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F I N A L   R E P O R T

PROJECT NUMBER: DP/GRE/ 83/005

PROJECT: Techno-Economic Investigation of Production of Deironed Refractory Bauxite

SUBCONTRACT: 84/108

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1. Executive summary

Technical and economic aspects of beneficiating Greek bauxites with the objective of producing a high alumina, low iron bauxite grade to be marketed domestically as well as abroad, have been investigated under a subcontract from UNIDO, Vienna for UNDP, New York and the Greek Government.

Current local demand for the refractory grade bauxite product was found to be around 12 thousand tons/yr.

This may increase significantly to enable supply of refractory products to the Soviet Union, and to European and Middle East countries. Current European demand for refractory grade bauxite is in the range of 300,000 tons. Greek plant should be able to sell upwards of 40,000 tons calcined bauxite and its total output of the iron oxide by-product. The market for iron oxide pigments in Europe is in the 100,000 ton range.

Ambient temperature leaching by hydrochloric acid, the most advanced technology currently available for the purpose, has been demonstrated to be suitable to remove over 90 % of the iron in the bauxite feed. Raw material selection is, however, a key factor in the technical and the economic viability of the project, as various alumina and iron oxide bearing minerals have been shown to react differently to leaching by HCl. Also, the refractory industry has some strict requirements on the physical properties of the 'white' calcined bauxite, and these properties are largely determined by the minerological structure of the raw material.

Although the availability of excellent raw material in Greece has been demonstrated, the government agency promoting the project in Greece had difficulties in obtaining sufficient quantities of these grades from the private sector companies operating the state owned mines. Consequently the pilot scale tests could be run only on a lower grade. A calcined refractory bauxite comparable to the Chinese bauxites and a red iron oxide pigment comparable to Bayferrox 645 were produced and tested in Minnova's Pécs, Hungary and Andritz's Vienna, Austria pilot plant.

For 40,000 ton output of calcined bauxite about 68,000 tons of the material tested in the pilot plant have to be processed, and some 21,000 tons hydrochloric acid have to be added to compensate for chloride loss mainly due to the extremely high Ca+Mg content of this feed. Main equipment needed include leaching/washing towers, spray roasting /Andritz-Ruthner/ type acid regeneration equipment and tunnel kiln for calcination. The plant consumes some 11.5 thousand tons fuel oil, 6 million kWh power and 1.6 million m^3 process water. Site area required is 40 acres. Most suitable location is close to an alumina plant.

Based on laboratory data estimates appear in the Report for a 40,000 ton output plant on the gray/yellow bauxite of the 3rd horizon in the Parnassus-Kiona-region. In this case 15 % less bauxite, 60 % less hydrochloric acid, 25 % less power, 35 % less fuel oil and 40 % less water are required, and 40,000 tons top grade refractory material comparable to the Guyanese RASC grade can be produced. In this case, however, about 45 % less iron oxide pigment is gained.

Total investment outlay for a 40,000 ton plant is 3,400 /3,000/* million Drs. Process equipment would cost 2,100 /1,850/ million, know-how and rights to the technologies used cost about 210 /185/ million. The working capital requirement is estimated to about 190 /165/ million Drs.

Manpower requirements for a 40,000 ton plant operating for 8000 hours a year can be covered by 9 university graduates, 23 other engineering and administrative staff and 50 skilled and semi-skilled workers. A plant is erected and installed in about two years. Production start-up takes 6 months, running-in another six.

Total production cost is calculated to be about 1,000 /850/ million Drs /excluding depreciation/. Bauxite, HCl and fuel oil account for 31 /42/, 13 /7/ and 28 /21/ per cent of the cost of operation, respectively. Fuel oil price used in the report is about twice the current Western European one.

The operating cost before depreciation is Drs 24,400 /21,175/ per ton of calcined bauxite. The product comparable to the Chinese refractory grades could fetch between US$ 114 and 135 /Drs 15,400 to 18,200/ per ton. The high grade raw material could yield a calcined bauxite matching the market standard Guyanese RASC grade and sell for an ex-works price of Drs 22,400 to 26,600. Iron oxide pigment sold at Drs 28 per kg solids could add about 50 % /15 %/ to the sales revenue of the plant.

*Figures in brackets apply to use of high grade feed.

Profitability of a plant using medium grade feed is not satisfactory. The pay-back period for a 40,000 ton plant is 21 years.

The alternative plant using high grade bauxite feed would benefit from its more favourable minerological and chemical composition through much lower hydrochloric acid losses, lower material flows and higher price for the calcined bauxite, etc. The internal rate of return on the owners' equity is calculated as 10.5 % when no outside loan is used and as 14 % when foreign exchange component of the investment outlay is covered by a Forex loan with 7 % interest.

The project's implementation could result in import substitution, create a new value added export item and provide work for 70 to 100 persons in the country.

For a full bankable feasibility study, there would be required

i/ a specification of the correct feed material;

ii/ further large scale tests on the finally specified feed material in order to determine consumption figures and other data;

iii/ market studies on both the local and foreign markets;

iv/ the selection of the site.

2. Background and history of the project

2.1. Introduction

Dissolution with hydrochloric acid, with all its advantages, has been known for a long time in hydrometallurgy. Metals are dissolved out of their ores usually faster and with a better efficiency than by the more usually applied sulphuric acid, but hydrochloric acid's higher price and the difficulties in treating the chloride solutions forming as wastes, also the serious corrosion of the equipment have prevented its propagation in practice.

Lately the industrial development has permitted the production of corrosion resistant equipment, including the apparatus of the Ruthner firm for decomposing chloride solutions with a process of spraying calcination. The metal chloride solution is sprinkled in a reactor at 300-900 °C where the following reactions occur:

$$MeCl_2 + xH_2O \rightleftharpoons MeO + 2HCl + /x-1/H_2O$$
$$2\ MeCl_2 + xH_2O + \frac{1}{2}\ O_2 \rightleftharpoons Me_2O_3 + 4HCl + /x-2/\ H_2O$$
$$2\ MeCl_3 + xH_2O \rightleftharpoons Me_2O_3 + 6HCl + /x-3/\ H_2O$$
$$2\ MeCl_3 + xH_2O + \frac{1}{2}\ O_2 \rightleftharpoons MeO_2 + 6HCl + /x-3/\ H_2O$$

The solution drops evaporate, the metal chlorides are decomposed and solid metal oxides and gases containing hydrochloric acid are the results. The hydrochloric acid gas is absorbed forming concentrated hydrochloric acid that can be used again for leaching. This process is closed with respect to the aggressive acid reagent and in comparison with the former processes it does not pollute the environment.

In Hungary the Mecsek Ore Mining Enterprise and the Tatabánya Coal Mines have long been working with hydrometallurgical processes. Utilizing the Ruthner process of acid regeneration, a new process was developed for lowering the iron content of bauxites with hydrochloric acid, known as TATABÁNYA Process /1/. Some of the features of the TATABÁNYA Process:

- selective dissolution /90-95 % of the iron can be removed from the bauxite, while only 0,5-7 % of Al_2O_3 is dissolved/;
- relatively coarse grained feed can be used;
- the phases are separated without use of filter;
- very good acid utilization.

The TATABÁNYA Process had been tested for use on bauxite of different origin /China, Malaysia, Yugoslavia, Hungary, etc./ and type /diasporic, gibbsitic, boemitic, etc./. It was found that diasporic bauxites are best suited for this treatment.

After years of detailed investigation the construction of the first plant to operate on the TATABÁNYA Processes was started in 1985. The plant located in Pécs, Hungary, has a design capacity of 10.000 tons/year refractory grade bauxite and some 3.000 tons pigment grade iron oxide and is due to start production in 1987.

This report covers the techno-economic aspects of the possible use of the TATABANYA Process in Greece.

2.2. History of activities connected with the project

2.2.1. Initial tests

The first Greek bauxite samples on which the TATABANYA Process was used were received back in 1981/82 through the good services of Mineral Resources and Mine Development S.A.

These samples were taken from the so-called "3rd bauxite horizon" of the Parnassus-Kiona-Helikon area that holds at least 3 million tons of economically recoverable deposits /2/. The different bauxite grades had been tested in 1981/83 in our Pécs, Hungary, laboratory. The tests included laboratory leaching tests on a few hundred kilo material and subsequent calcination of the samples. The technical results were extremely encouraging. Tables 2/1 and 2/2 present data for sample 3 /a gray-yellow colour lumpy material/ received in 1982. These data have been confirmed in tests by Ideal Refractories, Athens. A first estimate of the economic feasibility made in 1983 indicated that it was worthwhile to pursue the matter.

After UNIDO/UNDP agreed to support further work on the subject, MINNOVA was subcontracted to prepare this techno-economic feasibility study on the production of deironed refractory bauxite in Greece. Concurrently Dr. E. Mack, expert on mineral resources evaluation & mine development, with several years of experience in the Greek bauxite mining was retained to assist in selecting the suitable bauxite samples for use in the study and to assess the marketing possibilities for the products. Dr. E. Mack produced this report in December 1984 containing many useful data and recommendations, some of which will be used in this report /2/.

Table 2/1

Comparative data on the chemical composition

Composition	1	2
Al_2O_3	69.0	91.82
Fe_2O_3	9.7	0.86
SiO_2	2.8	3.85
TiO_2	2.9	3.28
CaO	1.1	0.21
MgO		
Na_2O	0.13	0.13
L.O.I.	14.2	-
	99.83	100.15

1 = Bauxite sample 3/82

2 = Calcined product from Sample 3/82

Table 2/2

Characteristic data of calcined product of Sample 3/82 from laboratory test made in 1982.

parameter	value
corundum	85 %
mullite	3 %
glass	8 %
water absorbtion	3 %
bulk density	3.45 gr/cm^3

2.2.2. Laboratory work prior to the pilot-scale test

HUNGALU [illegible] began work under the contract with UNIDO in November 1984 by paying visits to mining operations in the said Parnassus-Giona-Iti-Helikon area. Two visits have been arranged by HIMIC and Dr. L. Mack was invited to participate in them. During the visits it was made clear to the representatives of the mine operators that we were going to do large scale testing of the same material that was tested earlier, and we asked for their co-operation. We actually saw yellow and grey bauxites deposited in the Itea harbour of one of the operators and received verbal confirmation of the availability of such material in our discussion with the other operator. Dr. L. Mack did not join us for the visit to Bauxite Parnasse Mining Company /BMPC/ but he participated in the meeting with Hellenic Bauxite Mining Company of Helikon /HBMH/.

In our subsequent meeting with representatives of HIMIC we were told that the grades we worked with previously were not available and we were asked to base our study on another grade which we then agreed to select from what the mine operators promised to make available to HIMIC.

Back in Hungary, chemical data on eight grades, as well as minerological data on five of them were reviewed. Leaching and calcination tests were performed in early 1985 on four samples of 50 kg each representing 2 grades each of the two mine operators. It should be noted that samples received from MBMH were blends of different materials and one of the samples furnished by BMPC satisfied the criteria appearing in Column 1, Table 2/3, also to be found in Appendix 3 of /2/. Laboratory tests confirmed that the various grades show individual behaviour when leached and that the three grain size fractions 0.315 to 1.1 to 5 and 1 to 15 also behave differently. This latter difference was found to be more marked for the sample material received from HBMH.

The 1 to 5 mm grain size fraction of sample D, a grey/ /red material, could be leached to have a 2.46 % Fe_2O_3 content when calcined. Its 0.315 to 1 mm fraction had a residual iron content of 1.86 % after calcination. It was, therefore, agreed that -4mm material will be used in the pilot-scale test. Although sample A performed similarly, its price was about 50 % higher. /HIMIC information/.

2.2.3. Pilot-scale leaching

Sample material for the pilot-scale tests was delivered by HIMIC in June 1985 in two shipments of 20 tons and 40 tons, respectively, and it was then made clear to us that it was not possible for HIMIC to provide more. Results of the chemical analysis performed in our laboratory on homogenized samples taken from the two shipments are shown in Table 2/3. Some 10 % of the material received was found to be +4 mm, another 11.2 % of the material was -1 mm. The minerological composition of this material is given in Table 2/4.

Table 2/3

Chemical composition of different bauxite grades

/all data in w. %/

Component	1	2	3
Al_2O_3	min. 62	68.35	56.7 /!/
Fe_2O_3	max. 18	13.01	18.6 /!/
SiO_2	max. 3.5	1.22	2.1
TiO_2	/max. 3.0/	2.75	2.4
CaO	max. 1.3	0.69	3.0 /!/
MgO	max. 0.2	0.10	2.0 /!/
Na_2O+K_2O	max. 0.2	0.37	0.1
L.O.I.	/max.15.0/	13.12	14.7

1 = Specification for "guaranteed quality" by UNIDO expert /2/

2 = Established by MINNOVA for blend D

3 = Established by MINNOVA to be the average composition of the 60-ton feed for the pilot-scale test.

Material received by the first shipment was fed into the pilot plant column without delay to compensate for the time spent for material selection. Further quantities were fed into the system subsequently. In view of the large -1 mm fraction, flow problems were anticipated that were thought to result in lower leaching rate, thus aggrevating the product quality problem arising from the presence of +4 mm material. Figure 2/1 shows the pilot-scale leaching plant, demonstrated to representatives of UNIDO and HIMIC in July, 1985. Pilot-scale leaching of the 60 t sample, described in detail in the Interim Report /3/, was completed by the end of October, 1985. The first 8 tons produced were calcined at the Budapest facility of Magnezite Works, Budapest. Approximately 6 tons of calcined and some 29 tons of uncalcined, de-ironed bauxite were collected in December, 1985 by HIMIC and shipped to Greece. The leached, uncalcined product was analized chemically, as well as for its minerological composition by both MINNOVA and Société Hellenique de Surveillance S.A., Athens. The results appear in Tables 2/5 and 2/6.

2.2.4. Pilot-scale calcination

In the calcination tests bricks were pressed from the de-ironed bauxite with 6 % moisture, using pressures of 800 to 1.200 bar; drying and calcination were carried out in a tunnel kiln with gas firing, /width: 2.2 m, length: 144 m/. The green bricks were dried for 4 days at 60 to 80 °C. The tunnel kiln had a maximum temperature of 1.660 °C, the height of the stacks was 1.3 m. The material was fired

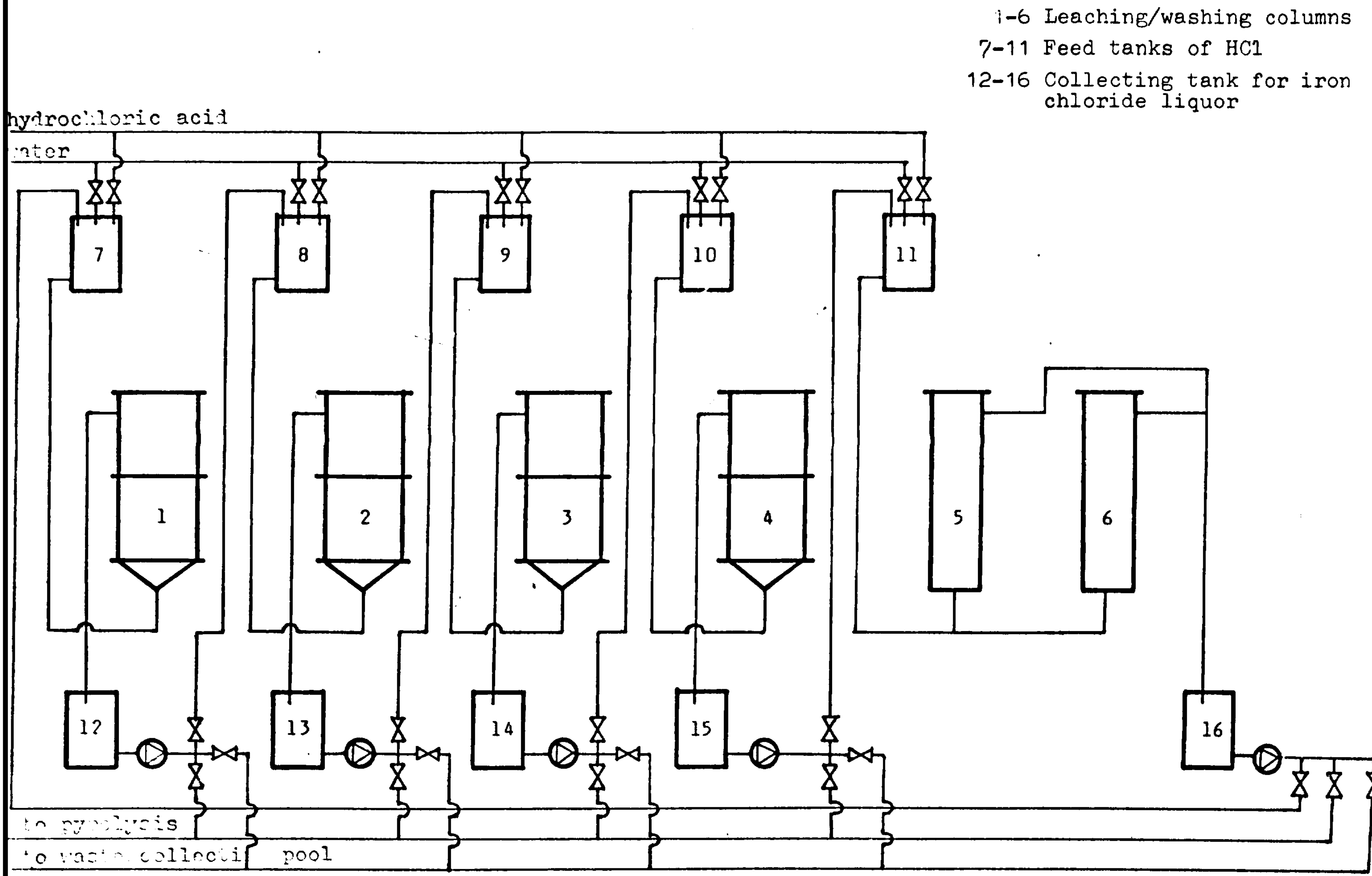


Figure 2/1: Multi-stage countercurrent system of the pilot plant

Table 2/4

Minerological composition

/all data in w. %/

Component	1	2
Diaspore	58.7	64.0
Boehmite	7.5	-
Hematite	7.0	4.1
Goethite	13.0	18.3
Quartz	1.5	-
Caolinite	1.0	6.6
Rutile	0.6	0.7
Anatase	1.8	3.5
Calcite	4.2	-
Corundum	-	2.0
Other minerals and H_2O	4.7	1.0
	100.0	100.2

1 = Average value, established by the Metal Research Institue, Budapest, for samples taken from the two bauxite shimpents subsequently processed in MINKOVA pilot plant.

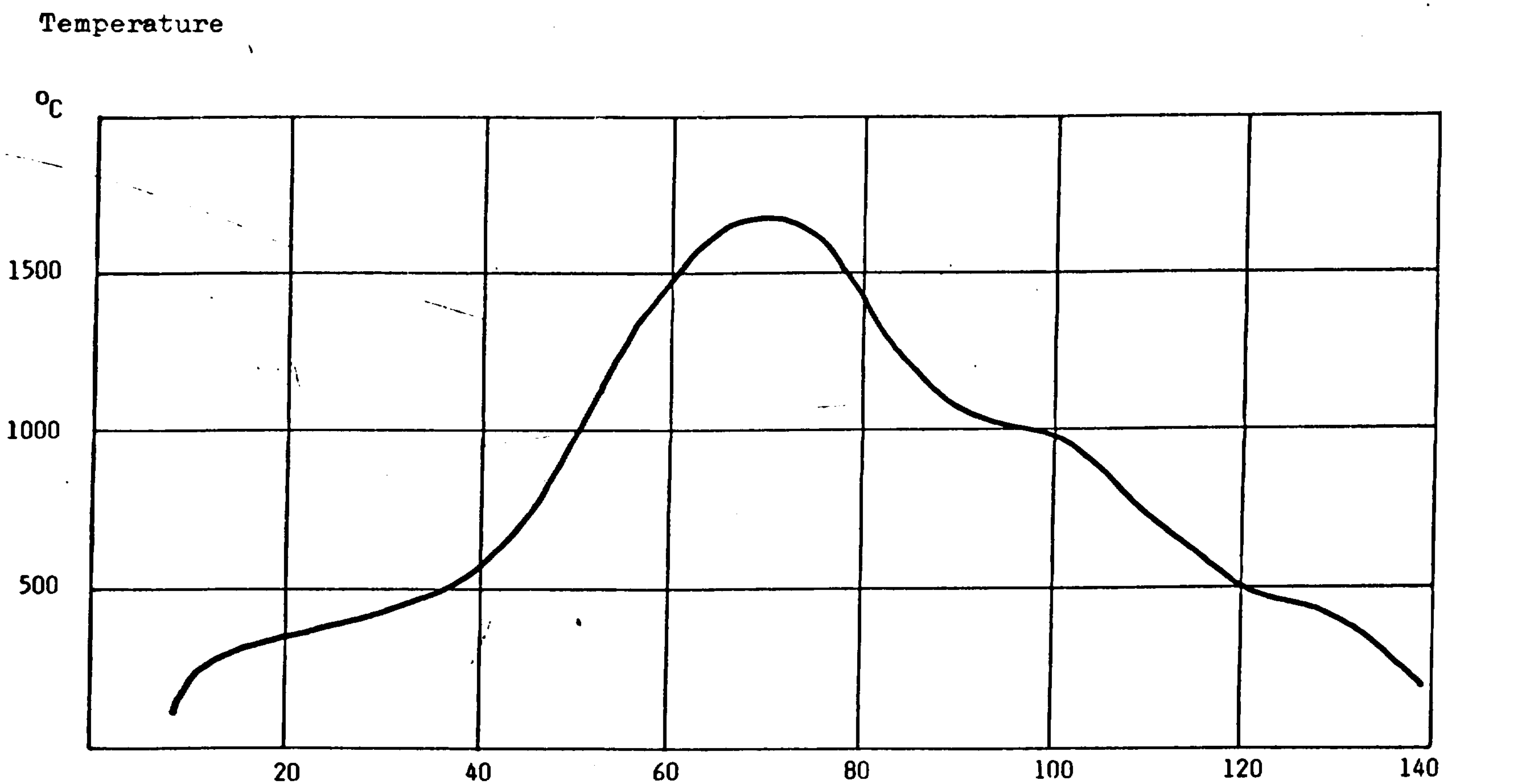
2 = Typical composition of diaspore-type Greek bauxite as it is given by the UNIDO expert in this Technical report /2/.

at SK 29 to 30 for 4 hours and spent altogether 100 hours in the kiln. Figure 2/2 shows the temperature distribution of the kiln.

