 Drachmas. Due to the fact that the USD-Drachma exchange rate changed considerably since the study was made (being today approx. 1 USD = 92 Drachmas), the only possible way of dealing with these figures was to reconvert them on the basis of the calculated rate of exchange (i.e. 1 USD = 57.18 Drachma) into USD and to calculate in USD. All further figures are hence USD ones.

It seemed to be necessary to analyze investment, financing and operation costs. It has to be stressed, that financing costs can even surpass investment costs, further that deviations in operation costs may have a larger effect on the cost of the product, than deviations of the same order of magnitude in investment costs. These will be shown by examples later in the present subchapter.

2.1.1 Investment costs

The Study worked out investment costs for two different sites. Due to the fact, that there is no significant difference between the costs of the different sites, only the Viniani sites' costs are analysed hereunder. The investment costs of this site are shown in Table I.

Table I.

INVESTMENT COSTS IN USD

	mln USD
A.) Know how, engineering, training, geo.survey	20.16 ^{x./}
Technical assistance	9.26 ^{x./}
Pre-production costs	14.41
	<hr/>
	43.83
B.) Machinery, equipment	194.52 ^{xx./}
Building and civil works	88.42
Erection	23.58
Site preparation, transport, customs, insurance	21.07
	<hr/>
	327.59
C.) Contingency on A.)+B.)	26.00 ^{/x/}
D.) Off sites	18.18

Total (A+B+C+D) = 415.6 mln USD

Remarks: x./ = costs largely in USD
 xx./ = costs fully in USD
 /x/ = about 60 % of costs in USD
 not marked items, = in Drachmas

Commenting these costs one could say the following:

For the case of the Study the cost estimate of machinery and equipment is acceptable; that of know how and engineering are in accordance with the global investment costs. Technical assistance costs will anyhow be depending on the assistance effectively used. Cost estimates for building, civil works, erection and off-sites on the other hand seem to be low. A general practice shows namely, that the value of imported goods and services on the one hand and that of local works and services on the other hand is about equal. Considering now the following items:

- Machinery and equipment	USD 194.5 mln
- Know how, engineering, technical assistance	29.4 mln
- 60 % of contingency	15.6 mln
	<hr/>
	239.5 mln,

say 240 mln USD, would mean, that the local part of the costs (i.e. all other costs not enumerated above) would amount instead of USD 176.06 mln USD to 240 mln USD, thus giving a total investment cost of USD 480 mln instead of 415.6 mln USD. The investment cost per t of alumina to be produced per year would hence increase from 693 USD/t to 800 USD/t invested, which is still a low figure. 1.)

A deeper analysis of the local costs was not possible in lack of sufficient data. The unit prices of certain works were given by the Greek party in a Protocol of talks, these may be different now. Besides that various factors influence both erection costs and building + civil works' costs. E.g. the stage of prefabrication of equipment has

1.) An OECD study of 1981 estimated investment costs of alumina plants to 800-1250 USD/t capacity in developed countries and to 1000-1550 USD/t capacity in developing countries in case of green-field plants and excluding infrastructure.

a large influence on the erection costs. At an average prefabrication one may consider about 20 % of the value of equipment as erection costs. This would mean about 40 mln USD and not 23.5 mln. The building and civil works' costs depend e.g. on using as many steel structures as possible or rather reinforced concrete as far as possible. If the steel structures are dominating, the machinery + erection price will increase, if the reinforced concrete, that of civil and building works. It is, however, not clear which way was chosen and there are no absolute figures to be able to control all local works.

Due to these and various other factors influencing the local costs (not forgetting about the price level in general of local works) a more accurate figure can only be worked out if having offers (at least informative ones) for the local works. These should be asked - as soon as possible - from local contractors.

2.1.2 Financing costs

Much has been discussed about financial costs during the consultations at Athens. In the present report attention has to be drawn to the following:

- The financing costs - even with an interest as low as 8 % - can be relatively large, nearly as large as the capital cost.
- The period of construction (length) influences financing costs to a large extent.

To explain the above in more detail some extreme examples are given below.

EXAMPLE A. (6+10 years)

Should the construction period be 6 years, the credited part of the investment cost has to be multiplied even

at interests of 8 % by a factor of about 1.3 for interim interests not paid during this period. (The multiplication factor depends on the break up of the amounts used up in each period of construction). If the pay back should be effected within 10 years from start up (i.e. from the end of the construction period and supposing still an interest of 8 % and equal yearly instalments (including capital repayment as well as interests), a further multiplication factor of 1.5 needs to be considered, which means that the global financial burden would amount to about the 1.95-fold of the credited amount. In other words for every credited USD 1.95 have to be paid back, i.e. 19.5 % of the credited amount per year during 10 years.