Several samples have been taken from this material. These were subsequently evaluated by the refractory makers MIM, Budapest, and Ideal Refractories, Athens, as well as Surveillance, Athens. Chemical analysis data are presented in Table 2/7.

Minerological analyses of calcined, refractory material made from the pilot-scale test product were also performed both by MIM and Ideal Refractories. These results are given in Table 2/8. Respective results by Surveillance, if any, did not reach us in time to be included here. The calcined, refractory grade bauxite from the pilot-scale test was measured in the laboratories of MIM, Budapest for its physical properties. Results are presented in Table 2/9.

Different compositions have then been made using the dried material from the pilot-scale test, clay, alumina and other ingredients, to adjust the properties of the raw material. Tests with these compositions, data from which are presented in Table 2/9, confirmed that all relevant parameters of the refractory material made from such compositions were acceptable. Microscopic investigations presented in Figures 2/3 and 2/4 confirmed that the relative inhomogenity of calcined material was significantly reduced in the product.



<u>Figure 2/2</u>

Temperature profile of tunnel kiln

Table 2/5

Chemical analysis data

/all data in w. %/

Component	1	2	3
Al_2O_3	77.3	75.5	56.7
Fe_2O_3	1.65	1.96	18.6
SiO_2	2.14	4.75	2.1
TiO_2	2.81	3.22	2.4
CaO	0.57	0.07	3.0
MgO	x	0.10	2.0
Na_2O+K_2O	x	0.18	0.1
L.O.I.	14.62	14.46	14.7

1 = MINNOVA analysis ⎧ of the de-ironed product
2 = Surveillance analysis ⎩ from the pilot-scale test
3 = MINNOVA analysis of the feed of the pilot scale test

Table 2/6

Minerological composition data

/all data in w. %/

Component	in bauxite feed	in de-ironed product
Diaspore	58.7	77.4
Boehmite	7.5	12.6
Hematite	7.0	1.5
Goethite	13.0	-
Quartz	1.5	1.5
Caolinite	1.0	1.5
Rutile	0.6	0.7
Anatase	1.8	2.1
Calcite	4.2	-

Table 2/7

Chemical composition of the product from the pilot-scale test /calcined/.
/All data in w. %/

Component	1	2	3	4
Al_2O_3	88.37	89.51	88.0	min. 88
Fe_2O_3	1.98	2.53	2.28	max. 1.7
SiO_2	3.58	3.37	5.53	max. 6.5
TiO_2	3.49	3.68	3.75	max. 3.5
CaO	0.68	0.10	0.08	max. 0.2
MgO	x	0.20	0.12	max. 0.2
K_2O+Na_2O	0.20	0.12	0.21	max. 0.2

1 = Average from repeated analyses by MIM.

2 = As found by Surveillance /4/.

3 = Calculated from Column 2 of Table 2/5

4 = Preliminary target specification, confirmed by UNIDO expert /2/.

Table 2/8

Minerological analysis data

/all data in w. %/

Components	1	2	3	4	5	6
Corundum	60	~80	60	75	75	80-90
Mullite	15	~10	10	0	0	max. 5
Tialite	10	~ 5	10	10	10	max. 6
Glass phase	15	> 5	20	10-15	15	max. 8

1 = As found by MIM, Budapest; /no additive/

2 = As found by HIMIC; /no additive/

3 = As found by Ideal Refractories /Athens/; /no additive/

4 = As found by Ideal Refractories; /sample prepared with catalitic agent/

5 = As found by Ideal Refractories; /sample prepared with catalitic agent and ground and sized/

6 = Preliminary target specification confirmed by UNIDO expert /2/.

Table 2/9

Comparative data on physical properties chemical and minerological composition

Properties	1	2
Bulk density /gr/cm^3/	3.25	3.38
water absorbtion /%/	4.8	2.8
porosity	15.4	9.5
Chemical composition /in w. %/		
Al_2O_3	88.37	88.58
Fe_2O_3	1.98	1.41
Phases /in w. %/		
Corundum	60	80
Mullite	15	10
Tiolite	10	5
Amorphous	15	5

1 = Calcined beneficiated bauxite /as is/

2 = Composition containing 75 % beneficiated bauxite

Figure 2/3

Structure of the calcined refractory grade bauxite ./Magnification factor: 42/

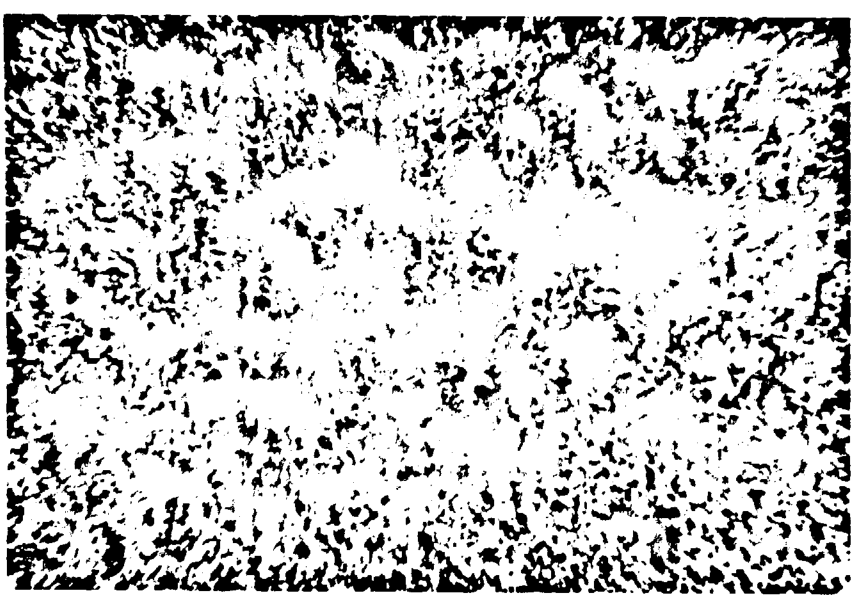


Figure 2/4

Structure of the material made from a composition containing 75 % dried, uncalcined refractory grade bauxite from the pilot scale test and 25 % alumina, ground, fired at 1.630 °C and screened to -5 mm. /Magnification factor: 42/

A brick made from composition named G-2 was subjected to a slag corrosion test according to the method described in Hungarian Standard 5917-83. Slag composition characteristic for Siemens-Martin furnaces with a basicity of 2.1 was used in test conducted at 1.580 Celsius. Penetration was similar to that established for other high-alumina refractory products.

2.2.5. Regeneration/Iron oxide

In the mean time two batches of 5 m^3 each spent liquor had been processed at Vienna facility of Maschinenfabrik Andritz, Ruthner Division. The chlorine content of the spent liquor had been successfully converted to hydrochloric acid and between 200 kg and 660 kg iron oxide /as shown in Table 2/10/ were collected for each batch in the reactor and in the cyclone of the regeneration plant, respectively. A discussion of the process was held with representatives of UNIDO and HIMIC. HIMIC was subsequently given 50 kg samples of the two reactor oxide grades produced.
A detailed description of the test and its results are to be found in the Interim Report.

A sample of the reactor oxide produced from the unpurified liquor has been treated in MINNOVA laboratory in Tatabánya to free it from water soluble chloride residues that did not dissociate at pyrolisis temperature /$CaCl_2$ and others/. For this purpose lime milk was used and the resulting product was washed repeatedly with water.

Table 2/10

Chemical composition of iron oxide samples
/average values in %/

Component	1	2	3	4
Fe_2O_3	97	94.8	70.3	68.3
$FeCl_3$	2.6	6.8	-	-
$CaCl_2$	-	-	17.1	16.6
SiO_2	0.4	0.4	-	-
Al_2O_3	-	-	3.8	3.9
MgO	-	-	8.2	7.6
other chlorides	-	-	0.6	3.6

1 = Reactor oxide from the purified liquor

2 = Cyclone oxide from the purified liquor

3 = Reactor oxide from the unpurified liquor

4 = Cyclone oxide from the unpurified liquor

A one-liter sample of a suspension containing 37.4 % solids, appropriately conditioned, was examined in the laboratory of a major paint maker for its suitability as a pigment for use in /a/ concrete products, /b/ in dispersion paints and /c/ in alhyd-type paints. The examinations were conducted according to the Hungarian Standards 10962 /"Man-made iron oxide red pigment"/, 21191 /"Pigments based on iron oxide"/ and 21189 /"Pigments for the cement & concrete industry/. The results also were compared to the properties to those of the industry standard products of Bayer AG, Leverkusen. Samples of pigmented concrete and of paints formulated were prepared, a set of which is being attached to HIMIC's master copy of this report. The results of the examinations are shown in Table 2/11.

2.2.6. Additional tests on possibilities to improve refractory properties

In May 1986 the test results then available have been discussed in Athens, where representatives of UNDP, UNIDO, HIMIC, Ideal Refractories and MINNOVA participated. The general feeling was that the raw material used for the pilot-scale test was not optimal and as a consequence the properties of beneficiated product were not up to the highest standard. Upon HIMIC's special request, MINNOVA agreed to perform additional laboratory tests on two more bauxite samples. MINNOVA representatives at the meeting asked that the type of bauxite called "grey/ /yellow" by the UNIDO expert and described on page 18 of his report be provided by HIMIC for these tests.

Table 2/11

Properties of iron oxide extracted from 60 t sample in the pilot plant beneficiation test /after treatment/

Properties	1	2	3
Iron oxide content /%/	-	82	86-88
$SiO_2 + Al_2O_3$	-	4.5	6
Sieve residue /%/	0.3	0.025	0.05
on 45 μm mesh	0.3	0.025	0.05
on 125 μm mesh	*	0.005	*
pH of the suspension	6-8	6	6
water soluble salts	1.5	1.2	0.4
organic content	none permitted	none	none
"blooming"	none permitted	none	none
alkali resistance	no colour change	no colour change	no colour change
colouring power /ratio of pigment to cement for same effect/	2-5	4.5	3
compatibility with acrilate dispersion	-	no	yes
compatibility with alhyde resin	-	yes	yes

1 = Values specified in relevant Hungarian Standard

2 = Sample

3 = Bayferrox brand product

The samples - 35 kg each - were received early July, 1986. The sample 457/1 had a pale yellow/brown colour, sample 457/2 had a fuller hue of the same colour. Both samples turned out to be blends of different grades. The samples lost their yellow hue when washed in water. The chemical composition of the two samples is shown in Table 2/12, the minerological one in Tables 2/13 and 2/14.

Both samples were then leached in laboratory glass columns for 96 hours at 80 °C by using a hydrochloric acid concentration of 438 gr/l in order to establish the limiting residual iron oxide content. The results are shown in Tables 2/12, 2/13 and 2/14.

Calcination of the samples was deemed unnecessary as properties superior to those of the beneficiated product from the pilot-scale test could not be expected.

In another attempt to improve the properties, beneficiated Greek bauxite from the leaching/washing stage was subjected to magnetic separation in high intensity magnetic separator. Field strength values between 10.000 and 15.000 gauss have been used and the material was passed through the system repeatedly in order to get a first indication of the technical viability of such a treatment of the sample. Table 2/15 shows the results. It should be noted that magnetic separation tests done on Guyana refractory grade bauxite in the United States, as well as similar investigations conducted in Brazil have been reported in the literature /4/.

Table [illegible]/12

Chemical composition of samples 457/1 and 457/2 before /1/ and after /2/ leaching

Component	457/1		457/2	
	1	2	1	2
Al_2O_3	67.75	78.25	63.55	78.2
SiO_2	1.49	0.97	2.23	0.99
Fe_2O_3	9.09	2.78	15.52	2.65
TiO_2	3.18	2.96	2.95	2.93
CaO	1.15	0.07	1.26	-
MgO	*	0.02	*	0.01
$K_2O + Na_2O$	*	0.02	*	0.02
SO_3	*	0.13	*	0.13
L.O.I.	14.78	14.79	13.95	15.06

Table 2/13

Minerological composition of 457/1, before /1/ and after /2/ leaching test

/all data in w. %/

Component	1	2
Diaspore	78	84
Boehmite	6	10
Anatase	2	2
Rutile	1	1
Hematite	8	3
Goethite	4	-
Calcite	1	-

Table 2/14

Minerological composition of 457/2, before /1/ and after /2/ leaching test

/all data in w. %/

Component	1	2
Diaspore	56	83
Boehmite	20	11
Anatase	2	2
Rutile	1	1
Hematite	14	3
Goethite	5	-
Calcite	2	-

Table 2/15

Results of a laboratory magnetic separation test

/All data in w. %/

Material	1	2	3
Initial sample	100	1.8	100
paramagnetic fraction	6.87	2.7	10.5
diamagnetic fraction	93.13	1.73	89.5
Diamagnetic fraction from the first run			
paramagnetic fr.	3.82	2.5	5.61
diamagnetic fr.	89.3	1.6	83.88

1 = Relative amount of fraction /initial sample = 100 %/

2 = Fe_2O_3 content of fraction

3 = Relative amount of Fe_2O_3/Fe_2O_3 content of initial sample = 100 %/

3. Evaluation of the test results

Most hydrometallurgical processes are made cumbersome and costly by the following technological stages:

- the grinding of the raw materials
- the provision of the higher than ambient temperature required for the chemical reactions
- the mixing and the separation by filtration of the fluid and solid phases
- the evaporation of the so arising relatively dilute solutions and its power consumption.

The technology jointly developed by Tatabánya Coal Mines, Mecsek Ore Mines, both of Hungary and Andritz-Ruthner Industrieanlagen AG, of Austria, for reducing the iron content of bauxites by hydrochlorid acid treatment is a hydrometallurgical process without the above stages. At ambient temperature, namely, concentrated hydrochloric acid does not attack the aluminium minerals and it dissolves iron from bauxite selectively. By keeping the flow of the solution at a slow rate the mixing of the fluid and solid phases and the production of a slurry can be prevented while the proper permeability of the bauxite bed can be insured by the correct determination of the upper and lower particle sizes of the bauxite. To ensure a possible maximum iron concentration in the iron chloride solution arising during digestion, a countercurrent leaching process has been developed.

To meet the above criteria the maximum and minimum particle sizes, the rate of solvent flow, the number of the acid treating units connected in countercurrent and the duration of the acid treatment best suited for the process must be determined separately for each type of bauxite.

The efficiency of the chemical processes taking place during the acid treatment and the residual iron content in the product following it depends not only on the above outlined requirements but also on the mineralogical composition of the starting material.

To establish the relationships valid for the diasporic Greek bauxite examinations were launched in 1983 at the Department of Mineralogy of the Chemical University of Veszprém under the guidance of Prof. E. Nemecz. The report drawn up on their result is enclosed as Annex I of this Report.

Tests done prior to and under the UNIDO Sub-Contract provided some information regarding the type of correlation that exists between the mineral composition of the bauxite feed and the conditions of leaching.

Tables 3/1 and 3/2 show the minerological composition of 9 bauxites received from Greece, their initial and eventual iron oxide content as well as some computed parameters.

Although the data is not sufficient for a full statistical correlation the following observations can be made:

Table 3/1

Initial minerological composition and iron oxide contents of Greek bauxites tested in 1982

Samples	Minerological composition	Iron oxide content /%/	
		initial	in in calcined product
1/82	much goethite, little hematite	16.7	1.3
2/82	little goethite, medium hematite	13.4	1.6
3/82	little goethite, medium hematite	8.5	2.0
4/82	little goethite, much hematite	13.7	2.2

Table 3/2

The effect of initial minerological composition on the iron oxide content of the calcined beneficiated bauxite

	Sample				
	"A"	"B"	60	475/1	475/2
Hematite, %	11	22	7 /1.5/	8 /3/	14 /3/
Goethite, %	2	2	13 /-/	4 /-/	5 /-/
Initial Fe_2O_3, %	12.2	23	17.8	9.1	15.5
Fe_2O_3 in calcined product, %	2.45	3.54	2.5	2.8	2.7
Diaspore, %	73	30	59	78	56
Boehmite, %	4	35	8	6	20
$\frac{\text{Diaspore}}{\text{Boehmite}}$	18.25	0.86	7.4	13	2.8
$\frac{\text{Hematite}}{\text{initial } Fe_2O_3} \cdot 100$, %	90.2	95.7	39.3	87.9	90.3
η Hematite, %	87.5	90.9	80	80.4	89.2

1. Iron oxide remaining in the calcined refractory grade bauxite is not proportional to the initial iron oxide contents of the bauxite feed.

2. Goethite type iron oxides can fully dissolved with the Tatabánya process from diasporic bauxites.

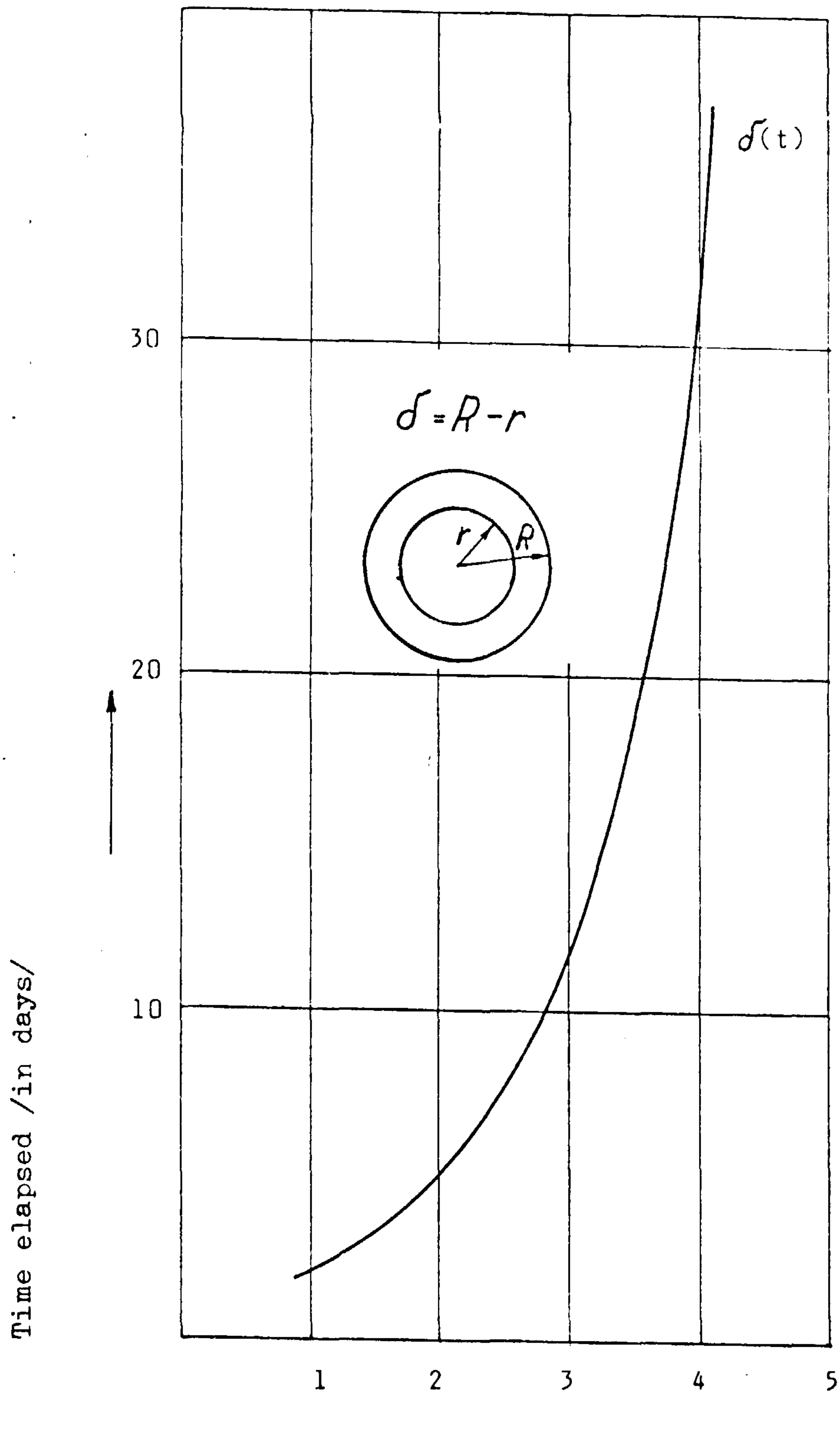
3. Hematite type iron oxides can be removed with the Tatabánya process with an 80-91 % efficiency from diasporic bauxites.

4. The ratio of diaspore to boehmite does not appear to have an effect on the solubility of hematite.

5. The iron oxide content of the calcined beneficiated bauxite apparently also depends on factors other than minerological composition.

The rate of acid treatment depends on the diffusive processes taking place in the particles. A lower concentration gradient reduces the rate of diffusion, with increasing particle size the time required for the reduction of iron grows exponentially.

If the particles of the Greek bauxite are 4 mm the acid treatment of the charge in one column takes 30 days. It has been established that a single mm larger particle size would increase beneficiation time by nearly 100 per cent while if the maximum particle size is, say, 3.15 mm, the beneficiation of the bauxite examined would require a shorter period of time /Figure 3/1/. It should however be remembered that the smaller the particle size to which the raw bauxite is ground, the more will be the dusty fraction, unsuited



Depth of leached zone; mm

Figure 3/1 leaching time vs. grain size
sample D

for the intended process. Besides, the reduction of the particle size would increase the danger of disturbed flow, canal formation and disturbances in the permeability.

The formation of canals would result in uneven contact between the bauxite and the acid.

The smallest particle size and the pertaining maximum flow rate must be established by running tests. In the course of pilot tests the flow rate was determined at 7.5 cm/h /this is the rate at which the liquid level rises in an empty column/. The permissible smallest particle size may be somewhere between 0.5 and 1.0 mm.

The pilot scale test has shown that the hard diasporic structure of the Greek bauxite is one of its great assets, i.e. it is not prone to fragmentation by the acid. Accordingly the probability of disturbances of flow is much lower than with gibbsitic bauxites.

The acid treatment cycle using five columns applied in the large-scale laboratory experiments was chosen on the basis of experience gained with Hungarian bauxites, but the higher stability of the Greek bauxites allows higher rates in washing and favourable modifications of the technological cycle. According to the modified technology acid treatment cycles can be completed in 40 day with only four columns: three times ten days in each cycle for the acid treatment which leaves ten days for washing and discharge. This modification reduces the specific investment cost with Greek bauxite.

As regards further processing, the Greek bauxite offers a further advantage in that after washing, it needs no filtration. After draining via the bottom of the column the moisture content of the bauxite will be as low as 15 to 20 % /30 to 35 % with the Hungarian bauxite/.

From the diasporic bauxite examined, under a pressure of approximately 1000 bar, bricks can be produced, without bonding materials, by dry pressing or semi-dry pressing and calcined in tunnel kilns.

The calcined refractory grade bauxite made in the pilot scale test was found to be of medium quality, comparable to Chinese Grade I and Grade II bauxites. Its properties do not match those of the gray bauxite from the 3rd horizon of the "Parnassus-Kiona-Helikon" region tested in laboratory.

The by-product from the pilot scale beneficiation of bauxite could be turned into a pigment grade iron oxide comparable to Bayferrox grade products.

4. Market appraisal and production programme for refractory grade bauxites

In this chapter comprehensive information on the market for refractory grade bauxites given by the UNIDO Expert in his Report /2/ will be complemented and a production programme will be proposed for products based on Greek raw material.

4.1. Refractory grade bauxites

The bauxite world production is in the range of 80 to 90 million tons per year; nearly 95 % of all bauxite mined is converted to alumina by the Bayer process and only about one and a half percent is sold as refractory grade bauxite. The market leader is Guymin /Guayana/ with a 1985 production capacity of 950 thousand tons calcined bauxite, actually selling about 600 thousand tons refractory grade and about 100.000 tons abrasive grade material. China's export grows at a rapid pace and its sales are reportedly approaching 0.5 million tons a year, part of this being calcined in Massa, near Livorno in Italy. Surinam, Malaysia and the USA are producing between 50.000 and 100.000 tons refractory grade bauxite each. India and Brazil are also producers, mostly for the domestic market. South Africa is selling a comparable material called Andalusite. Australia does not sell refractory grade bauxite yet, but a part of its calcined abrasive grade material /annual production in 1980=285.000 tons/ is processed into brown fused alumina and sold to refractory makers as high alumina, low iron material.

Refractory grade bauxite is normally offered as a calcined product. It typically has low iron and low silica content. The industry standard, against which the others are judged is the so-called Refractory Aggregate Supercalcined /RASC/, available from Guayana through the U.S. Company Philip Brothers. This product is specified to have max. 2.5 % Fe_2O_3, max. 7.5 % SiO_2, max. 3.5 % TiO_2 and min. 86,5 % Al_2O_3 /the latter often nearer to 90 %/. /5/

The Shanghai International Trading Co. handling the export of some of the Chinese refractory grade calcined bauxites only specifies Al_2O_3 and iron oxide contents. The latter is max. 2 % the former is min. 85 % for 'Super Grade' and min. 80 % for 'Better Grade'. /6/

Minmetals also sells Chinese refractory grade bauxite. Two grades are offered: Grade I and Grade II. Grade I typically has 87.50 % Al_2O_3, 6 % SiO_2, 1.50 % Fe_2O_3, 3.70 % TiO_2, 0.20 loss on ignition and a bulk specific gravity of 3.10 g/cm^3. Grade II has 84.50 % Al_2O_3, 6.50 % SiO_2, 1.50 % Fe_2O_3, 4 % TiO_2, 0.20 % loss on ignition and a BSG of 2.80 g/cm^3 /5/. Most producers offer lower quality grades as well - Guymine has a 84 % min. Al_2O_3, BSG 3.0 material, the Chinese are selling "calcined diaspores" /having 50 to 70 % Al_2O_3/ /6/.

These materials are often treated before calcination. Chinese and Indian refractory bauxites are handselected, and partially calcined. Guayanese bauxite is washed, dried and screened. None of the products available on the market is known to have undergone hydrometallurgical beneficiation, though.

Technical development in the market is going in the direction of increased Al_2O_3 content /up to 93 %/, decreased SiO_2 /as low as 3.25 %/, TiO_2 /as low as 2.5 %/ and Fe_2O_3 contents /as low as 1.25 %/. Guymine, the state owned producer of the RASC grade aims at a specification of BSG min. 3.6 and max. 5 % porosity and is reported to be working on a flotation method to reach this. /7/

4.2. Uses and applications

The main use for material called refractory grade bauxite is in the production of high alumina refractories. These represent a growing portion of the refractory materials used, as alumino-silicate based products lose ground due to inferior refractoriness and strength. Refractory grade bauxite's use, however, is not limited to refractory industry: it has other applications as anti-skid surfacing of roads and floors, is used in the manufacture of high strength porcelain as well as in coatings of welding rods, etc. The uncalcined low-iron bauxite has various additional applications. When processed into aluminum sulphate it is widely used in water purification and in paper manufacture. As thermally activated bauxite, it is sold in the USA as an absorbant for desulphurisation, decolorisation and as drying agent in food and chemical processing industries.

As the refractory use component of the demand decreases with technical process in steel making /specific consumption of refractories was reduced in W-Germany from 26 kg in 1960 to 15 kg in 1980 for a ton of steel/ and negative growth of the iron and steel industry in many parts of the world, and non-refractory uses of the same grade stagnate or grow /e.g. in water purification/ it is hard to say whether more or less high alumina, low iron bauxite can be sold in 5 or 10 years time.

4.3. Prices

Price information appearing in Industrial Minerals, a monthly published by Metal Bulletin Journals, Ltd. in London provides a periodical guide to the prices obtained by producers and dealers. In the past 5 years the three major grades on the market have been quoted as appears in Table 4/1.

The RASC grade from Guayana have suffered some price loss in the early 1980's, but as the supply situation normalized, its price has not changed much in dollar terms. /European users able to buy full shiploads are of course paying up to 30 % less in their own currency now as the dollar fell./ Chinese producers could continuously improve the quality of their product and this is reflected in the prices, too. The present average prices of £ 85 and 77 are the equivalent of USD 127.5 and 115.5, respectively, which says that the RASC is still considered to be superior to the Chinese Grades. This difference is even more pronounced than it may seem since the price for the Guyanese material is quoted F.O.B. Baltimore and there is additional freight of USD 35-60/ton plus to be paid by the European user. The authors

Table 4/1

Prices of refractory grade bauxites

/Source: Industrial Minerals, London/

	Chinese bauxite Grade I /typical 85 % Al_2O_3/ CIF European port /L/t/	Chinese bauxite Grade II /typical 80 % Al_2O_3/ CIF European port /L/t/	Guayana bauxite RASC FOB Baltimore /$/t/
August, 1981	76	68	204.16
January, 1982	73	62.5	214.53
September, 1982	73	62.5	200.95
February, 1983	73	62.5	172.23
December, 1984	78-80	71-73	164.28
February, 1985	78-80	71-73	164.28
July, 1985	84-86	76-78	164.28
March, 1986	84-86	76-78	164.28

are not aware of a numerical formula that could be used to weigh the influence of the various technical parameters on the price of this material. It is apparent, though, that Al_2O_3 and Fe_2O_3 contents are just two of the many factors effecting the price, one of the reasons being that the different grades are not necessarily substitutable for each other.

Actual contract prices are effected, among other things, by the customers' ability to by a full shipload on the one hand and on the grain size, delivery times, and vendor's reliability record, etc. Ground and sized grain fractions would typically sell at a 15 to 20 pct. premium over the standard RASC price. The cost to the refractory maker may include freight, customs duty, handling charges, commissions, etc. Of these freight, especially if by rail, can be quite significant. /Users in Central Europe are paying up to DM 100/ton for freight./

A comparison of the prices of refractory grade bauxite with abrasive grade /min. 86 % Al_2O_3, permitted to have up to 5 % each of iron oxide and titania/ shows this latter grade to have stable prices of about 20 % less than the Chinese Grade II. Industrial Minerals has been quoting a price range between £ 57 and 66/ton for the past 24 months /USD 85.5-99/ton/ for abrasive grade calcined bauxite, CIF European port.

Although refractory grade calcined bauxite prices have been fairly stable recently and this is what this report assumes for the life of the project as well, there is a potential for changes: Political disturbances can result in a shortage of supply as experienced towards the end of the 1970's, an increase in the energy prices /at their lowest level for 15 years in real terms at the time of writing/ could push up cost of calcination, etc.

As many refractory makers are developing new products and continuously try to cut costs to make existing ones there is plenty of opportunity to exploit the individual benefits of a new material.

4.4. The Greek products: possible markets

This report covers experimental work conducted on several Greek bauxite grades. In the authors opinion, which is in full agreement with the recommendation given by the UNIDO Expert in his Report /2/, the objective of a project to beneficiate Greek bauxite should be to produce a product quality that is second to none in the market. This is definitely not the case with the product from the pilot scale test, although this material is a high alumina, low iron bauxite.

As a laboratory work showed /Table 2/1 and Table 2/2/ sample 3/82 could be processed into a calcined product that is superior to RASC grade. As a result of the beneficiation, it would have a higher degree of reproducibility and homogenity. There are indications from further tests conducted by third parties, that this material could yield an excellent quality brown fused alumina, sold normally as abrasive as well as raw material for high alumina refractories. Further work could expose additional benefits of the material over competition, as well as further applications possibilities.

In Greece the beneficiated bauxite could substitute imports now running in the range of 10-15 thousand tons a year. It could be used also in Greece to produce high quality refractory products for export in the Middle East, in the Soviet Union and other countries. While the Soviet Union is the biggest steelmaker in the world and it has its own refractory producers, Greek-Soviet trade relations may prove close enough to provide opportunity for the development of this business. The fact that the Soviet Union is playing a key role in the establishment of the new Greek alumina plant is probably important, as large Soviet exports are due that will have to be balanced by Greece.

Steel making is at a relatively low output level in the Middle East now. Current production is reportedly about 5 million tons a year. There is apparently no local refractory production in the region. As detailed statistics were not available to the authors, consumption of refractory grade bauxite and equivalents has been estimated as follows: Relating EEC's imports of some 300.000 tons refractory grade calcined bauxite and its steel production of roughly 125 million tons to the steel production in the Middle East, the latter's consumption is put in the 12 to 15 thousand ton range.

It should also be possible to export the refractory grade calcined bauxite. In this case markets would include the Soviet Union, European countries, etc.

4.5 Production programme, revenues

The performance of a beneficiation plant producing refractory grade bauxite will depend to a large extent on its raw material, as demonstrated in chapters 2 and 7 of this report. The use of inferior raw material will result in lower product quality and may also increase production costs. As input material varies over time, one approach can be to blend the raw material and/or the product to ensure consistent quality for the latter. Another way can be to produce more than one final product grade. It may be practical from the marketing point of view also, to have several product grades at different prices, for different customers. As treatment time increases quasi-exponentially with decrease in residual ironoxide content and leaching time is an important element in the cost of operation, as described in Section 7.2, it may be prohibitive for cost reasons to keep processing an inferior raw material for an extended period of time.

The price of the beneficiated material will be affected by the cost to make it as well as by the supply/demand situation. The extent to which competing materials be substituted and vica versa will be important, too. Even in the hypothetical case of a full two-way substitutability, however, there would be differences in the prices obtained for the two equivalent materials. In this report the assumption has been made that the top quality material characterized in Tables 2/1 and 2/2 could be sold for net ex-plant price in the range of USD 165 to [illegible] /Drs. 22,[illegible]00 to 26,600/, this range being centered on 90 % of the CIF price of the RASC grade, lumps, loose /1 USD = Drs 135/.

The medium grade produced in the pilot plant and characterized in Tables 2/7, 2/8 and 2/9 could be used as high alumina, low iron refractory material, too. Price of this material has been related in this report to that of the Chinese refractory bauxites. The net ex-plant selling price range for this grade has been selected as between Drs 15,400 and 18,200/ton /USD 114-135/, centered on the average of prices of the Chinese Grade I and II materials.

Revenue estimates in Table 4/2 for plant capacities ranging from 20,000 to 80,000 tons have been made for the two extreme cases of producing 100 % top grade or 100 % medium grade product, taking both low and high limits of the price ranges into account. Price premium possible for ground material sold in bags is not considered in the Table, but a 6 percent export subsidy is.

Table 4/2

Export[1] revenue from bauxite sales

/in '000,000 Drs/

Feed grade	85				83
Output in '000 tons	20	40	60	80	
Revenue at 1. USD 114 per ton /Drs 15,400 + 6 %/	32[illegible]	653	979	1,306	-
2. USD 165 per ton /Drs 22,400 + 6 %/	-	-	-	-	950
3. USD 135 per ton /Drs 18,200 + 6 %/	38[illegible]	772	1,158	1,543	-
4. USD 197 per ton /Drs 26,[illegible]00 + 6 %/	-	-	-	-	1,128

(1) Export subsidy: 6 %

5. Iron oxide

5.1. Introduction

In the TATABANYA process refractory grade bauxite is produced by removing a major part of the initial iron oxide content of the feedstock. The iron chemically bound in iron chloride at the end of the leaching stage is turned into iron oxide again in the acid regeneration stage. This iron oxide has a various impurities depending on the composition of the liquor, on the roasting temperature, and on other factors. It is apparent from Table 2/10 in Chapter 2 that there is a substantial amount of impurities in the iron oxide produced from the untreated liquors of the leaching/washing stage. Impurities could be significantly reduced by intermediate ion-exchange purification, described in detail in the Interim Report. This however is a costly process. The alternative way, that is to purify iron oxide afterwards, is much cheaper. As Table 2/11 in Chapter 2 shows this material is similar to what is used as pigment for colouring concrete and some other building materials. Respective laboratory tests described in Chapter 2 confirmed this and indicated further that it may be possible to use the purified and processed regenerated iron oxide in alkyd resin paint systems. Based on consultations with RTR-Ruthner GmbH the authors feel, however that it will not be economically feasible to process iron oxide from Greek bauxite for use in the ferrite industry, as proposed by the UNIDO expert in his Report /2/, purity requirements there being more strict.

5.2. The market

Iron oxide is the second largest colour in the world, after titanium dioxide; its market share exceeds that of all other coloured pigments combined. Present estimated world market is 670.000 tons, about 50 % of which is supplied by Bayer of Leverkusen, Germany and its subsidiaries. Various chemical processes are used to supply about 85 % of the market; the balance is natural iron oxides. The most important use /60 % worldwide/ is to colour concrete. /Coloured mortar, concrete paving stones, concrete roof tiles, etc./ Coating applications /29 % worldwide/ including anticorrosion paint, latex, etc. as well as use in the plastic, /trash bags/ paper and other industries should also be mentioned. Iron oxide red accounts for approximately 43 % of the US iron oxide consumption, with yellow, black and brown following /8/. The authors estimate that the Greek market for regenerated iron oxide pigment could be developped to reach 5.000 tons a year.

Iron oxide pigments contribute little to the cost of the coloured product, as they are relatively cheap and are used in low percentages /Bayer recommends the use of 3 parts pigment for 100 parts cement for concrete colouring applications/. Manufacturers normally offer a range of shades in red, brown, yellow and black. The prices of the Bayer products are up to 30 % above those of the competition. Bayferrox Brown 645 T, a grade similar in shade to the pigment made from the material used in the pilot scale test, is currently sold in Austria for öS 1988 /USD 136/ - per 100 kg

/minimum lot size 500 kg/, ex warehouse in Vienna. The export quotation price for the same grade for a 1000 tons/year has been stable for the past years at around DM 2000/ton /USD 1000/ton/ FCO Furth/Germany. Red and yellow grades are sold at within 10 % of this price, black is about 35 % cheaper. An operator of Ruthner spray-roasting equipment in W-Germany is obtaining between DM 500 and 800/ton iron oxide /USD .25 - .50/kg/, which however requires further conditioning when used as a pigment.

5.3. Revenue from iron oxide sales

To estimate the revenue from iron oxide sales it is assumed that iron oxide produced in the bauxite beneficiation plant will be processed to pigment grade using a proprietary technology. Considering the fine granulometry of the spray roasted iron oxide, this is best done within the plant. For simplicity's sake, one grade only is considered, although it should be possible to produce different shades of brown and possibly red.

Table 5/1 shows the revenues for various plant sizes based on the assumption that the total amount is sold at one price. Quantities used in this table have been taken from the material balance in Section 6.1. and from similar balances not appearing in the Report. In order to make a sensitivity analysis possible, a price range has been used. This is centered on Drs 21/kg /USD .15/kg/, and covers the Drs 14 /USD .10/ to Drs 28 /USD .20/ range. The low price is proposed to attract sufficient interest for the product and to leave room for cost of promotion and distribution.

Table 3/1

Revenue from iron oxide pigment sales

/in million Drs/

Bauxite feed grade / Plant size /in '000 tons/ / Revenue	85				83
	20	40	60	80	40
Pigment produced /'000 tons solids/	5.5	10.95	16.4	21.9	5.7
1. at US$.10 /Drs 14/ per kg solids	77	153	230	307	80
2. at US$.20 /Drs 28/ per kg solids	154	306	460	617	160
3. When 700 t are sold in Greece and balance abroad /1/, at Drs 28 per kg solids	161	324	486	648	171

/1/ Export Subsidy: 6 %

6. Processes and Plant

In this chapter technical and technological information is given on the Tatabánya process and on a plant with an annual output of 40.000 tons of calcined refractory grade bauxite, based on the use of the same raw material as in the pilot plant test. Estimated material flows and balances appear also for the high grade raw material /83/ known from earlier testing for the sake of comparison as well as to make the financial and business evaluation in subsequent parts of this Report possible.

Using the findings from laboratory and pilot plant tests, detailed information is provided on the material flows of the plant, on the individual processes and technological steps including pollution control and environmental protection measures. Basic engineering data is presented for the equipment and machinery needed. Location criteria are reviewed briefly and a layout is proposed.

Data from this chapter together with data on other plant variants generated similarly is used in subsequent part of this Report for purposes of financial and economic evaluation.

6.1. Material balances

Material balances for the medium grade raw material are based on the analysis appearing in Column 3 of Table 2/5 for the feed, in Column 2 of Table 2/7 for the bauxite product and in Table 2/10 for the iron oxide product.

The relevant chemical reactions taking place in the leaching step are as follows:

$Al_2O_3 + 6\ HCl$	$2\ AlCl_3 + 3\ H_2O$
$Fe_2O_3 + 6\ HCl$	$2\ FeCl_3 + 3\ H_2O$
$TiO_2 + 4\ HCl$	$TiCl_4 + 2\ H_2O$
$CaO + 2\ HCl$	$CaCl_2 + H_2O$
$MgO + 2\ HCl$	$MgCl_2 + H_2O$

Tables 6.1 and 6.2 show the distribution of the various elements of the medium-grade and high grade bauxite feeds between the 'white' bauxite product and the iron oxide product, indicating also the yields of the above chemical reactions for the medium grade material. Results for the high material are for orientation only.

The full material balance based on the pilot scale test of the medium grade material appears in Table 6/3.

A Shanky diagram of material flows connected with bauxite appear in Table 6/4.

In Figure 6/1 material flows for medium grade /85/ raw material are presented in a block diagram.