Supposing further that the total investment costs amount to 480 mln USD out of which 20 % is the equity and 80 % are to be covered by loans, the yearly pay back (instalment + interest) would amount to 74.8 mln USD under the prementioned conditions and the return on equity (if 10 %) would amount to 9.6 mln USD per year. Calculated on the basis of 600,000 t of alumina produced, this would mean an amount of 124.6 USD + 16 USD = 140.6 USD per ton of alumina, not counting yet the costs of the working capital. This figure is too high, hence

- a) the construction period should be shortened
- b) additional credits should be looked for to stretch the payback period by an additional 10 years to 20 years
- c) a higher equity could also be taken into account in certain cases

EXAMPLE B. (4+20 years)

If the construction period is only 4 years, the multiplying factor of 1.3 of EXAMPLE A. decreases to 1.2 for

the construction period, under the same conditions as in EXAMPLE A. Should the payback period be extended to 20 years the further multiplying factor of 1.5 could be decreased to 1.02 under the same conditions, hence the global amount to be paid back per year would diminish to 1.224 for every 1 USD. Taking the same figures of 384 mln USD as the credited amount and 96 mln as the equity, the yearly payback would only be 47 mln USD for the credited part and 9.6 mln USD as return on equity, which would mean only $78.3 + 16 \text{ USD} = 94.3 \text{ USD}$ per ton of alumina

EFFECT of percentage of equity.

Should the equity be 30 % in lieu of 20 % in the case of EXAMPLE A, the figure counted per t of alumina would be more favourable, i.e. only 133.2 USD in lieu of 140.6 USD. In case of EXAMPLE B. however, the effect of raising the percentage of equity from 20 to 30 % would result in a higher figure per ton of alumina, namely 97.5 USD instead of 94.3 USD.

Naturally if the rate of interests or the payback time is different, the above figures change; they may be calculated with the help of the tables handed over. It has also to be mentioned, that equal instalments for the capital + interest payment are not foreseen in the Study nor are they usual for such types of loans. Hence the cash flow should count on equal capital instalments, but non equal interest ones, i.e. a high interest amount at the beginning and decreasing with time, which would result in a negativ cash flow in the first few years of operation.

Anyhow ways and means should be found to keep the figure charging the effective cost of one ton of alumina due to investment cost + the interests to be paid after said cost as low as possible, but surely below 100 USD per ton of alumina.

2.1.3 Operating costs

According to the Study the operating costs amount to about 176.5 USD/t of alumina on 1981 prices (page 29 of Vol. I. of Study). These costs should be reduced as far as feasible.

In Chapter 1. of the present Report certain ways and means of reducing operating costs are mentioned (e.g. the elimination of the high silica containing Scalistirio bauxite, certain energy savings, etc.). All these could result in a reduction of costs in the range of 10-15 USD/t of alumina, thus lowering the operation cost level to about 160 USD/t.

It should be emphasized, however, that operation costs were calculated on an 1981 price level in the Study, so they can hardly be taken as a basis for calculating costs of alumina to be produced in 1989 or 1990. For this purpose a certain increase should be considered (even if cost is expressed in USD-s). Due to the fact, however, that today's oil prices e.g. are similar to those considered in the study (in the Greek region), it is hard to predict the 1990 costs, but considering 176.5 USD as the present basis, they can be estimated to 230-250 USD in 1990.

A further remark relates to the question if the decreasing of production costs needs additional investment, does it pay or not. Calculations show that a change of the same magnitude expressed in % in the production costs and the investment costs (i.e. a decrease of 10 % in the production cost versus an increase of 10 % in the investment cost) have still a positive balance. An increase of 10 % investment costs related to the global investment cost of 480 mln USD would cause a plus burden of USD 14.8 per t of alumina in case of EXAMPLE A. (in 2.1.2) and only 9.4 USD/t of alumina in case of EXAMPLE B. versus the gain

of 17.5 USD in operation costs. So the decrease of operation costs should also be stressed if causing plus investment, naturally the effective figures have to be investigated case by case.

2.1.4 Global costs

For the purposes of calculating the global costs of producing 1 t of alumina the figures shown in Table II. were considered.

Table II.

GLOBAL COSTS OF 1 t OF ALUMINA

	1981	1990
Cost of production	160-176.5 USD/t	probably 230-250 USD/t
Global charge due to investment (loans, financing, return on equity)	95-140	100-145 */
Cost of working capital	5	7
Global cost	<hr/> 260-321.5 USD/t	<hr/> 337-402 USD/t

Remark: */ = The investment cost does only change slightly, because the price of imported goods will be a fixed one, that of the local part may increase, however, if counted in Drachmas. Due to the fact, however, that the inflation of the Drachmas seems to go faster than that of the USD, only a slight change of these costs should be expected if counted is USD.

From the year 1990 on only the working costs and the costs of working capital will increase, the burden due to investment will remain a fixed amount. This gives a reality to the project, i.e. it can be assumed that the market prices of alumina will sooner or later reach the global cost figure and thereafter even surpass it.

2.2 Engineering works

Engineering works contain two main parts, the basic and the detailed engineering. The basic engineering is often called "Conceptual Process and Engineering Design (C.P.E.D.)" or simply Conceptual design. A basic engineering has always to be made by the party giving the technology; it has to be made in such detail that any expert shall be able to make the detailed engineering out of the basic one. Architectural, civil and structural basic engineering or a large part thereof can, however, be made by the Buyer on the basis of Sellers data if the job is not a turn-key one and Buyer executes the architectural, civil etc. works himself.

The typical scope aswell as contents of a basic engineering for an alumina plant are shown in Appendix I.

The normal period of preparation for such a basic engineering is about 8 month from the date when all necessary data to prepare said engineering are in the hand of the party preparing it.

In connection with the detailed engineering a practical guideline could be, that this engineering should possibly be made by the party supplying the relevant goods or executing the relevant works (e.g. civil works), but the owner of the technology has to check whether his data had been correctly understood, i.e. whether the detailed engineering is in accordance with the technology and the

data given. Hence detailed engineering works are often split between the parties in case of non turn-key jobs.

The detailed engineering for an alumina plant can be done in 12-18 month reckoned from a ready basic one.

The engineering works of off-sites are often made solely by the Buyer. The Seller (and owner of the technology) has to provide, however, the necessary data - in accordance with its technology - to prepare it. E.g. if the water supply has to be secured by the Buyer, he has to make the necessary engineering for those equipment which shall secure it, but the owner of the technology has to specify the exact quantity and characteristics of the water needed, aswell as the point (at battery limit) where it enters the plant. The engineering within battery limits will most probably be then Seller's task.

Attention is drawn to the following practical questions in connection with engineering works:

(a) If the machinery and equipment are only ordered after finishing the designing works this causes a certain delay in the realization of the project. It is practical to order hence the equipment simultaneously with the engineering. Although this may cause slight extra costs due to some uncertainties in this early stage, but these may be less than the financial costs of one extra year in the realization of the project.

(b) It is unnecessary to prepare "detailed engineering" drawings of usual stock items or of works which are better executed by an "engineering at site" (e.g. the route of electric wiring in the wall). Such superfluous engineering works cost money and time.

(c) When splitting engineering works between the parties it is normal that the party receiving a certain document shall have the right to submit remarks to the

received document within say 30 days from receipt. Such remarks should be commented or discussed within a reasonable period not to hinder, however, further works (e.g. 30 days). Lack of remarks means consent. In case of disputes and in lack of agreement the view of the technology owner has to prevail in matter of technological nature.

(d) Modification of once submitted documents are a usual problem of engineering works. These can be requested by either party. Smaller amendements are unavoidable, they cause mostly only inconvenience and should be hence handled accordingly, but should the modifications influence the agreed terms or other conditions these have to be agreed upon.

(e) Technical conferences should be arranged according to a fixed schedule, this may simplify the common work; any disputes could be arranged during such conferences.

(f) The starting basis (basic data) of any basic engineering should be fixed in the contract itself with great care. It is also practical to fix battery limits in order to avoid later misunderstanding. Standards, specifications and related codes to be applied on engineering works have to be specified in the contract. If the Buyer has to apply certain standards due to prescriptions in his country (e.g. fire protection prescriptions) this should be laid down in the contract and such prescriptions have to be handed over.

(g) Documents should always be sent air freight and not air-mail or parcel post, or handed over personally. Postal shipments can sit for a too long time in custom houses.