Table 6/1

Distribution of elements of the medium grade feed between the products

	Elements in the feed /1/		Elements in the calcined bauxite /2/		Dissolved		Elements in the iron oxide product	
	%	ton	%	ton	ton	%	ton	%
Al_2O_3	54.0	36,616	89.51	33,804	812	2.2	597 /4/	5.1
Fe_2O_3	17.8	12,070	2.53	1,012	11,058	91.6	11,058	94.1
SiO_2	2.0	1,356	3.37	1,348	8	0.6	8	0.07
TiO_2	2.3	1,560	3.68	1,472	88	5.6	88	0.7
CaO	2.9	1,966	0.1	40	1,926	98.0	- /4/	-
MgO	1.9	1,288	0.2	80	1,208	93.8	- /4/	-
K_2O+Na_2O	0.1	68	0.12	48	20	29.4	- /4/	-
moisture	4.9	3,523	-	-	3,323 /3/	-	-	-
loss on ign.	14.1	9,561	0.49	196	9,365 /3/	-	-	-
Total	100,0	67,808	100,0	40,000	27,808	-	11,751	99.97

Notes: /1/ Taken from Table 2/5 Column 3 and adjusted for 4.9 % moisture

/2/ Taken from an Analysis by Surveillance, Athens

/3/ Evaporates during drying and calcination

/4/ Missing material discharged as waste gas or effluent

Table 6/2

Distribution of the elements of the high grade feed between the products

	Elements /1/ in the feed		Elements in the /2/ calcined bauxite		Elements in the iron oxide product	
	%	ton	%	ton	%	ton
Al_2O_3	65.78	38,024	91.82	36,673	11.8	712 /4/
Fe_2O_3	9.25	5,345	0.86	343	83.3	5,002
SiO_2	2.67	1,543	3.86	1,538	0.1	5
TiO_2	2.76	1,593	3.28	1,310	[illegible].8	288
CaO+MgO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	- /4/
Na_2+K_2O	0.125	72	0.13	52	-	- /4/
moisture /3/	4.91	2.839	-	-	-	-
loss on ign. /3/	13.45	7.775	-	-	-	-
Total	99,995	57,802	100,16	40,000	100.0	6,007

Notes: /1/ Taken from Table 2/1, Column 1 and adjusted for 4.9 % moisture

/2/ Taken from Table 2/1, Column 2

/3/ and /4/ see Table 6/1

Table 9/3

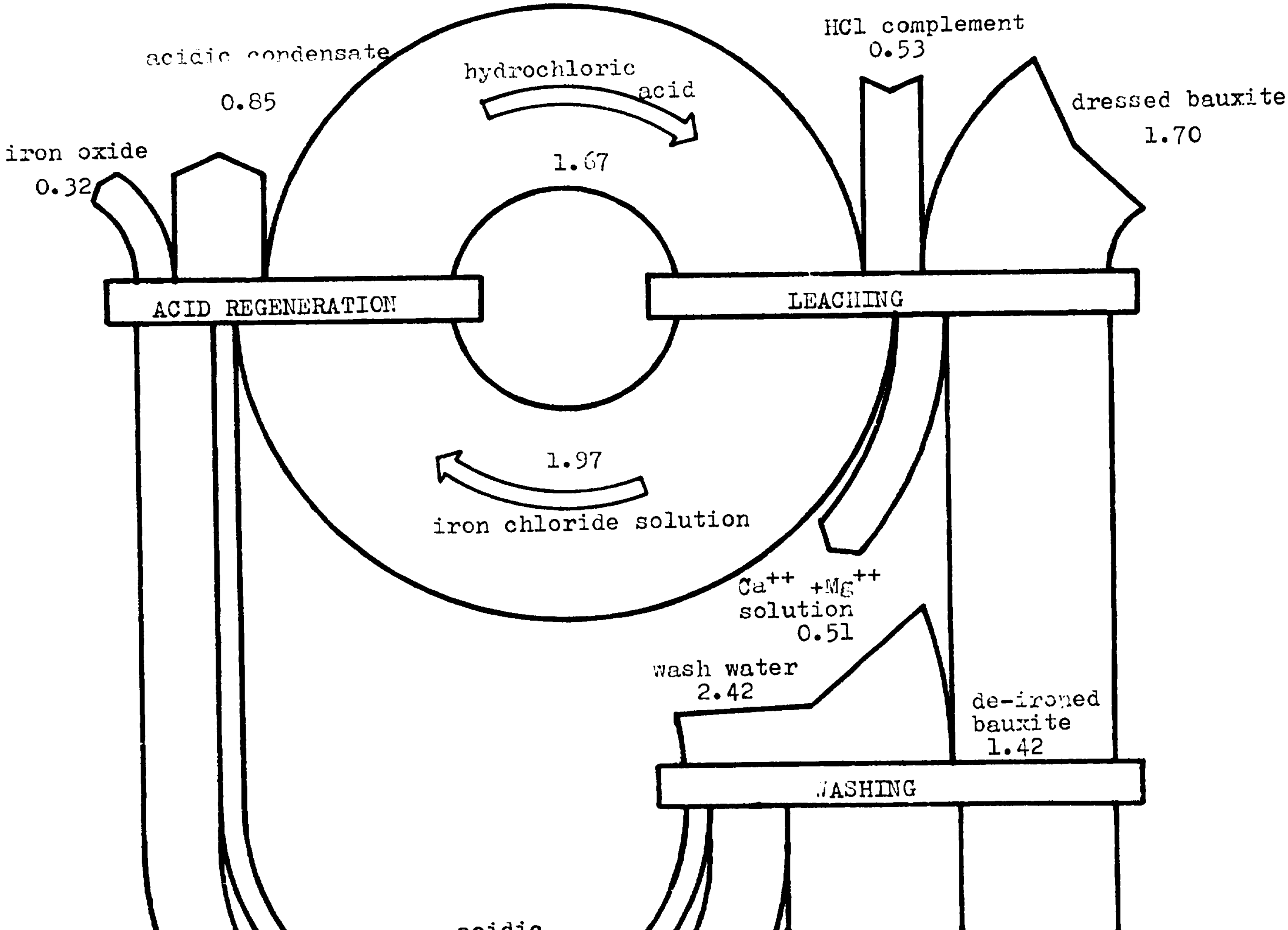
Material balances of a 40,000 ton plant to process medium grade /85/ bauxite

	Quantity m^3/yr.	Quantity t/yr.	Specific weight t/m^3	Remarks
Leaching				
In: Bauxite	46,128	67,808	1.47	5 % moistur
Hydrochloric acid	76,737	88,247	1.15	330 g/l HCl
Out: Iron chloride liquor	59,343	86,641	1.46	130 g/l Fe
De-ironed bauxite	34,002	56,783	1.67	20 % moistu
Calcium + Magnesium solution	15,396	20,631	1.34	
Washing				
In: De-ironed bauxite	34,002	56,783	1.67	20% moisture
Process water	96,582	96,582	1.00	
Out: 'White' bauxite	33,948	55,675	1.64	
Acidic wash water I.	6,823	7,232	1.06	150 g/l HCl
Acidic wash water II.	27,371	27,918	1.02	50 g/l HCl
Acidic wash water III.	61,921	62,540	1.01	1 g/l HCl
Acid regeneration				
In: Iron chloride liquor	53,864	78,641	1.46	130 g/l HCl
Acidic wash water I.	6,823	7,232	1.06	150 g/l HCl
Acidic wash water II.	27,371	27,918	1.02	50 g/l HCl
Process water	39,500	33,500	1.00	
Cooling water	1,676,500	1,676,500	1.00	
Fuel oil	2,700	2.500	0.93	Caloric value 41 MJ/t
Steam	-	29,500		160 °C, saturated

Table 6/3 /Cont'd/

	Quantity m^3/yr.	Quantity t/yr.	Specific weight t/m3	Remarks
Out: Iron oxide	27,136	12,754	0.47	
Spent cooling water	1,676,500	1,676,500	1.00	
Flue gas	5[illegible],000	-		'000 Nm^3/year
HCl	58,108	66,824	1.15	330 g/l HCl
Thin acidic liquor	33,080	33,742	1.02	6.8 g/l HCl
Condensation water	29,500	29,500	1.00	
Acidic condensate	33,160	33.823	1.02	6.8 g/l HCl
Calcination				
In: White bauxite	33,338	55,675	1.67	20 % moisture
Fuel oil	5,700	5,300	0.93	Caloric value: 41 MJ/t
Slaked lime	250	374	1.50	
Water for flue gas scrubber	187,000	187,000	1.00	
Out: Calcined bauxite	26 316	40,000	1.52	
Flue gas	136 000	-		'000 Nm^3/year
Waste liquor from flue gas scrubber	157.376	158,950	1.01	
Production of iron oxide pi nt				
In: Iron oxide	27,136	12,754	0.47	
Process water	318,850	318,850	1.00	
Slaked lime	17	25	1.50	
Additive	40	48	1.20	
Out: Iron oxide slurry	18 333	22,000	1.20	50 % water
Spent wash water	294 930	309,677	1.05	

SECTION 1



acidic condensate
0.85
hydrochloric acid
1.67
HCl complement
0.53
dressed bauxite
1.70
iron oxide
0.32
ACID REGENERATION
LEACHING
1.97
iron chloride solution
Ca++ +Mg++
solution
0.51
wash water
2.42
de-ironed
bauxite
1.42
WASHING
acidic

SECTION 2

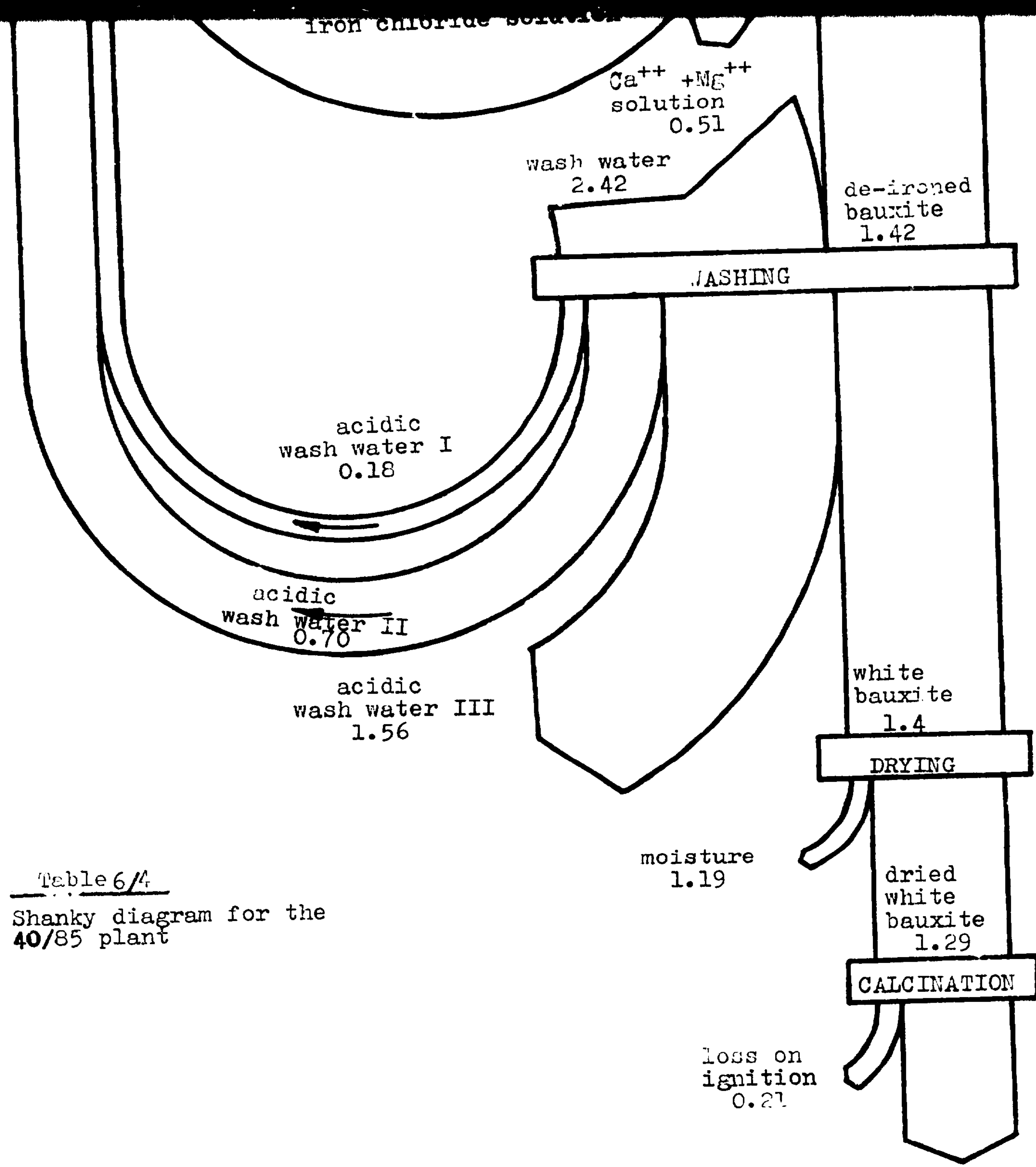
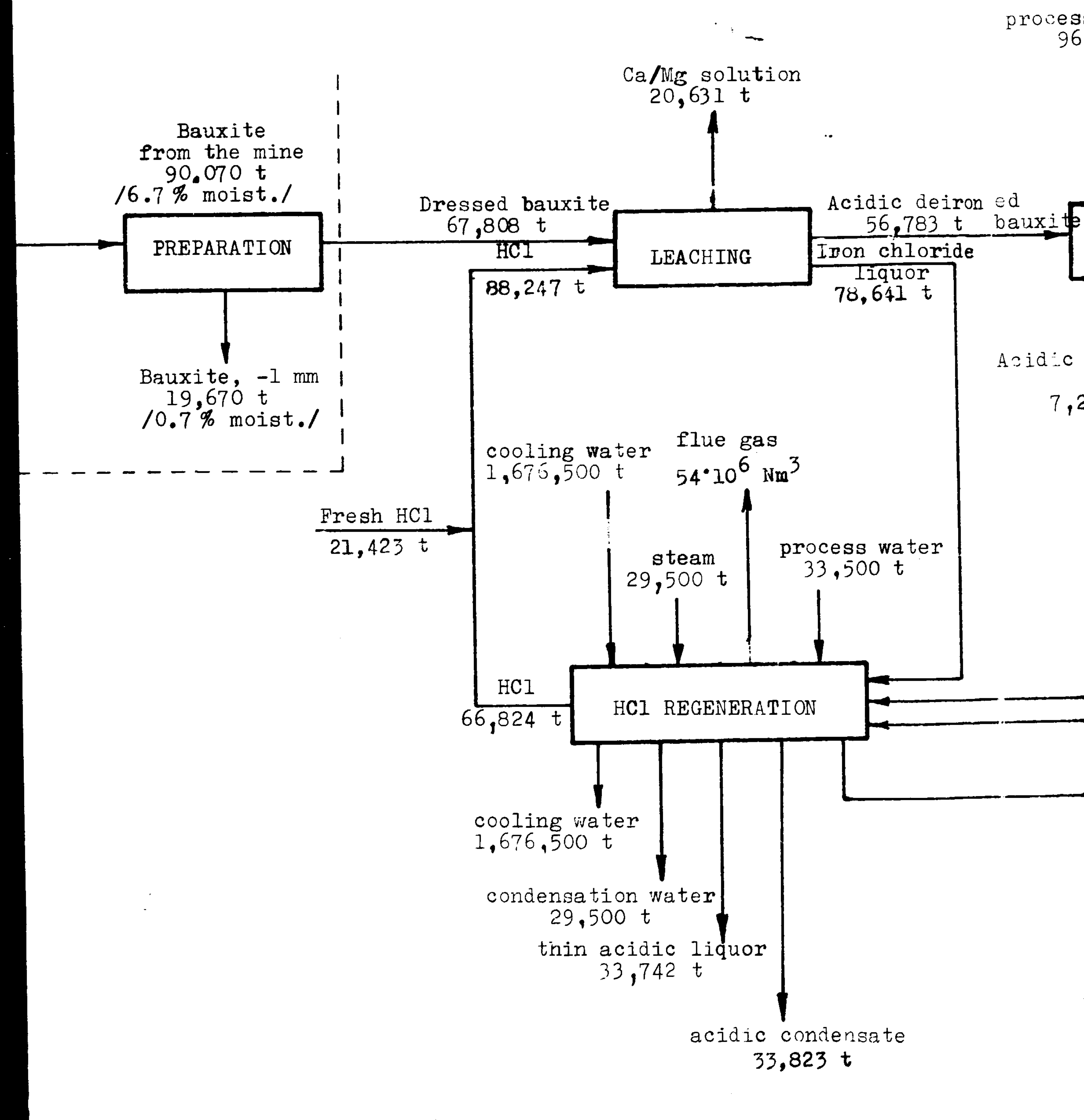


Table 6/4

Shanky diagram for the 40/85 plant


proces
96
Ca/Mg solution
20,631 t
Bauxite
from the mine
90.070 t
/6.7 % moist./
Dressed bauxite
67,808 t
HCl
88,247 t
PREPARATION
LEACHING
Acidic deiron ed
56,783 t
bauxite
Iron chloride
liquor
78,641 t
Bauxite, -1 mm
19,670 t
/0.7 % moist./
Acidic
7,2
cooling water
1,676,500 t
flue gas
$54 \cdot 10^6$ Nm^3
Fresh HCl
21,423 t
steam
29,500 t
process water
33,500 t
HCl
66,824 t
HCl REGENERATION
cooling water
1,676,500 t
condensation water
29,500 t
thin acidic liquor
33,742 t
acidic condensate
33,823 t

SECTION 1

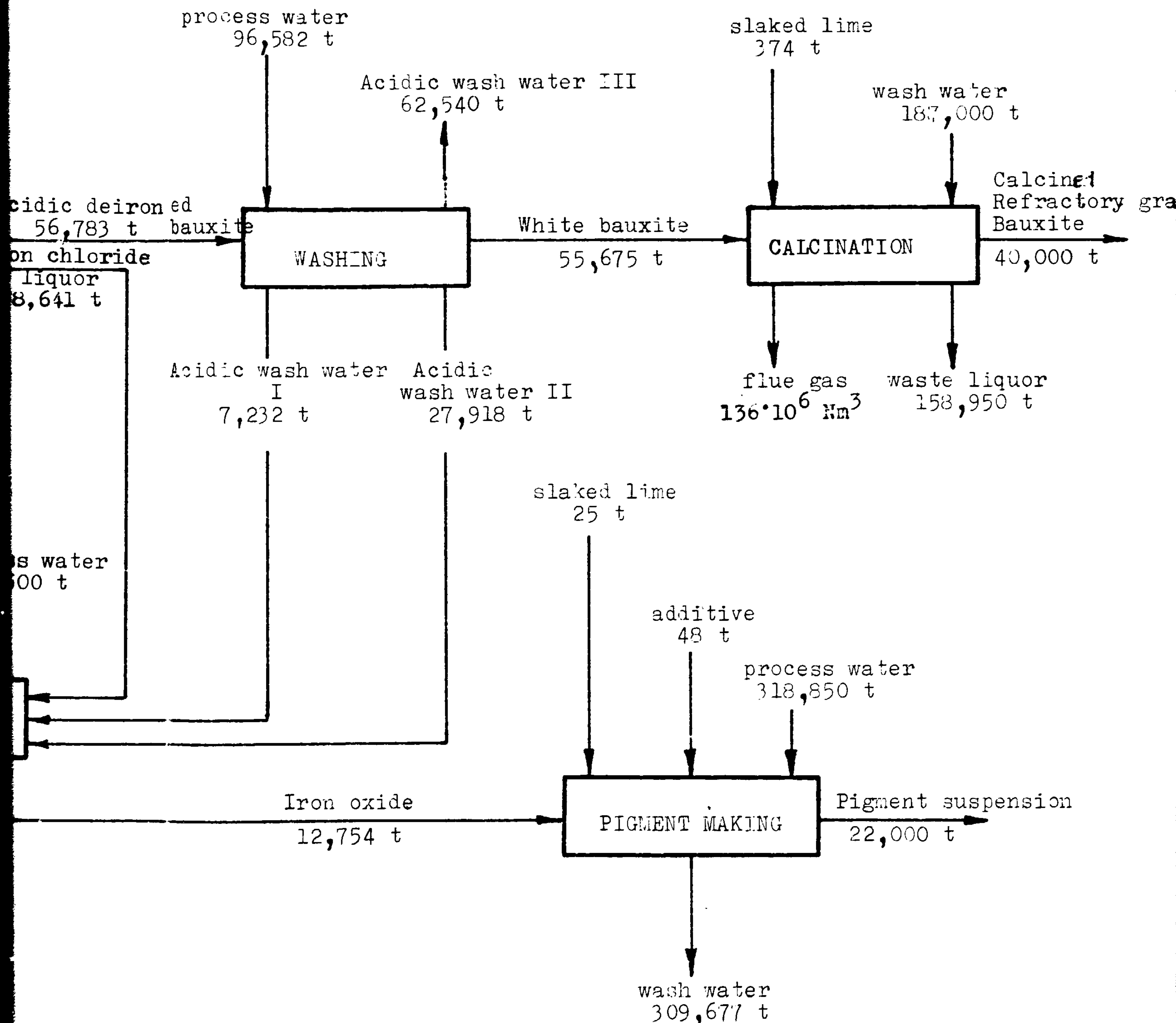


Figure 6/1

Block schematic with
material flows
/Plant size: 40.000 tons/yr/
Feed grade: '85'

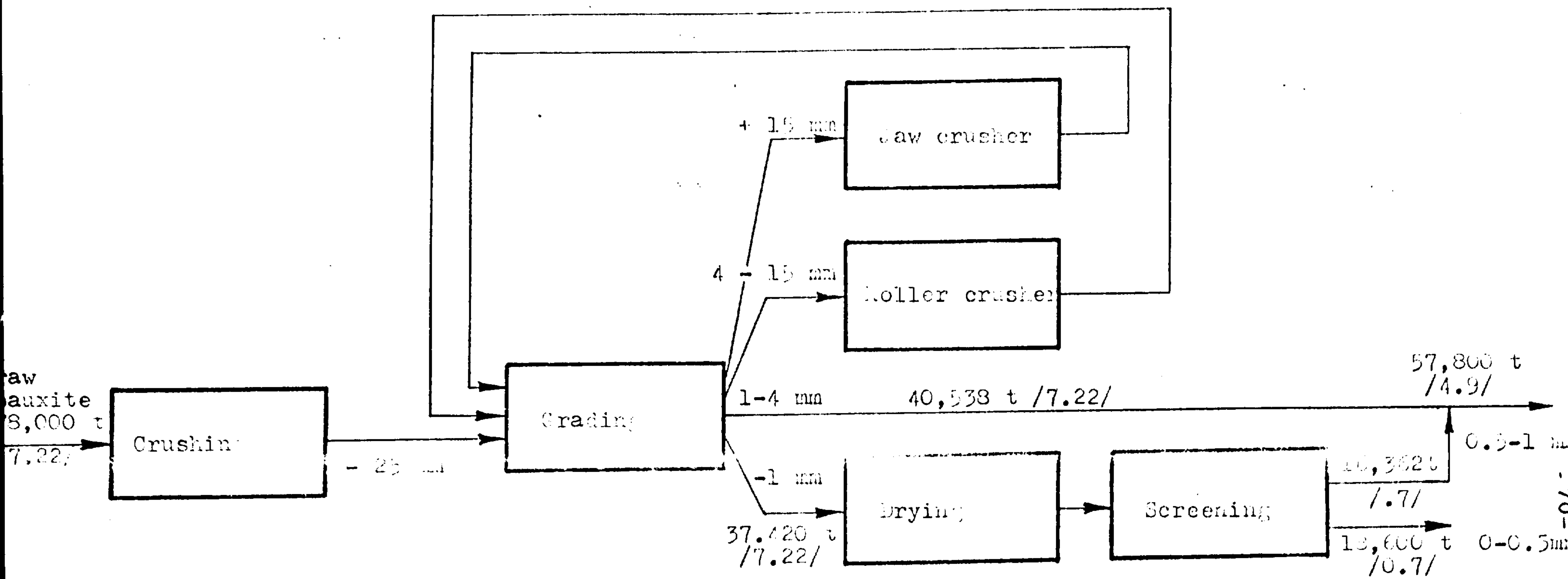
SECTION 2

6.2. Processes

6.2.1 Ore preparation

Crushing and screening tests of the medium grade bauxite are outside the Terms of Reference for this project as it was felt that the mines asked to supply the raw material would deliver the required grain size. It appeared, however, that feed for the plant will have to be purchased from a number of mines, possibly 3 or 4. These will be able to supply a consistent grain size bauxite, though this may differ from mine to mine.

If this situation prevails in the future, a dressing facility has to be provided at the bauxite processing plant. Incoming material has to be stored /estimated storage requirement is 75 days' supply i.e. some 15,000 tons bauxite/, crushed, graded, ground, dried, screened, possibly blended and stored. Figure 6/2 shows a flowsheet developped for the high grade /83/ raw material based on the limited information available on this material. The dressing unit is laid out for 78,000 tons bauxite of as-mined grade /moisture content: 7.22 %/. Apart from the production of 57,800 tons bauxite suitable for processing in the leaching stage, some 18,000 tons of fines /-0.5 mm/ is produced /moisture content: 0.7 %/.



Note: Figures in parenthesis indicate moisture content

Figure 6/2

Material flows for preparation of bauxite for
a 40,000 ton plant using high grade /S3/ feedstock

6.2.2 Leaching/Washing

Bauxite having suitable grain size is treated with concentrated hydrochloric acid. Columns are filled with bauxite and the acid is slowly flowing through the fill.

The acid cycle /see Figure 3/ is carried out in four columns numbered by 1, 2, 3 and 4. Let's assume that column 1 is empty and ready for filling, column 2 is fed with acid, column 3 receives the solution leaving column 2 and column 4 delivers the solution to the collecting tank of the hydrochloric acid regenerator:

After a certain time, when the ion concentration of the solution leaving column 4 begins to decrease and reaches a determined limit value /1[illegible]0-120 g/l Fe/, the cycle is stepped forward. The solution of column 4 is delivered to the previously filled or just being filled column 1. Column 2 is disconnected from the acid, rinsing is started in it. The other columns are also stepped up. In column 1, after saturation with solution, the so-called "calcium/ /magnesium solution" appears which is neutralized. After decomposition of the carbonates, Fe^{3+} concentration increases in the solution leaving column 1 and at a given concentration the solution is switched over towards the pyroliser. 10 days after the start of charging, the Fe^{3+} content in the solution begins to decrease and the cycle is stepped up again. Column 3 is rinsed, column 2 is charged. In this sequence column 1 is being charged again on the 40th day.

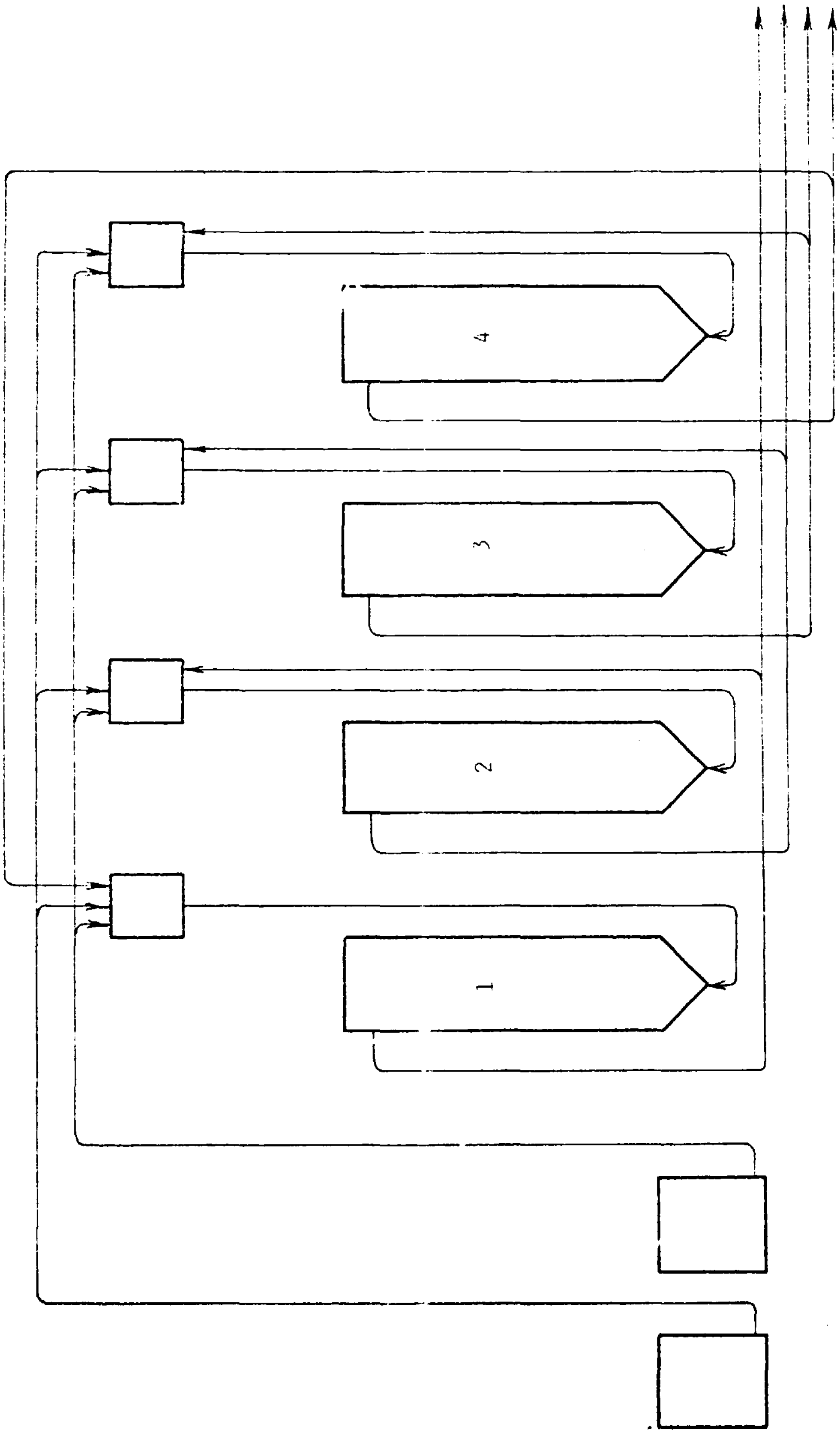


Figure 6/3
Schematic for leaching

The line diagram of above cycle is shown below. The abbreviations used mean /in chronological order of operations/:

A = rinsing + bauxite removal

B = filling + draining the calcium/magnesium solution + production of iron chloride solution for the pyrolizer

C = leaching, phase two

D = leaching, phase three

Column number	Operations						
1	B	C	D	A	B	C	
2	A	B	C	D	A	B	
3	D	A	B	C	D	A	
4	C	D	A	B	C	D	
	0	10	20	30	40	50	60 /days/

Phase "A" comprises the following steps:

- draining the acid from the bauxite; 12 hours
- rinsing with water; 192 hours
- draining with wash water; 8 hours
- removing the bauxite; 28 hours

The time required for phase "B" is as follows:

- charging: filling the column voids in the bauxite fill of the iron chloride solution; 60 hours
- draining the calcium/magnesium solution; 25 hours
- iron chloride solution to the pyrolizer, 155 hours

The bauxite is filled into 24 steel tanks of 4.40 m diameter, 9 m high, having acid resistant rubber lining, arranged in two double rows. These columns are filled from above, by a conveyor track moving on a discharge car. This equipment should be laid out to transport 10 tons/hour of the bauxite to permit the continuous filling of a column within the 10 days' cycle in each of the six leaching units. After filling the tanks are closed with a cover preventing the escape of acid fumes. Figure 6/4 shows the sectional view of the leaching unit.

During leaching 1098 l/hour of 30 % HCl should flow through the bauxite charge. A definite hydrostatic pressure must be provided for this purpose at the bottom of the bauxite charge. From the pilot plant experiences, this can be achieved by placing the feed tank 5 m higher than the upper level of the bauxite charge. The leached and thoroughly rinsed white bauxite is removed through large openings at the bottom of the column. The bauxite is fed on to a conveyor which in turn forwards it to a covered up area, where the water is allowed to drain.

6.2.3 Calcination

In accordance with the requirements of the tunnel kiln used for calcination the bauxite is pressed into bricks. The crude white bauxite should have 5 - 7 % moisture for this operation. Therefore, it must be dried before pressing. Moist white bauxite spread in a layer of 30 cm thickness will dry to a sufficient extent within 7 - 9 days without forced drying. The dry

1 Leaching column
2 Trolley hoist
3 Conveyor belt
4 Discharging screw
5 Conveyor belt with cars

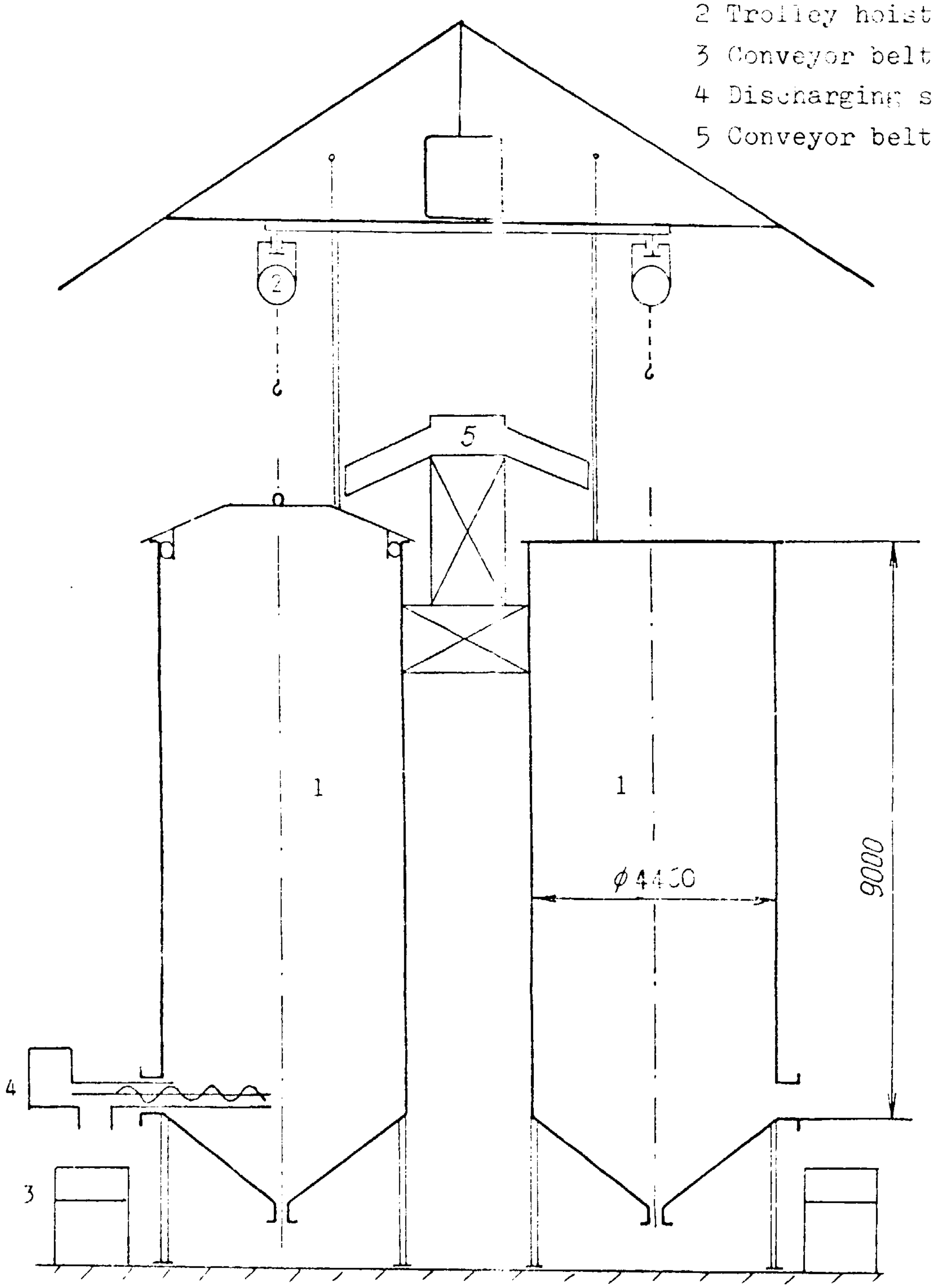


Figure 6/4
Sectional view of the leaching plant

white bauxite is charged onto a rubber conveyor belt transporting it to the hopper of the press.

The bricks from the press are placed by an automatic charger onto the kiln trolleys. 9.5 tons of brick may be loaded on each 2.5 x 2.5 m trolley. Before calcination, the moisture content of the bricks must be reduced; the loaded kiln trolleys spend 48 hours at 80 - 110 °C in the drying tunnel. Next the cars pass into the tunnel kiln for calcination.

After calcination the bricks discharged from the trolleys are crushed and screened as required.

The medium grade /85/ bauxite is expected to yield relatively little fines, due to its mechanical properties. A jaw crusher can be used to break it to -40 mm. In a further crushing stage, -10 mm material is produced. Roller crushers and a 2-level vibration screen can be used to produce various grain sizes, such as the one most in demand: 1-3 mm as well as 0.5 - 1.6 mm, 1-3 mm, 3-6 mm, etc.

6.2.4 Hydrochloric acid regeneration

During the 240 hours' leaching cycle, a high $FeCl_3$ solution /130-140 g/l Fe^{3+}/ may be drawn off from the freshly charged bauxite for approx. 155 hours and delivered for regeneration to the pyrolysis type acid regeneration unit. For a continuous operation of the pyrolizer 600 m^3 solution has to be stored. During the storage the solid particles floating in the iron chloride solution will settle and can be removed.

Apart from the iron chloride liquor two effluents from the washing operations are also recycled through the pyrolizer and their HCl content is also recovered.

The regenerated acid from the pyrolizer is fed into a buffer tank, where fresh acid is added to compensate for losses.

6.2.5 Production of iron oxide pigment

The method used in the pilot plant test to upgrade the iron oxide powder produced in hydrochloric acid regeneration an ion exchange procedure has been found to require much equipment in comparison with the possible benefit and produced a high amount of waste solutions with high salt content.

Therefore an alternative process is considered to remove the contaminants from the iron oxide powder and condition it for use as a pigment with good coloring properties. The iron oxide powder leaving the pyrolizer is mixed in a tank with agitator with water and a lime milk solution according to its chloride content. The slurry is pumped into a tank with conical bottom for settling. The thick part is separated from most of the liquid on a vacuum filter. The retained iron oxide is again mixed with water in the tank with agitator. The slurry is settled and filtered. Washing with water is repeated. The washing efficiency is increased by sprinkling wash water onto the filter during filtering.

The required particle size of the iron oxide pigment is obtained by wet grinding. A slurry with 50 % iron oxide content is prepared from the filtered iron oxide and the additives for adjusting the quality parameters of the end product are blended into this. Two ball mills connected in series are used for fine grinding. The pigment slurry is stored in tanks with agitators. The product can be delivered in plastic drums, or plastic containers, etc.

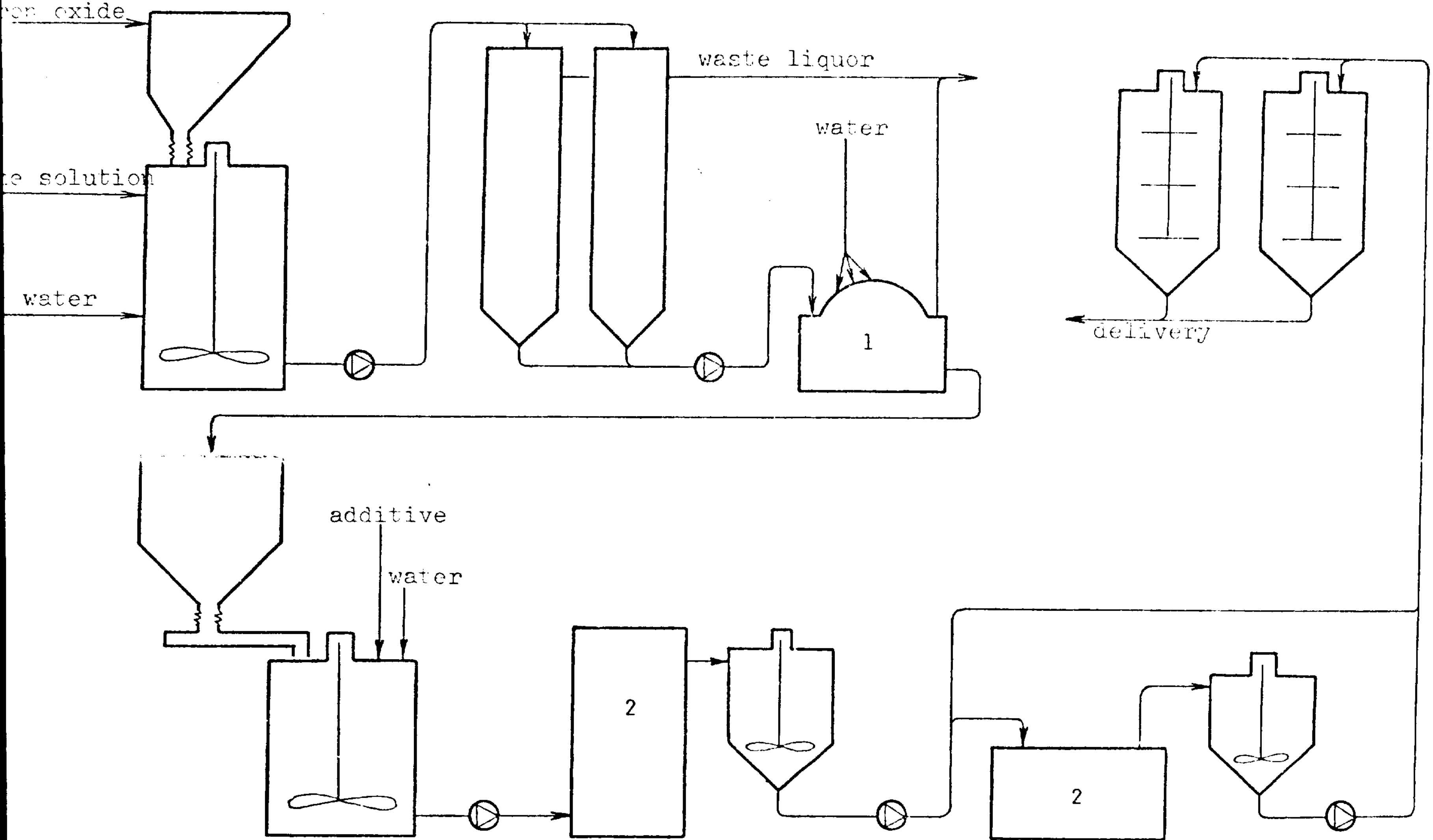
Figure 6/5 shows the tentative flow-sheet of iron oxide purification and pigment production.

6.2.6 Process and cooling water treatment

The two large water consumers are the hydrochloric acid regenerator and the iron oxide purifier. If through flow type cooling is used, cooling water used in the pyrolizer can be used for rinsing the iron oxide. The following requirement is to be made on the cooling water in this case:

- content of solids	max. 5 mg/l
- pH value	7-8
- carbonate hardness	max. 17 German degree
- $KMnO_4$ consumption	4,5 mg/l
- temperature	max. 22 °C
- free CO_2	not permitted

Water treatment is determined by the quality characteristics of the available sweet water. As a site for the plant has not yet been selected, it is assumed that sufficient volume



1 = Vacuum drum filter
2 = Ball mill

Figure 6/5
Iron oxide processing

of water with the required temperature and quality will be available at the plant site, so water treatment procedure is restricted to storage, aeration and filtering through sand filters.

4.2.7 Environment protection

The Tatabánya process is aimed at the complex utilisation of the bauxite ore, more than 70 % of non-water weight of the feed turned into products for sale. Hydrochloric acid used in the bauxite beneficiation plant is recirculated and re-used. The bulk of balance leaves the plant together with the hydrochloric acid losses and the oxidation products from the fuel.

a/ Liquid wastes

About 8.3 m^3 waste water is produced in the plant for each ton of raw bauxite. This is collected and treated as shown in Figure 4/6.