2.3 Delivery of equipment

2.3.1 Timing, assuring deliveries

The specification of the equipment has to be fixed in the Contract. A delivery schedule (detailed) will also be necessary for the execution of the investment, but such schedule can not be made when contracting, only later. In the Contract only the starting point and the end-point of the deliveries can be fixed, if possible by plant section.

The detailed delivery schedule (to be agreed upon later) has to be in accordance with the final CPM program, i.e. a network made in accordance with CPM system based on time demands necessary to build the plant in due time^{1.)}. A typical CPM Program, i.e. one based on estimated time demands forms part of the basic engineering, but this has to be finalized later. A certain rescheduling of such final Programs is, however, unavoidable; care should be taken, however, that the critical points of such programs should still be met.

For such types of plants the delivery schedule has to be detailed at least per quarter years. A certain rescheduling possibility should be granted for supplier, provided this can be followed by amending the CPM program in a way that it does not jeopardize the scheduled termination of erection.

Deliveries - if the equipment are ordered from Seller together with the engineering - can start at about the 15 month from contracting and may end 36 month from the same date. If the equipment are only contracted later, delivery dates will be probably the same, but reckoned from this contract and not from the starting of the works. The 36. month is a date up to which about 96-98 % of all goods can be delivered, the rest can come a little later.

1.) Instead of CPM system similar other ones could also be used.

It is usual to penalize the failing to meet the delivery terms. This penalties could be asked for delivery terms fixed for each quarter, but this has not much sense, only if the non-performance effects strongly the realization schedule. Penalties for failing to meet the end date (96-98 % of the total deliveries for a fixed date) are more practical, provided that the delay effects construction or erection works.

It is usual to agree in penalties amounting to 0.5 % per full week based on the value of the non delivered goods, or if the delay is a longer one and effects seriously the works at site, based on the value of units, plant sections or even the whole plant. A period of grace of 30 days is, however, also usual.

It is not unusual to foresee in a contract the partial termination for goods being in delay for say 6 month, buth this does realy not help much. It is rather put into a contract as a safety valve for cases of unusually long delays with the thought that should the Buyer be able to get the goods in delay from other sources earlier than from the original Seller, he should not be bound to the original Seller for such goods.

2.3.2 Stage of prefabrication

The stage of prefabrication aswell as other characteristics of the deliveries are an important factor in the costs. Some practical aspects should also be considered, e.g. certain pieces can not be delivered in one piece, others could, but their delivery in one piece would be very inconvenient.

Appendix II. contains an example of how to determine prefabrication and some other important general characteristics of deliveries. It has to be emphasized, that this Appendix is only illustrative, the parties can agree in a different way, important is, that they should fix a similar agreement. This is important for the Buyer to know what he has to do at site, aswell as for the price he can give for the equipment and the cost he has to consider with in erection.

2.4 Spare parts

Spare parts necessary for a 2 years operation are normally ordered together with the equipment. This may have the advantage that such deliveries could be incorporated into the credit of the original supplies.

The normal way is to agree a frame amount (say 3 %) and to request the Seller to give an itemized list and specification of spare parts (with itemized prices) e.g. within 15 month from starting the contract. The Buyer then has to decide within say 2 month what to order within the agreed frame amount or even beyond it.

It has also to be fixed in the Contract which will be future dead-lines to order spare parts each year. A guarantee should be asked that if such dead-lines are followed, delivery of the spare parts will be secured by the Seller within fixed dates from such orders.

It has to be mentioned here generally that there are companies having relatively short delivery dates for spare parts, because they keep these on stock, but in such cases spare parts have rather a higher price. Other companies do not hold a large stock, they are manufacturing parts on


order; delivery dates are in this case longer, but prices are also lower. In the present case rather this latter situation prevails.

As a general policy it could hence be recommended to have more spare parts on stock at the plant (especially of those having a long delivery period). It should also be looked for how the plants' own maintenance shop will be able to manufacture certain spare parts for their own use later.

2.5 Some other remarks

It is highly advisable in the present case:

- a) To have Greek specialists working from the beginning on the project and thus learning a lot about the plant during the design and construction period
- b) To let train key personnel in due time (and not only engineers) and to assure their stay with the company for a period of at least 10 years
- c) To make use of services of consultants or a consulting engineering company and probably also to assign construction management duties to companies active in such type of activities.


Ferenc Orbán


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Appendix I

TYPICAL SCOPE AND CONTENT OF BASIC ENGINEERING WORKS, FOR
AN ALUMINA PLANT

Scope: The seller has to provide the following within
battery limits:

- (a) the conceptual drawings and documents determining the process technology and its ancillary requirements and layout of the entire plant
- (b) the process linkage of the individual plant units
- (c) the process control of production as well as quality of the finished products
- (d) material and heat balances, material and energy consumption figures
- (e) the necessary data and information on the basis of which the detailed engineering designs will be produced, the standard equipment will be ordered, and the non-standard and proprietary equipment will be designed
- (f) the conceptual architectural and civil engineering data for the plant
- (g) main oriented CPM Summary Network for establishment of the plant
- (h) typical CPM Program showing the likely activities and their likely scheduling for implementation and control of the establishment of the plant.

Contents: 1. Technology

- 1.1 Laboratory tests performed by the Seller on the bauxite samples selected and supplied by the Buyer with the assistance of Seller; the technology selected on the basis of the experiments and tests;
- 1.2 Detailed description of the technological process and the conceptual technological flow-sheets for each plant unit.
- 1.3 Material and heat balance; specific material and energy consumptions and the specifications of the alumina quality.

2. Mechanical engineering

- 2.1 Technical description per plant unit, relating to the task of machinery, equipment and piping.
- 2.2 Equipment layout plans per unit with sufficient number of sections, elevations, containing the outline of the main equipment, the space requirement for machinery, and all the pipelines, the overall dimensions of buildings, design and supply limits indicating the linkage with other plant units.
- 2.3 Master Plot Plans will be elaborated on the basis of the Unit Plot Plans taking into consideration the space requirement of the utilities, roads and process lines.
- 2.4 Process flow diagramm per unit will contain:
 - the equipment and machinery with installed spares showing the equipment numbering

- technological and non-technological pipelines with the installed valves, test taps, by-passes indicating the material flow, technical parameters and sizes
 - control, recording, indicating and regulating loops, safety equipment and instruments.
- 2.5 Equipment list per unit will contain the characteristic data of the main equipment and the specification of other machinery (technical parameters, performance data, size and weights, performance data of drives including electrical motors).
- 2.6 List of pipes per unit, containing the estimated quantity of pipes, specifying the same according to the diameter, as well as indicating the bends, flanges, gaskets, bolts, nuts and fittings on a percentage basis in weight of pipe, or where possible, in quantity.
- 2.7 Estimated quantity of steel structure per unit for light steel structures and pipe-supporting structures.
- 2.8 Estimated data concerning the insulation and painting of the equipment, machinery and piping (area of insulation, specification of insulation material).
- 2.9 Fire protection system.
- 2.10 Safety system.

3. Architectural, Civil and Structural Engineering (A.C.S.E.)

A.C.S.E. will be made by the Buyer on the basis of data supplied by Seller. The Seller will supply all the basic data required for the A.C.S.E. works as follows:

- 3.1 Final layout (master plot plan) within the fence with the reference level of the plant units.
- 3.2 Traffic load of the road network including the external connections.
- 3.3 Data for main network of public utilities and piping.
- 3.4 Data supply for detailed soil and hydrological investigation (red mud disposal included) to be made by the Buyer.
- 3.5 All necessary data (main loads, space, room, technological and sanitary engineering requirements, corrosion, etc.), and suggested engineering constructions of all buildings and structures within the battery limit with technical descriptions, water treatment included.
- 3.6 Basic data for off-site buildings and constructions, e.g. port, storage, connections and traffic requirements between plant and port, red mud disposal, etc.
- 3.7 Requirements for design of building and structural engineering works in relation to foundation design, bolt hole spacing, supports and connections to other Sellers' design works.

Note: The delivery date of Buyers drawings has to be agreed in the Contract.

4. Electric design

4.1 Electric power supply and distribution system for the switching stations, transformer station, technological objects, containing the following:

4.1.1 technical description, basic data, preliminary short circuit calculations, power supply, operation, fault indication and contact protection

4.1.2 single-line diagram

4.1.3 operating current flow scheme

4.1.4 block scheme

4.1.5 cable routing diagram

4.1.6 arrangement and cable tracing plan

4.1.7 layout design, outline drawing of the switching gears, distributors, building dispositions required for location

4.1.8 material list covering the technical characteristics and quantity of the electrical equipment, distributors, devices, fittings, etc., as well as the technical characteristics and estimated quantity of the cables.