The actual quantities of liquid waste are shown in Figure 4/7. Spent cooling water from the pyrolizer with a temperature of approximately 40 °C is used as process water for the other units and the remaining 60 % is used to dilute the effluent obtained after approximately 4,000 tons of sludge is separated from it.

... water in from:

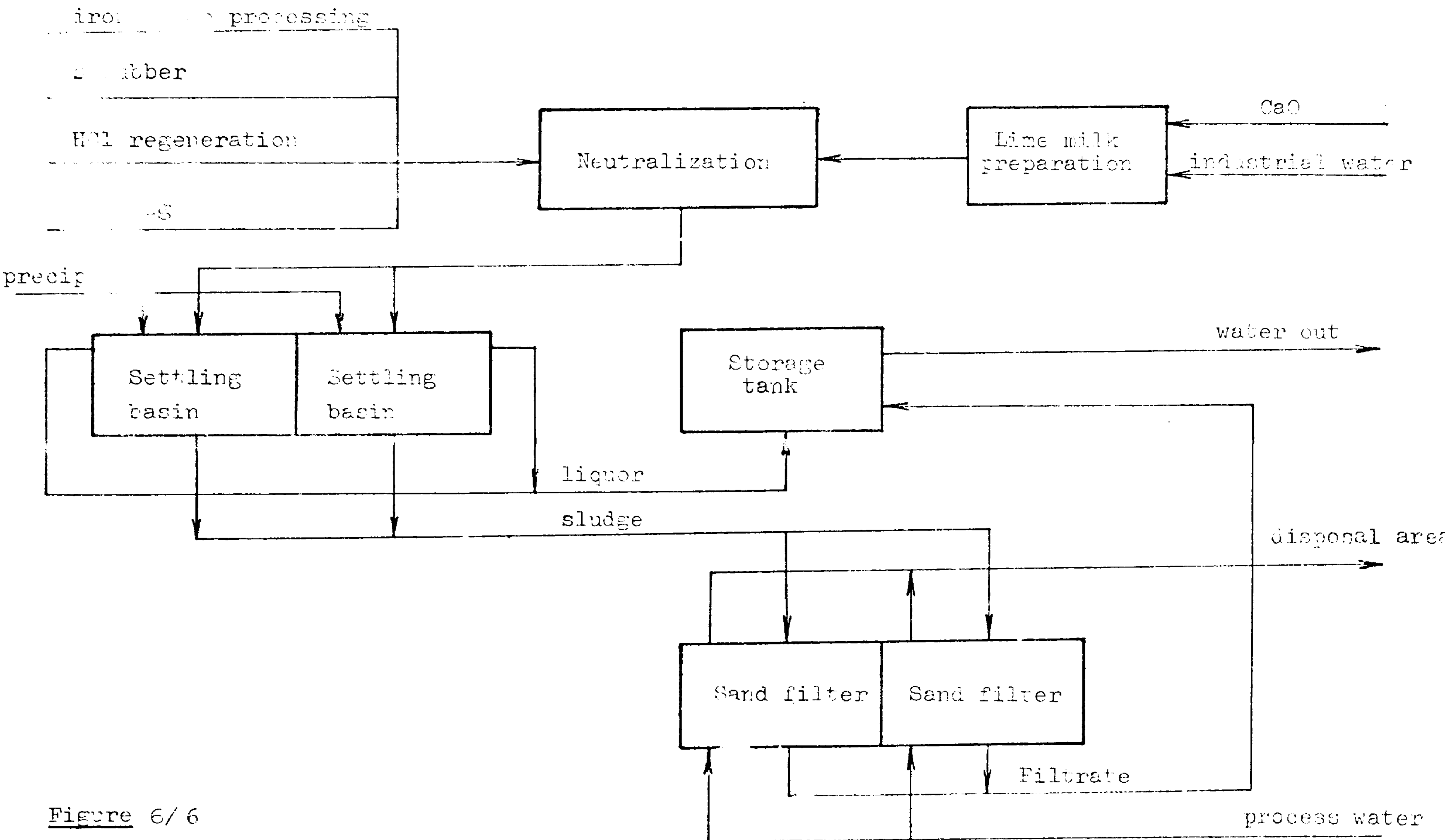


Figure 6/ 6
Waste water treatment

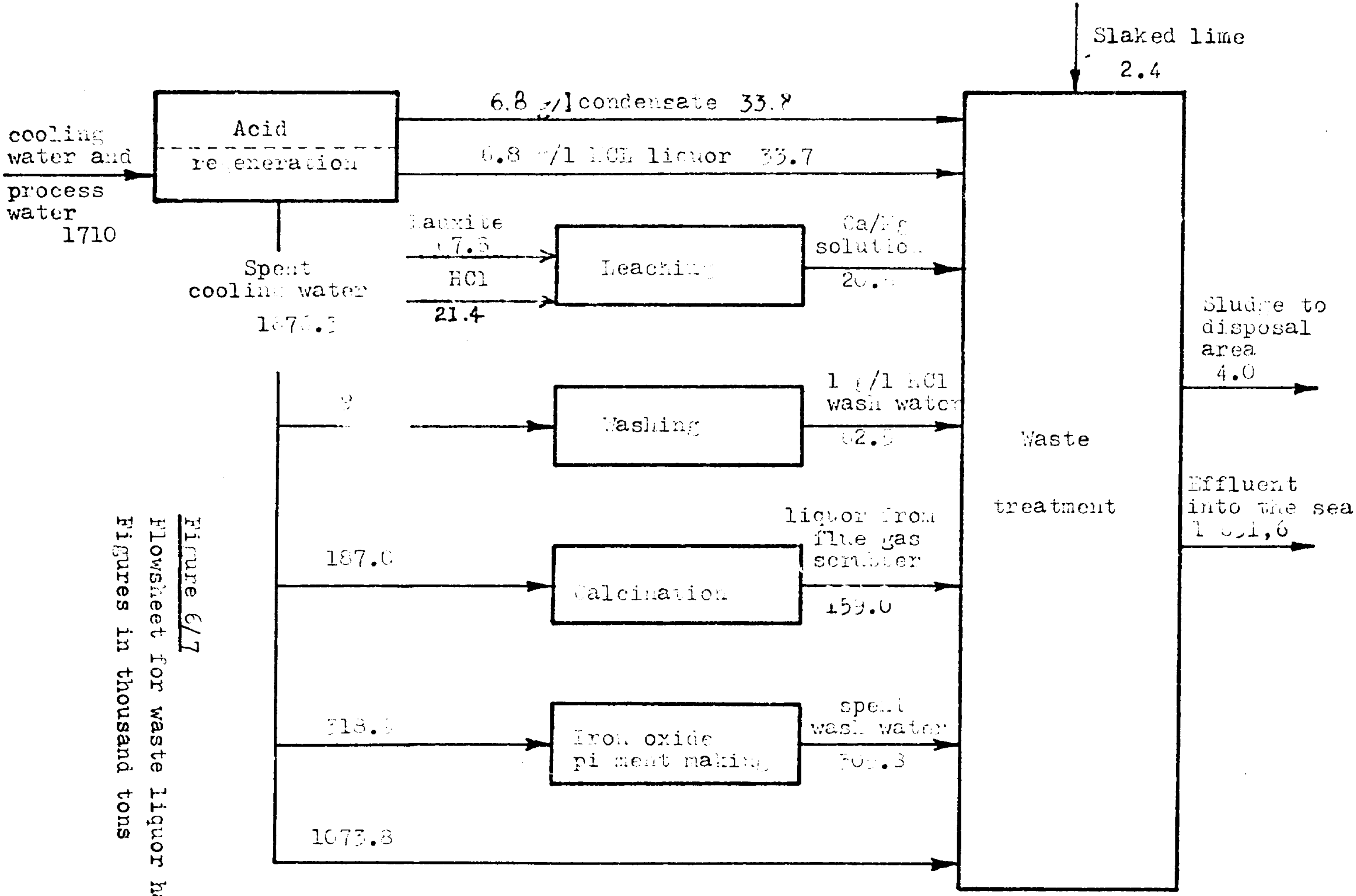


Figure 6/7
Flowsheet for waste liquor handling
Figures in thousand tons

The sludge is expected to have the following main components:

$Al(OH)_3$:	8 %
$CaSO_4 \cdot 2H_2O$:	28 %
Iron oxide powder:	19 %
Water:	45 %

The salt content of technological origin in the waste water emitted from the plant is estimated not to exceed

$CaCl_2$	0.21 %
$MgCl_2$	0.17 %
NaCl+KCl	0.005 %

b/ <u>Flue gases, Fumes</u>

The sources of flue gas in the plant are the pyrolizer, the funnel kiln, and the steam generator.

The pyrolizer should be fitted with a dust removal unit to catch iron oxide dust. All flue gases should go through a wet scrubber.

Table 6/5 shows the estimated parameters of the flue gases emitted from the plant.

Table 6/5

Flue gas parameter

Parameter	Unit	Pyrolizer	Kiln + Steam generator
Temperature	°C	approx. 70	approx. 70
HCl content	mg/m^3	max. 100	-
SO_2 content	mg/m^3	-	max. 50
Solids content	mg/m^3	max. 100	max. 100
Quantity	Nm^3/ton of raw bauxite	800	2,000

6.2.8 Fuel oil storage

As natural gas is not available for industrial purposes in the part of Greece in question, fuel oil will have to be used for operating the hydrochloric acid regeneration equipment, the tunnel kiln and the steam generator. It is proposed that 8 % of the annual fuel requirement of 10,670 tons, i.e. about 850 tons fuel is stored in tanks at the plant.

6.2.9 Tank park

The tank park serves for the storage and the buffering of material circulation among the different solutions, fresh HCl, regenerated HCl, etc.

6.2.10 Winter operation

At temperatures below 15 °C, bauxite treatment does not provide satisfactory results. For continuous production, a temperature above this minimum must be provided in the leaching columns. In the winter season if leaching columns without heat insulation are to be used the solutions fed into it should have a minimum temperature of 25-30 °C. Graphite heat exchangers can be connected to each column to increase the temperature of the particular solutions.

6.3. Equipment list

A tentative list of the major pieces of equipment for a plant with a production capacity of 40,000 t per year and its technical features are given in the Table 6/6. A more detailed and accurate equipment list can be produced as a result of the detail engineering documentation of the plant.

Letter symbols in the "Number of units" column have the following meaning:

A = No. of installed units
B = No. of functioning units
C = No. of stand-by units.

Unalloyed structural steel is suitable for cooling water, steam and fuel oil pipes. Hard PE pipes are proposed for hydrochloric acid, iron chloride and waste solutions. Special piping material necessary for the high temperature operation of the pyrolizer is assumed to be supplied by the Contractor delivering the pyrolizer unit.

Table 6/6 page i

Equipment list of 40.000 ton plant

Technological step	Serial no.	Name of unit	Technical data	Number of unit A	B	C
1. Leaching, washing	1.	Front charger	Spoon size: 1 m^3	-	1	1
	2.	Charging conveyor	W = 600 mm, L = 35 mm	2	2	-
	3.	Conveyor with discharging car	W = 600 mm L = 65 mm	2	2	-
	4.	Acid treatment column	Steel tank with acid-resistant rubber coating dia. 4.46 x 9 m	24	24	-
	5.	Overflow tank	Polyethylene tank dia. 0.[illegible] x 9 m	24	24	-
	6.	Iron chloride collector tank	Steel tank with acid-resistant rubber lining dia. 6.3 x 5 m	4	4	-
	7.	Waste acid tank	Steel tank with acid-resistant rubber lining dia. 6.3 x 5 m	2	2	-
	8.	Dilute acid tank	Steel tank with acid-resistant rubber lining dia. 6.3 x [illegible] m	4	4	-

Table 6/6 page ii

Equipment list of 40.000 ton plant

Technological step	Serial no.	Name of unit	Technical data	Number of unit A	B	C
	9.	Hydrochloric acid tank	Steel tank with acid-resistant rubber lining dia. 6.5 x 5 m	1	1	-
	10.	Water tank	Steel tank dia. 4 x 4 m	1	1	-
	11.	Feed tank	Polyethylene tank $V = 2\ m^3$	48	48	-
	12.	Underground shaft tank	Steel tank with acid-resistant rubber lining and agitator, dia. 2 x 2 m	3	3	-
	13.	Shaft pump	Acid resistant Q = 12 m3/hour H = 16 m	5	3	2
	14.	Transfer pump	Acid resistant Q = 1 m3/hour H = 24 m	52	48	4
	15.	HCl pump	Acid resistant Q = 10 m3/hour H = 24 m	2	1	1
	16.	Iron chloride pump	Acid resistant Q = 10 m3/hour H = 24 m	2	1	1

Equipment list of 40.000 ton plant

Technological step	Serial no.	Name of unit	Technical data	Number of unit A	B	C
	17.	Waste liquor pump	Acid resistant Q = 12 m3/hour H = 16 m	1	1	-
	18.	Diluted HCl pump	Acid resistant Q = 12 m3/hour H = 16 m	1	1	-
	19.	Water pump	Q = 10 m3/hour H = 24 m	1	1	-
	20.	Discharging screw	With gear & motor cty: 6 t/hour dia. 250 x 5.000 m	4	4	-
	21.	Trolley hoist	Electrical operation manual operation for 1 t load	4	4	-
	22.	White bauxite discharge conveyor	W = 600 mm L = 70 m	4	4	-
	23.	White bauxite collecting conveyor	W = 800 mm L = 20 m	1	1	-
	24.	Conveyor	W = 800 mm L = 35 m	1	1	-
	25.	Covered storage yard	Area: 2.200 m2	1	1	

Table 6/6 page iv

Equipment list of 40.000 ton plant

Technological step	Serial no.	Name of unit	Technical data	Number of unit A	B	C
2. Calcination	1.	Front charger	Scoop size: 2 m^3	1	1	-
	2.	Charging conveyor	W = 600 mm	1	1	-
	3.	Storage bunker /for the press/	V = 10 m^3	1	1	-
	4.	Brick press	Hydraulic operation Cty.: 6 t/hour	1	1	-
	5.	Car charging equipment	Mechanically operated cty.: 6 t/hour	1	1	-
	6.	Drying tunnel	L = 70 m	1	1	-
	7.	Furnace car transfer device	15 cars/day	1	1	-
	8.	Tunnel kiln	Max. calcinining temp. = 1.700 °C, L = 140 m	1	1	-
	9.	Car discharging equipment	Mechanically operated	1	1	-
	10.	Chain scraper	L = 16 m Cty.: 6 t/hour	1	1	-
	11.	Jaw crusher	with air cooling, 10 t/hour max. lump size: 300 mm	1	1	-
	12.	Chain scraper	L = 10 m Cty.: 6 t/hour	1	1	-
	13.	Three-level screen	Screen dimensions: 2 mm, 5 mm, 15 mm	1	1	-

Table 6/6 page v

Equipment list of 40.000 ton plant

Technological step	Serial no.	Name of unit	Technical data	Number of units A	B	C
	14.	Conveyor	W = 600 mm, L = 5 m	2	2	-
	15.	Jaw crusher	Max. lump size: 80 mm Cty.: 6 t/hour	1	1	-
	16.	Gas scrubber	Cty.: 10.900 Nm^3/hour	1	1	-
	17.	Roll crusher	Max. lump size: 15 mm Cty.: 6 t/hour	1	1	-
	18.	Conveyor	W = 600 mm, L = 12 m	2	2	-
	19.	Front charger	Scoop size: 1 m^3	-	1	-
3. HCl regeneration	1.	Andritz-Ruthner iron chloride decomposition equipment	Cty.: 7.25 m^3/hour hydrochloric acid with with 330 g/l	1	1	-
	2.	Iron chloride settling tank	Steel, with conical bottom and acid-resistant rubber lining dia.: 2.5 x 10 m	3	3	-
	3.	Emergency water tank	Steel, dia.: 2 x 2 m	1	1	-
	4.	Iron chloride pump	Acid-resistant Q = 10 m3/hour H = 24 m	2	1	1

Table 6/6 page vi

Equipment list of 40.000 ton plant

Technological step	Serial no.	Name of unit	Technical data	Number of unit A	B	C
	5.	Slurry pump	Acid resistant Q = 12 m3/hour H = 16 m	1	1	-
	6.	Water pump	Q = 4 m3/hour H = 36 m	1	1	-
	7.	Iron oxide bunker	V = 50 m^3	1	1	-
4. Iron oxide pigment production	1.	Bucket charger	Cty.: 2 m^3/hour	1	1	-
	2.	Charging bunker with balance	V = 10 m^3, 5 t	1	1	-
	3.	Tank with agitator	Steel tank V = 75 m3	1	1	-
	4.	Slurry pump	Q = 40 m3/hour H = 24 m	1	1	-
	5.	Settling tank	Steel V = 40 m3/hour	2	2	-
	6.	Slurry pump	Q = 40 m3/hour H = 24 m	1	1	-
	7.	Vacuum drum filter	Cty.: 20 m3/hour iron oxide slurry	1	1	-
	8.	Discharging screw	Cty.: 2 t/hour moist iron oxide	1	1	-

Table 6/6 page vii

Equipment list of 40.000 ton plant

Technological step	Serial no.	Name of unit	Technical data	Number of unit A	B	C
	9.	Storage tank for filtered iron oxide	V = 8 m3	1	1	-
	10.	Charging scew with balance	Cty.: 6 t/hour	1	1	-
	11.	Tank with agitator	V = 10 m3	1	1	-
	12.	Slurry pump	Q = 10 m3/hour H - 16 m	1	1	-
	13.	Ball mill	Milling volume: 4.5 m3 Steel balls	1	1	-
	14.	Storage tank	Steel tank with agitator V = 10 m3	2	2	-
	15.	Ball mill	Milling volume: 2.2 m3	1	1	-
	16.	Slurry pump	Q = 12 m3/hour H = 24 m	2	2	-
	17.	Storage tank	Steel tank with agitator dia. 6.3 x 5 m	2	2	-
5. Neutralization of waste liquors	1.	Slaking tank	Steel, dia. 1.5x1.5 m	1	1	-
	2.	Discharge screw	Cty.: 200 kg/hour	1	1	-
	3.	Lime milk tank	V = 10 m3	1	1	-
	4.	Neutralizing tank	V = 25 m3	1	1	-
	5.	Settling basin	V = 200 m3	2	2	-

Table 6/6 page viii

Equipment list of 40.000 ton plant

Technological step	Serial no.	Name of unit	Technical data	Number of unit A	B	C
	6.	Flocculant tank	V = 5 m3	1	1	-
	7.	Slurry pump	Q = 2 m3/hour H = 12 m	2	2	-
	8.	Pump	Q = 50 m3/hour H = 24 m	2	1	1
6. Water treatment	1.	Collector basin with aerator	V = 1.000 m3	1	1	-
	2.	Water pump	Q = 250 m3/hour H = 55 m	2	1	1
	3.	Sand filter	P = m3/hour	2	2	-
	4.	Filter rinsing pump	Q = 25 m3/hour H = 36 m	1	1	-
7. Fuel oil storage	1.	Gear pump	Q = 380 l/minute p = 5 bar	2	1	1
	2.	Gear pump	Q = 16 l/minute p = 5 bar	2	1	1
	3.	Storage tank	Steel, V = 450 m3 dia.: 6.3 x 5 m	6	6	-
	4.	Oil filter	Q = 400 l/minute	2	1	1
	5.	Oil filter	Q = 20 l/minute	4	2	2

Table 6/6 page ix

Equipment list of 40.000 ton plant

Technological step	Serial no.	Name of unit	Technical data	Number of unit A	B	C
8. Winter operation	1.	Condensate tank	Steel, V = 50 m3	1	1	-
	2.	Graphite heat exchanger	Surface: 0.5 - 1.5 m^2	48	48	-
	3.	Warm water pump	T = 90 °C Q = 25 m3/hour H = 36 m	2	1	1
9. Automatic measurement and control system	1.	Central processor	For 1024 TTL channels Interface RS 232	2	1	1
	2.	Colour display with disc drive	2 x 27 MByte Winchester disk	2	1	1
	3.	Magnetic disc unit	1 MByte floppy	4	2	2
	4.	Printer		2	1	1
	5.	Level sensors	Inductive			
	6.	Temperature sensors				
	7.	Alarm sensors				
	8.	Pump activators	with magnetic valve			

Table 6/6 page x

Equipment list of 40.000 ton plant

Technological step	Serial no.	Name of unit	Technical data	Number of units A	B	C
10. Auxiliary equipment						
10.1. Compressed air supply	1.	Compressor	Cty.: 150 Nm3/hour	1	1	-
	2.	Compressed air tank	V = 20 m3, p = 6 bar	1	1	-
10.2. HCl complement	1.	Storage tank	Steel, with acid-resistant rubber lining, dia.: 6.3 x 5 m	3	3	-
	2.	Discharge pump	Acid-resistant, Q = 24 m3/hour H = 24 m	1	1	-
10.3. Steam generation		Steam generator incl. water treatment unit	3 tons/hour 158 °C saturated steam	2	2	1

6.4 Location criteria, utility requirements

When site selection criteria for the bauxite beneficiation plant are developped availability and cost optimum issues have to be considered.

Requirement data from earlier sections of this Chapter 6 is used to calculate the parameters for a 40,000 tons plant laid out to process the medium grade /'85'/ bauxite arriving to the plant in 0.5 to 4 mm grain size. Following a suggestion from [illegible], estimates for a plant with similar output capacity processing Grade '83' bauxite are also given. These, however, necessarily have a higher confidence margin as laboratory results were used to generate them.