4.2 Lighting design of the technological units as well as outside areas, covering the following:

4.2.1 technical description containing: lighting equipment, values of illumination, power supply, contact protection, lightning protection, as well as mounting

- 4.2.2 indication of number of light sources
- 4.2.3 single-line diagram of distributors
- 4.2.4 lightning protection
- 4.2.5 material list covering the technical characteristics and quantity of the electric equipment, distributors, switches, lamps, fittings and technical characteristics and estimated quantity of the cables and lines.

5. Instrumentation and Automatization design

- 5.1 Technical description covering the process control system, the function and structure of the measuring and control loops.
- 5.2 Process Flow diagram per unit, indicating the measuring and control loops with the sensing and manipulating points.
- 5.3 Specification and list of the selected instrumentation and automatic elements.
- 5.4 Front-design of the instrument panels.
- 5.5 Layout plan of the instrument rooms.
- 5.6 Telephone and communications network.

Appendix II

EXAMPLE
FOR
PREFABRICATION AND OTHER IMPORTANT CHARACTERISTICS OF
DELIVERIES

Goods will be supplied in the following condition:

1. completely assembled
2. disassembled to transportable dimensions (due to technical and economic reasons,^{1.)} e.g. according to railway regulations of the relevant transit countries; notwithstanding: some special goods, not to be divided owing to technical reasons - e.g. digesters - will be transported by special means, if necessary
3. in part units, in elements prepared for local assembling, in units transportable as described above

Goods according to points 2 and 3 above shall be assembled and set up (or welded, bolted-up, screwed, etc.) on the site by Buyer and at his own costs.

Goods mentioned in points 2 and 3 above are as follows:

a) Tanks

In case of tanks exceeding \emptyset 3 m, the jacket, cover and bottom shall be delivered cut to transportable size, or smaller than that, resp., welded into units up to transportable size.

Jacket elements of tanks over 3 m dia, shall be delivered rolled in so called belts or belt parts prepared for welding (mitred), fastened in bundles, unpainted, welding seam edges provided with suitable protection against corrosion.

1.) an important economic reason could be that some equipment would need too much shipping space

Sheets will be suitably match-marked in manufacturers' works to allow correct local erection.

Reinforcement, foot-path, steps, manholes and supports for tanks shall be delivered prefabricated, and if necessary in several assembly-units, in transportable dimensions.

The mixers of the tanks shall be first assembled, than disassembled to transportable parts and delivered like that.

b) Steel structures

The steel structures indicated under various unit numbers - belt conveyor bridges, supporting structures, platforms, access stairs and casings of the equipment - will be delivered manufactured in transportable dimensions, prepared for welding, match-marked, together with accessories, fastening indicated in the technical documentation.

c) Pipings

Pipings shall be delivered in factory length without preparation of the welding seam form in seamless, resp. spiral seam design, with normal fitting (bends, knees). Bent pipes shall only be delivered for pipings forming the structural part of some equipment and for piping over 25 at and 50 mm dia. Various bends, flanges, fittings, necessary for the piping shall be mounted on the pipes, resp. welded on the site.

d) General

All goods shall be delivered with single prime coating, except:

- finished goods, e.g. motors, drives, etc. provided with final paint coating
- pipes and tank elements without prime coating.

e) Other remarks

- Equipment like e.g. boilers, steam turbines, etc. which owing to their dimension or weight can only be delivered in part units, will be assembled (welded, bolted-up, etc.) and set up on the site by Buyer at its costs.
- Rubber belt conveyors at out-door installation are covered with removable protecting plates to ensure easy access for maintenance. The frame of the conveyors are made of steel structure.
- Feed and transfer chutes are covered with steel plates and connected to the dust separation systems.
- Centrifugal pumps are delivered with electric motors, flexible couplings or Vee-belt drives, coupling guides, mounted on common base frames.
- Pumps for liquor services are provided with cast steel casing, impellers, heavy duty shafts and bearings.
- Pumps for slurry services (bauxite slurry, settler underflow, hydrate slurry) have special wear resisting parts.
- Tanks made of proper quality steel plates suitable for caustic liquor services, at different concentrations and temperatures.
- Flat bottom tanks for slurry services are equipped with heavy duty stirring mechanism.
- Flat bottom tanks for aluminate liquor and spent liquor services are side agitated.
- All pressure vessels will be designed and delivered to meet the requirements of the boiler regulations of the manufacturing country (NOTE: If Greek is special, this should be clarified before contracting).

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- Piping includes all the necessary fittings, flanges, valves, pipe supports; brackets, cantilivers, supporting columns are included in the steel structure.