1. Land

Grade '85'	Grade '83'
310 x 450 m	290 x 540 m
14.0 ha	15.7 ha
34.5 acre	38.7 acre

This is based on the tentative layout in Section 6.5. Figure proposed for Grade '83' includes bauxite handling. A schematic diagram of this appears in Figure 6/8. /If it proves to be necessary to dry the 0-1 mm fraction, waste heat from the tunnel kiln should be used./

An increase of the plant output capacity by 20 % in either case would require an additional land area of up to 10 %.

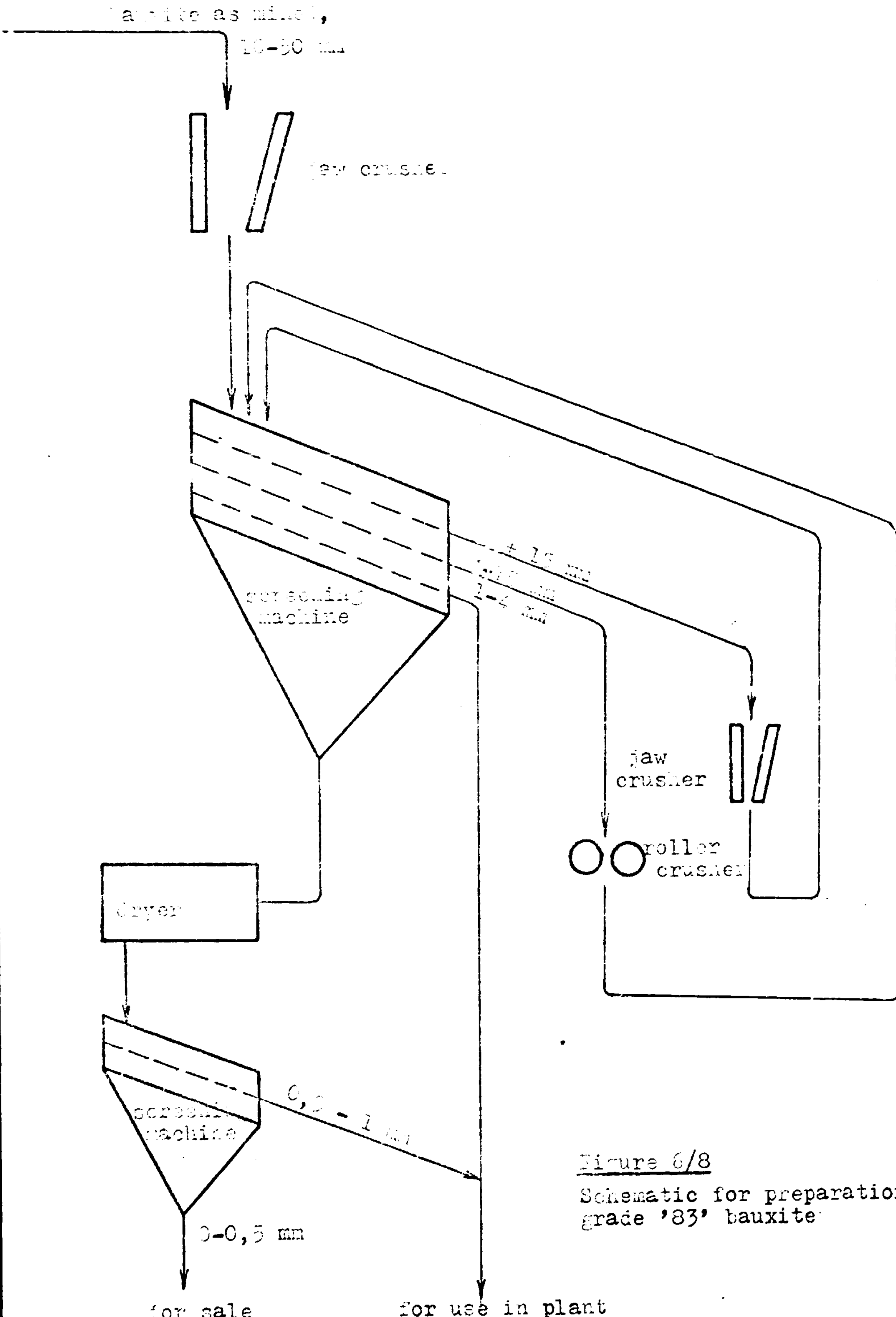


Figure 6/8

Schematic for preparation of grade '83' bauxite

Table 6/7

Main raw materials/Products

	Grade '85'	Grade '83'	Mode of transport
Bauxite, as mined, '000 t/yr	[illegible]0	73	loose by sea / road
Bauxite, 0.5-4 mm, '000 t/yr	[illegible]7.8	57.8	loose by sea / road
Hydrochloric acid, 30 %, '000 t/yr	21.4	8.4	in tanks by sea / road
Slaked lime, '000	2.8	2.0	loose by sea / road
Calcined refractory bauxite, '000 t/yr	40.0	40.0	loose or in bags by road / sea
Air dried (7 % moisture) white bauxite, '000 t/yr, up to	50.0	50.0	loose by road / sea
Iron oxide pigment, 70 % solids, '000 t/yr	22.0	11.2	in tanks by road / sea
Bauxite reject 0 - 0.5 mm, '000 t/yr	19.7	18.6	in bags by sea / road
Total, '000 t/yr, up to	275	226	—

2. Main raw material and products

Data for this section is taken from Tables 6/3, and 7/4. Results are in Table 6/7. The total material forwarding requirement for the plant is in the order of 275,000 tons /225,000 tons in the case of high quality feed/ per year.

3. Utilities

The consumption figures are derived in essence from the basic engineering data, and list of equipment appearing in Sections 6.2 and 6.3. An input/output schematic has been drawn up for the 40/85 plant and is shown in Figure 7/1. Overall utilities figures are summarized in Table 7/3.

4. Wastes

This is described in detail in Section 6.2.7. The 40/85 plant will produce approximately the following wastes:

flue gases, fumes	$190 \cdot 10^6$	Nm^3/yr
waste water	$1.7 \cdot 10^6$	t/yr
solid waste /sludge/	4.0	t/yr

The 40/85 plant would produce roughly the same amount of flue gas, about 40% of the waste water produced by the 40/85 plant, that is about $0.68 \cdot 10^6$ ton/yr, since this is more or less proportional to the HCl consumption; Solid waste is estimated for 2.5 ton/yr.

5. Weight of plant equipment

This is derived from Section 6.3 and estimated as 4,700 tons for the 40/85 plant.

6. Labour requirements

Based on the experience from MINKOVA's PÉCS plant, prior to commissioning a workforce of 30 to 35 is needed in the 4 months' period of earth moving / foundation laying,

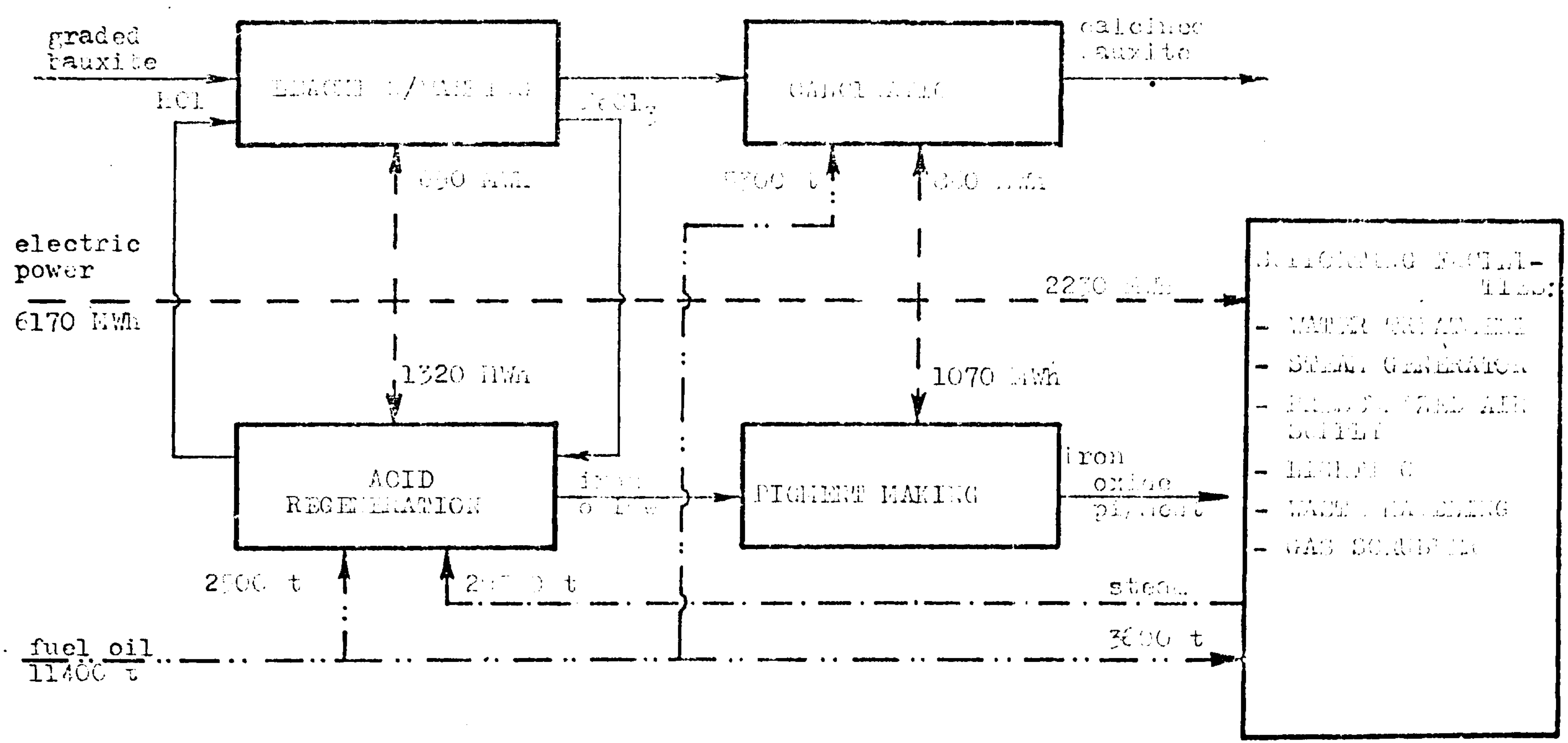


Figure 6/9
Energy used in the Al/33 plant

Table [illegible]

Utilities

	Grade '8[illegible]'	Grade '8[illegible]'
Electric power, Consumption, MWh/yr Max. load, KW	6,170 [illegible]	4,[illegible]70 7[illegible]
Fuel oil Ton	11,[illegible]00	7,3[illegible]0
Process water m^3/hr	230	13[illegible]
Potable water m^3/hr	4	4

about 2[illegible] workers during the 9 months of building and an average of [illegible] for 14 months of erection, start-up, etc. These figures include the workforce of various contractors on site as well as the personnel of the owner of the plant.

For the operation of the plant, altogether 62 persons will be required, [illegible] of which is management. As [illegible] workers are expected to work in continuous work order, there would be a maximum of 37 people in work at any one time.

7. Site requirements

Probably the most difficult requirement to satisfy is that of water supply. The 2[illegible]0 m^3/hr value is for flow-through type cooling of the pyroliser. If cooling water is re-cycled, the [illegible]/85 plant's consumption of process water is about 100 m^3/hr, subject to the maximum requirements on chlorides in the effluent.

Vicinity to an alumina plant is advantageous from the point of view steam supply, laboratory facilities, possible exchange of materials, /cut-of-spec alumina for [illegible].

Closeness to a mine becomes less important if supply is to be covered from several mines at various places.

Location close to or on the seaside helps to save transport costs for both raw materials as well as the products. Chlorides in the effluent of the plant are all natural components of seawater.

6.5 Layout

Figure 6/10 shows the tentative layout for a bauxite beneficiation plant with an annual output of 40,000 tons /Feed: Grade '85'/. The arrangement was based on the principle of keeping feed stock as well as iron oxide as far as possible from the calcined white bauxite in order to reduce the danger of contamination of the end product.

The figures in the drawing are explained below:

1. Raw material preparation
2. Bunker for -0.5 mm fraction
3. Dryer
4. Gas scrubber
5. Bauxite feed conveyor belt
6. Leaching/Washing column
7. 'White' bauxite conveyor belt
8. Dewatering area for white bauxite
9. Brick press
10. Trolley loading machine
11. Drying tunnel
12. Tunnel kiln
13. Trolley unloading machine
14. Calcined bauxite, handling
15. Calcined bauxite, storage
16. Cooling water system
17. Fuel oil tanks
18. Steam generator
19. Pyrolizer
20. Iron oxide, washing
21. Pigment shop
22. Tank park
23. Waste liquor treatment

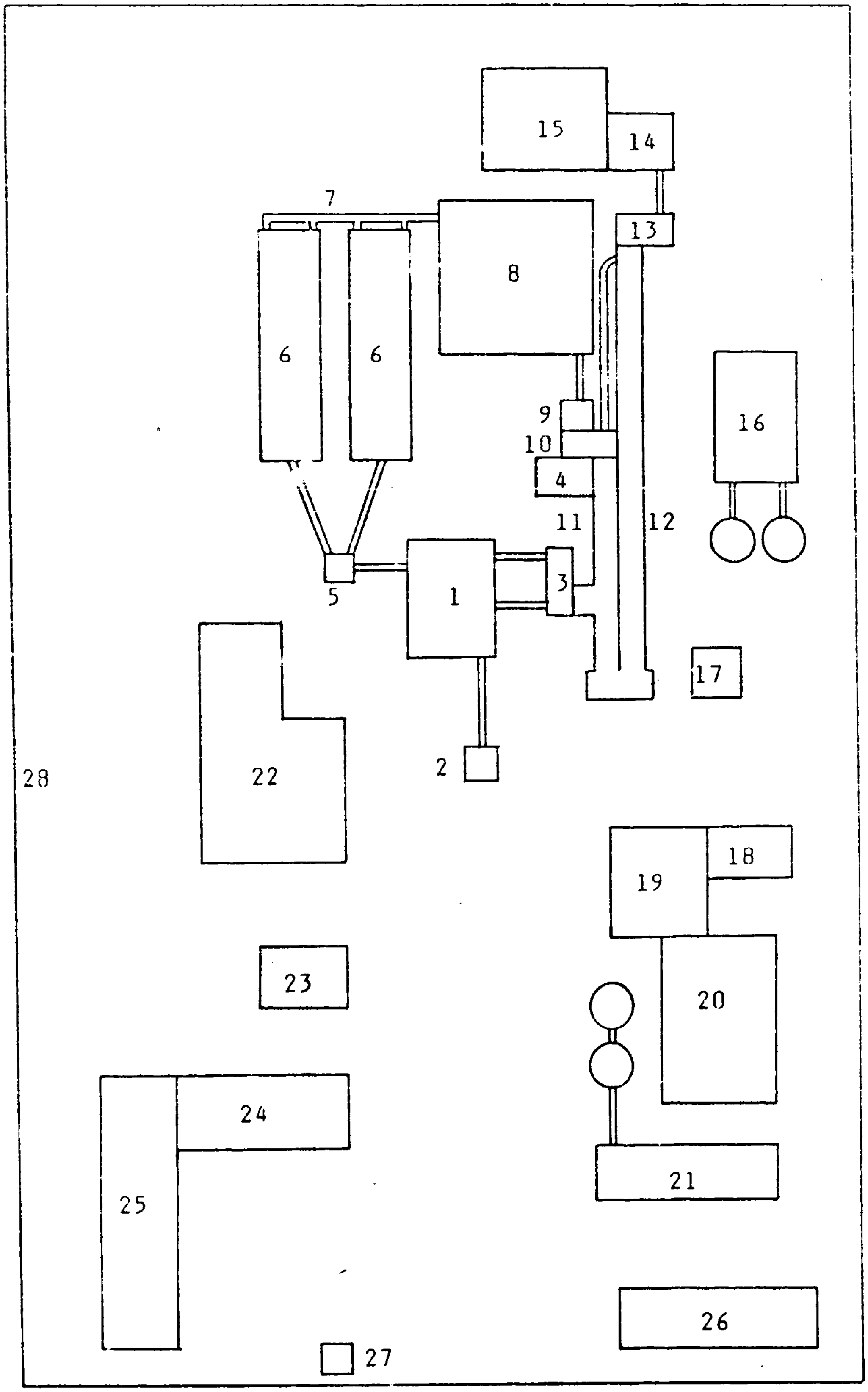


Figure 6/10

Tentative layout /40/85/

24. Service building

25. Offices and labs

26. Shops and warehouses

27. Gate

28. Fence

7. Cost estimates

In this chapter investment and operating costs will be estimated for alternative plant capacities for processing a raw material similar to the grade tested in the pilot plant /see Tables 2/3 and 2/4/, to be referred to as Grade 85. Four plant sizes with outputs of 20, 40, 60 and 80 thousand tons refractory grade bauxite, respectively will be covered. Investment and operating costs given have been reached on individual assessment in each case. The 40 thousand ton plant is selected as base variant. The cost figures used in the report are, as a rule, actual at the time of writing. Prices of imported equipment include sea freight, but no import duty.

Although limited amount of engineering information could be developed for the bauxite grade tested in laboratory in 1982/83 with excellent results /to be referred to as Grade 83/, an attempt has been made in this section to estimate, for the purposes of comparison, the investment and operating costs for a 40.000 ton Grade 83 plant.

Based on tables containing relevant data developed for altogether 5 variants, comparisons will be made and an evaluation will be given.

7.1. Investment cost

Investment cost of realizing the project will depend on site selection, on the scope of the project, feedstock grade, capacity installed, and on other factors. In this section estimates for the investment cost will be given taking the effect of the feedstock grade on the one hand and that of the installed capacity on the other, in consideration. Following a request by HIMIC, local and Forex components of cost of equipment and machinery have been estimated for each item.

Table 7/1 lists cost of equipment, installation cost, as well as the cost of building and construction for the base variant of 40.000-ton annual capacity. Cost of land is estimated for Drs 500,000 per acre unit cost inclusive site preparation. The cost of making the necessary amount of electrical power and water available to the plant as well as those of making the plant accessible by road and/or rail are not included in the figures given. The cost estimates for the individual plant sections have been based on the equipment list in Section 6.3, as well as on respective data from MINNOVA's own Pécs plant now under construction. Although it is not clear at this time, if bauxite can or cannot be purchased from the mines in the required grain size range of 0.5 to 4 mm, and it may prove necessary to allow for in-plant dressing facilities, these have not been included in the Table, as too little is known at this stage

Table 7/1

Cost of fixed assets for a 40.000-ton capacity plant /Grade '85'/
/all figures in '000.000 Drs/

Plant section	Cost of Building and Construction	Cost of Equipment and Machinery			Cost of Installation	Total
		Total	Foreign	Greek		
Site, developped	17	-	-	-	-	17
Subtotal, site	17	-	-	-	-	17
Leaching/Washing	75	528	40	488	92	681
HCL regeneration	7	564	520	44	79	650
Calcination	65	380	380	-	65	510
Gas Scrubber	11	72	72	-	12	95
Waste Treatment	2	18	-	18	2	23
Pigment Processing	45	76	76	-	14	135
Subtotal, Process Equipment	205	1638	1071	550	251	2094

Table 7/1 /Cont'd/

Plant section	Cost of Building and Construction	Cost of Equipment and Machinery			Cost of Installation	Total
		Total	Foreign	Local		
Piping, Sewers and Roads	40	14	-	14	8	62
Electric Power Supply, Lighting	9	15	-	15	5	29
Steam Generator incl. Water Treatment	9	51	51	-	5	29
Instrumentation and Process Control	-	37	37	-	11	48
Water Supply	22	12	-	12	4	38
Compressed Air Supply	-	8	-	8	1	9
Fuel Oil Storage and Handling	3	9	-	9	3	15
Final Product Handling Packaging	12	7	-	7	2	21
Sub-total, Auxiliary Facilities	95	153	[illegible]	[illegible]	42	290
Maintenance shops and stocks	22	11	-	11	1	34
Plant management buildings and other facilities	29	-	-	-	-	29
Sub-total, Buildings	51	11	-	11	1	63
Total fixed assets	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2464

about the behaviour of the material.

When estimating the foreign exchange component of the cost of plant, it was assumed that the leaching/washing columns will be fabricated in Greece. HCl regeneration equipment, calcination kiln and other machinery, the gas scrubber required for their flue gases as well as pigment shop equipment will be imported, as all these incorporate special engineering know-how and high grade materials. These assumptions are rather conservative for lack of precise information and it may well be possible to further decrease the Forex component.

Table 7/2 shows the cost of equipment and machinery for different variants. The sources of equipment price estimates are as follows: Some are unit prices actually incurred for equipment items in MINMOVA's own plant at Pécs. Others are quotations obtained from suppliers including Andritz of Austria, Netzsch of FRG, A4GM Röck Electric of Hungary and others. It can be seen, that overall cost approximately doubles when the capacity increases fourfold. The use of Grade '83' over the ideal Grade '63' makes it necessary to process more material and to recycle more HCl for a given output. This and other factors bring about an increase of approximately 10 to 20 % in equipment costs, even though bauxite dressing is included for Grade '83', as requested by MIMIC in the review meeting.

Table 7/2

Cost of equipment and machinery for different plant capacities /in '000 tons/
/Cost figures '000.000 drachmas/

Feedstock

Plant section / Plant capacity	Grade '8[illegible]' 20	Grade '8[illegible]' 40	Grade '8[illegible]' 60	Grade '8[illegible]' 80	Grade '33' 40
[illegible] preparation	-	-	-	-	74
[illegible]	119	[illegible]	[illegible]	656	[illegible]
[illegible] generation	353	564	730	844	355
[illegible]	323	390	433	472	[illegible]
[illegible] processing	[illegible]	76	96	122	[illegible]
[illegible]	100	244	277	290	211
[illegible]	1 243	1 [illegible]	2 173	[illegible]	1 [illegible]

Table [illegible] provides a divided total investment cost break-down for the different variants. The cost of obtaining licences for the use of the proprietary bauxite beneficiation and pigment making technologies has been estimated for 10 % of cost of process equipment, plus running royalties to be mentioned again later. Cost of detail planning has been estimated for 5 % of the total cost of fixed assets, pre-investment studies as 1 % of the total investment cost. These figures are purely estimates for the purposes of the present economic assessment exercise and do not represent actual offer by any party.

It has been assumed, that a staff of [illegible] qualified persons may be necessary for a period of up to 2 years, for the management of the implementation of the Project including supervision and overall coordination of the installation, test run and take-over of civil works, equipment and plant, regardless of the installed capacity. Based on a monthly average salary of [illegible].000 Drachmas, the actual cost estimate for this activity is 2[illegible] million Drachmas.

A reserve item is foreseen at 10 % of the total investment cost.

The working capital requirement estimates for the various variants are based on the cost of purchasing 75 days

Table 7/3

Total investment cost

/All cost figures in '000.000 Drs/

Estimate for / Plant capacity in '000 tons	Feedstock					
	Grade '85'				Grade '83'	
	20	40	60	80	40	40*
Plant site, developed	12	17	21	27	19	15
Sub-Subtotal, Site	12	17	21	27	19	15
Crude Bauxite Preparation	-	-	-	-	88	88
Leaching/Washing	442	681	795	920	584	584
HCl Regeneration	440	650	780	870	450	450
Calcination	433	510	570	590	510	-
Gas Scrubber	77	95	108	116	84	55
Waste Treatment	19	23	27	30	23	23
Pigment Processing	94	135	160	175	95	95
Sub-Subtotal, Process Equipment	1,510	2,094	2,440	2,701	1,834	1,235

Table 7/3 /Cont'd/

Estimate for / Plant capacity in '000 tons	Feedstock					
	Grade '85'				Grade '83'	
	20	40	60	80	40*	40
Piping, Sewers and Roads	54	62	71	77	58	58
Electric Power Supply/ Lighting	25	29	33	35	27	29
Steam Generator, incl. Water Treatment	46	68	81	98	55	55
Instrumentation and Process Control	46	48	49	49	40	47
Water Supply	30	38	41	45	30	30
Compressed Air Supply	8	9	10	11	8	8
Fuel Oil Storage/Handling	12	15	17	18	10	12
Final Product Handling/ Packing	17	21	24	26	6	21
Sub-Subtotal, Auxiliary Facilities	238	290	326	359	234	260
Plant Management and Welfare Building	31	34	36	38	34	34
Maintenance Shops, Stores, etc.	29	29	31	32	29	29
Sub-Subtotal, Buildings	60	63	67	70	63	63
Sub-Total, Fixed Assets	1 820	2 464	2 834	3 154	1 [illegible]07	2 176

[illegible]

[illegible] / [illegible] capacity [illegible]	[illegible]					
	Grade '[illegible]'				Grade '63'	
	20	[illegible]	[illegible]	[illegible]	40	[illegible] *
[illegible] for [illegible]	[illegible]	211	[illegible]	[illegible]	[illegible]	130
[illegible], [illegible]	[illegible]	[illegible]	[illegible]	275	[illegible]	130
[illegible]	[illegible]	[illegible]	40	[illegible]	30	25
Retail [illegible]	91	123	143	158	109	83
[illegible]	[illegible]	25	[illegible]	[illegible]	25	25
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] % of the [illegible] annual requirement [illegible] acid, [illegible] of the [illegible] oil + 10% of electric power [illegible] as well as the cost of manpower for three months. [illegible] the unit cost of Grade '35' bauxite is 25 [illegible] of Grade '47' and the cost of providing [illegible] supply accounts for some 45 [illegible] of the total [illegible] capital requirement, the latter is still somewhat lower if Grade '35' bauxite is projected for use.

As can be seen from Table 7.3, about 20 [illegible] of the total investment cost is to be spent on process equipment for leaching [illegible], 15-20 % on HCl regeneration equipment [illegible] as a whole. Other process [illegible] equipment and various additional items [illegible] up to 40 [illegible] of the total cost of putting up a plant [illegible] to operate it. The total investment [illegible] with plant capacity: The 20 thousand-ton plant [illegible] about 35 [illegible] of the 80 thousand-ton [illegible] makes savings of approximately 12 [illegible] investment possible. [illegible] making [illegible] to 25 % to the revenues of the plant, [illegible] about 4 %, but the actual additional investment [illegible] over cost of disposal is still lower.

[illegible]

[illegible] capital costs connected with [illegible] will [illegible]. Beside the [illegible] capacity plants [illegible] are given for a [illegible],000 ton plant [illegible].

[illegible] developed for the different variants [illegible] in Table 7/4.

[illegible] for the plant is bauxite grade [illegible] size, for which a moisture [illegible] has been assumed. Hydrochloric acid losses [illegible] concentrated technical [illegible] /[illegible]/.

[illegible] the operating cost for the 4 variants [illegible] '8[illegible]' bauxite, as well as [illegible] '[illegible]' material. This latter is taken in [illegible].

[illegible] for the different variants have [illegible] Table 7/4. Unit costs were obtained from various sources as given below.

- [illegible]: Using the formula proposed by the UNIDO expert in his Report /2/, Grade '85' should be available at Drs 4[illegible].-/ton, Grade '83' at Drs 5110.-/ton. (Mine [illegible] have been quoting somewhat higher prices.)

Table 7/4

Consumption data estimated for various plants

Input	unit	Variants 20/85	40/85	60/85	80/85	40/85
Bauxite	ton	33.904	67,808	101,712	135,616	57,800
HCl	ton	11,800	21,400	31,200	40,500	10,000
Slaked lime	ton	1,400	2,800	4,200	5,600	2,000
Precipitant	kg	11,800	22,000	31,700	42,000	10,000
Additive for Pigment making	kg	24,000	48,000	72,000	96,000	24,000
Fuel Oil	ton	5,675	11,400	17,125	22,850	7,350
Steam	ton	14,750	29,500	44,250	59,000	16,500
Compressed Air	'000 m^3	820	900	980	1,060	860
Electric Power	MWh	3,600	6,170	8,700	11,000	4,570
Process water	'000 m^3	895	1,710	2,590	3,470	990
Potable Water	'000 m^3	25	27	30	33	27
Spares and wear Parts	'000 Drs	36,000	40,000	42,000	43,000	35,000

Table 7/5

Cost of operation estimated for various plants /Plant capacities in '000 tons/
/all cost figures in '000.000 Drs/

Unit Drs/unit	Cost item / Plant capacity (Feedstock)	Cost for Grade '35'				Cost for Grade '83'	
		20	40	60	80	40	% of total operating cost
4,455 6,193	Crude Bauxite, ton	151	302	453	604	358	42.27
7	Cost of Transportation ton/km	7	14	21	28	16	1.89
6,100	Hydrochloric acid, ton	72	130	190	247	61	7.2
-	All other materials	12	22	31	40	16	1.89
-	Sub-Subtotal, Materials	242	463	695	379	451	53.25
24,000	Fuel Oil, ton	136	274	411	548	176	20.77
7,000	Electric Power, kWh	25	43	60	77	32	3.77
-	Other Utilities/supplies	3	5	7	9	3	0.35
-	Sub-Subtotal, Utilities	164	322	478	634	211	24.91
-	Royalty on refr. sales	7	14	21	28	22	2.6
-	Royalty on pigment sales	8	16	24	32	9	1.6
-	Sub-Subtotal, Royalties	15	30	45	60	31	3.66
-	Subtotal, Variable costs	417	814	1,211	1,604	691	81.53

Table 7/5 Cont'd

Cost item / Plant capacity	Cost for Grade '35' (Feedstock)				Grade '83'	
	20	40	60	80	40	% of total operating cost
Wages and Salaries	100	109	118	127	109	12.87
Factory overhead	40	42	43	45	36	4.25
Administrative costs	8	11	13	14	11	1.3
Subtotal, Fixed Costs	148	162	174	186	156	18.42
Total	565	976	1,385	1,790	347	100.00

The purchase price of Drs 4455/ton is used in this Report for the 0.5 to 4 mm medium grade /'85'/ bauxite assuming a 10 % surcharge for dressing. A different assumption is made for the high grade raw material as agreed at the Review Meeting held in Budapest and Pécs on 22-25 October 1986 /9/: raw material bought as-mined for USD 42,-/ton /Drs 5670/ton/ and fines from grading and screening resold at USD 39,-/ton /Drs 5265/ton/. Table 7/6 shows how a unit price of Drs 6193/ton was finally arrived at, based on the material flows of Figure 6/8.

- Cost of transportation: Drs. 7.-/ton kilometer /source: HIMIC./ An average road distance of 30 km is assumed.
- Hydrochloric acid: Drs 6100/ton /30 %/
- Fuel oil: Unit cost of Drs 24,000 has been assumed, although HIMIC stated Drs 27,150.

It should be noted, however that present world market prices for suitable quality fuel oil grades are up to 50 % lower /from USD 80/ton, equal Drs 10,800/.

- Electric power: Drs 7000/kWh /source: HIMIC/
- Additive for pigment making: Drs 220/kg /preliminary information obtained from owner of technology/
- Precipitant: Drs 300/kg
- Royalty on refractory sales: running at a rate of 2 %, /preliminary information obtained from owner of technology/
- Royalty on pigment sales: running at a rate of 5 % /preliminary information obtained from owner of technology/.

Table 7/6

Cost estimate for Grade '83' bauxite

/Plant capacity: 40.000 tons/

	Quantity (tons)	Price (Drs/ton)	Cost ('000 Drs)
Raw material procurement	78,000	5,670 /1/	442,260
Transportation			13,650 /2/
Loss sold rejected raw material	18,600	5,265 /3/	/97,929/
Raw material input	57,800	6,193	357,981

/1/ Equal to USD 42/ton

/2/ 174.96 Drs/ton

/3/ Equal to USD 39/ton

The manning requirements for a shift in a 40.000 ton plant are given in Table 7/7. Based on a 8-hour working day and a five-day week, taking 20 working days as the average paid holidays and further 10 working days as lost, the continuous operation of the plant for 8000 hours a year makes it necessary to budget for 4.5 shifts. The cost of man-power for the same plant is shown in Table 7/8. Wage and salary rates are based on HIMIC's information, cost-to-employer figures have been calculated on the basis of 14 monthly pays a year. Social security contributions are estimated at a rate of 35 %. In the larger plants two additional semi skilled workers are foreseen for each shift in the leaching/washing department, resulting in an additional cost-to-employer of Drs 9.36 million for each 20.000 ton capacity increment.

Factory overhead includes spare and wear parts estimated as 1.0 to 1.5 % of the total cost of fixed assets, as well as auxiliary materials and supplies. Administrative costs including cost of repair, communications, office supplies, etc. have been estimated as approximately 10 % of the salaries.

Depreciation figures have been calculated from the original value of fixed assets using the straight line method, applying a uniform rate of 9.25 %, derived from 10 % for equipment and 5 % for buildings. /Table 7/9./

Table 7/7

Manning requirements

Process / Location	Number of work places with qualification Codes								
	9	8	7	6	5	4	3	2	1
Bauxite preparation		(1)							
Leaching/Washing		(4)	(1)				(1)	1	
Drying			(1)						
Calcination			(1)				(1)		
HCl regeneration						2			
Material handling			2						
Laboratory	3							1	
Maintenance and Repair					7				1
Plant management				4				2	4
Total	3	25	16	4	7	9	9	4	5

Note: Number of jobs in continuos work-order appears in circle

Table [illegible]

Manpower costs
[illegible] /000 [illegible]

[illegible]	[illegible] No.	Qualification/Post	Salary /000 Drs/Month	Annual [illegible]
1	5	Management	110-250	10,[illegible]
2	4	[illegible]ineering/ [illegible]	100-1[illegible]	[illegible]
3	2	Engineering school	90	[illegible]
[illegible]	3	[illegible] school	75	[illegible]
5	[illegible]	Skilled labor	70	[illegible]
	[illegible]	[illegible] school	[illegible]	3,[illegible]
	[illegible]	Semi-skilled labor	60	[illegible]
[illegible]	7	[illegible]-skilled labor/ clerk	55	1,[illegible]
[illegible]	[illegible]	[illegible]	50	[illegible]
[illegible]	[illegible]			[illegible]
[illegible]				= [illegible]

Table 7/9

Depreciation schedule /straight line depreciation/

	20/85	40/85	60/85	80/85	40/83
Auxiliary facilities	238	290	326	359	260
Process equipment	1 522	2 111	2 461	2 725	1 853
Buildings	60	63	67	70	63
Licences	152	211	246	273	185
Capital expenditure	388	520	605	672	463
Total	2 360	3 195	3 705	4 099	2 824
Annual cost /9,25 %/	218	296	343	379	261
Residual value after 10 years	180	235	275	309	214

As can be seen from Table 7/5 the inputs with the largest relative cost are /a/ the raw material /24 to 31 % for Grade '85' and 42 % for Grade '83'/ and /b/ the cost of fuel /22 to 27 %/. Operating costs for a plant processing high grade /83/ material are some 20 % below those of the comparable Grade '85' plants, despite the former's higher bauxite cost.

If the white bauxite is left uncalcined, the estimated savings for 40,000 ton output areas follows:

	million Drs
electric power	5.4
fuel oil	128
spare parts, supplies	8
labor	12.8
	154.2

The total cost of operation of the 40/85 plant is reduced to Drs 822 million, that of the 40/83 plant to Drs 693 million.

8. Economic and financial evaluation

In this chapter various size plants processing Greek bauxite [illegible] are reviewed from the point of view of their estimated economic and financial performance.

8.1. Profitability

Revenue for the various plant sizes has been calculated for a case in which the total production of refractory grade calcined bauxite from the plant is exported, 700 tons of the iron oxide pigment is sold in Greece, the balance is exported. The calculation is based on maximum prices from chapters [illegible] and [illegible] and uses 6 % export subsidy. The total revenues appear in Table 8/1.

Cost of operation taken from Table 7/5 and depreciation taken from Table 7/9 have been used to calculate the profitability of operation, shown in Table 8/2. Pay back period is calculated using the total investment cost figures from Table 7/3 and allowing for the 25 % grant as per law 1262/82.

All plants except for the 20/85 variant make a profit in the maximum prices case. Plant 20/85 would break even if its revenue would increase by 3 %. If 75 % of the depreciation calculated in Table 7/9 is included in the cost of operation, 40/85 and 60/85 plants join 20/85 in making a loss rather than a profit. To break even 40/85 plant's revenue would have to increase by 12 %, 60/85 plant's by 2.5 %.

Table 8/1

Revenue /in million Drs/

Feed grade	85					83
Plant size	Drs/ ton	20	40	60	80	40
Refractory bauxite	19,292	386	772	1 158	1 543	–
(100 % export)	28,196	–	–	–	–	1 128
Iron oxide pigment 700 t sold in Greece	28,000	20	20	20	20	20
the balance for export	29,680	141	304	466	628	151
Total		547	1 096	1 644	2 191	1 299

Table 8/2

Profitability of operation

Drs figures in millions

Variants	20/85	40/85	60/85	80/85	40/83
Revenue	547	1 096	1 644	2 191	1 299
Cost of operation less depreciation	565	976	1 385	1 790	847
Gross profit /loss/	/18/	120	259	401	452
Total investment cost less grant /1/	1 851	2 537	2 980	3 333	2 242
Pay-back period /years/	-	21	11.5	8.3	5.0
Depreciation /2/	135	254	298	333	224
Net profit//loss/ after /2/	/203/	/134/	/39/	68	228

/1/ Grant: 25 % of Total Investment Cost /Law 1262/82/

8.2. Sensitivity

The effect of the price of the raw material, the single biggest item in cost of production, can be examined using the sensitivity curve of Figure 8/1. Feedstock price has been varied in a range of ± 25 % of the median value. Gross profit of 40/85 plant increases by Drs 140 million to almost 4-fold over the ± 25 % bauxite feed prices range. This effect is even more pronounced for larger plants.

The effect of the fuel price can be seen in Figure 8/2. A range from Drs 24,000, the price chosen for use in the calculation of the operating cost, to Drs 14,850 /USD 110/ has been selected. Gross profit of the 40/85 plant increases by Drs 100 million over the full fuel price range.

In Figure 8/3 the effect of the iron oxide content of the feed on the cost of spent acid regeneration is shown. Cost of equipment was kept constant for the sake of simplicity. As iron in the feed gets higher decreasing cost of bauxite feed cannot balance increasing cost of regeneration /including cost of complementary HCl/.

Figures 8/4 and 8/5 show the effect of the selling price of the calcined refractory bauxite and the level of production on gross profits of the 40/85 and 40/83 plants respectively. Changes in the iron oxide pigment sales proceeds would have about half of the effect in the case of the 40/85 plant, and about one-seventh in the 40/83 plant, compared to those caused by changes in the proceeds from bauxite.

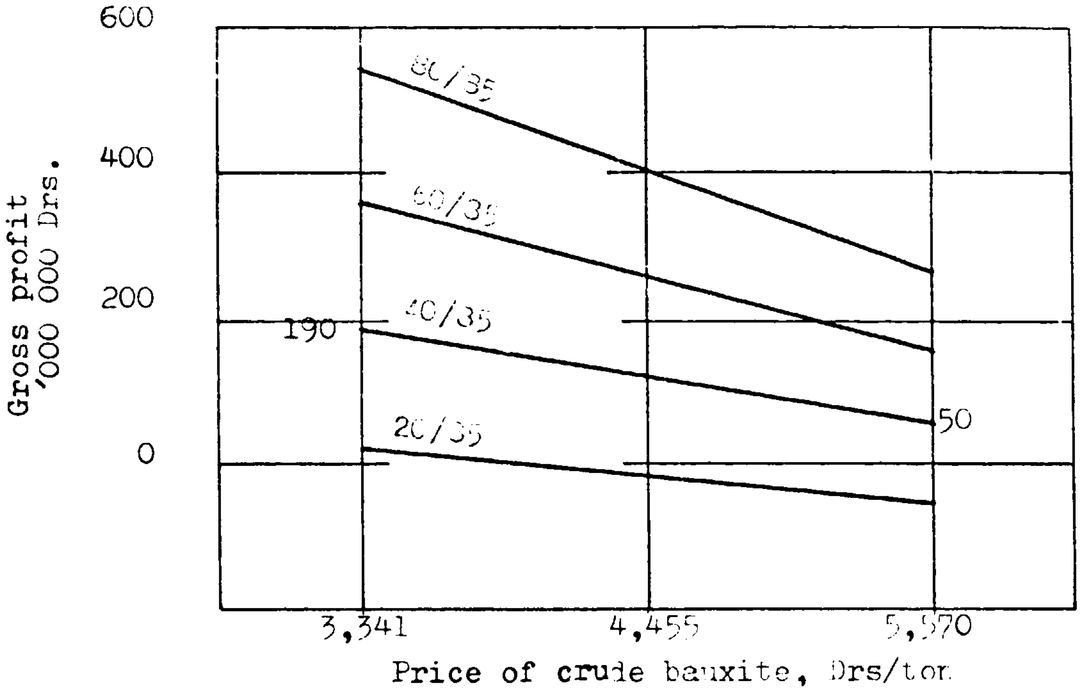


Figure 8/1: Effect of bauxite purchase pric on gross profit of plant, using Grade '85' feedstock

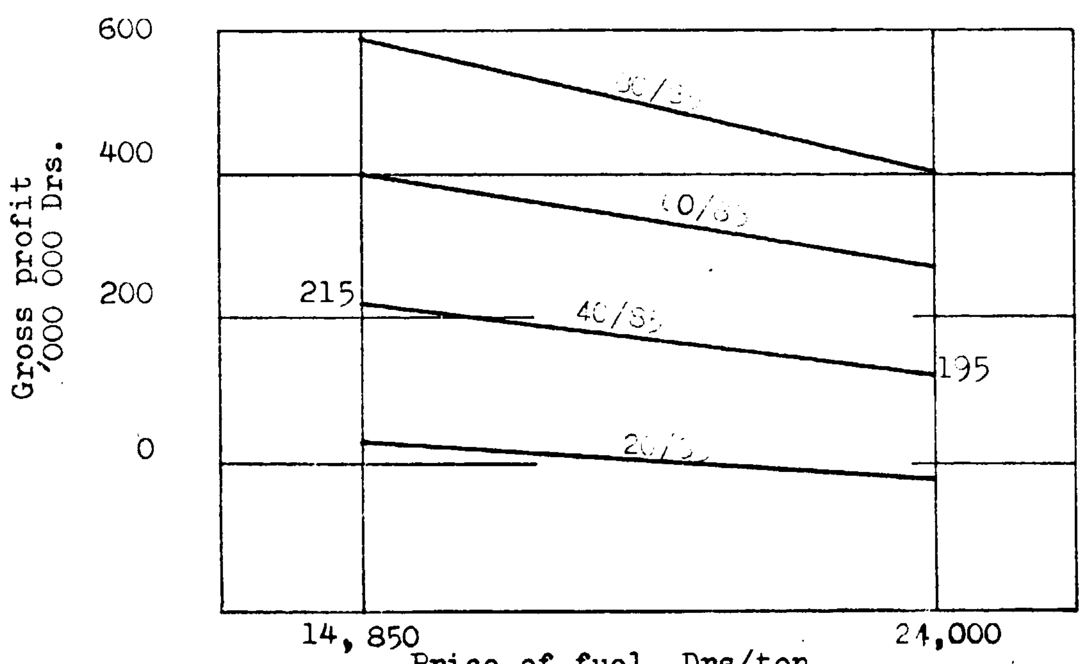


Figure 8/2: Effect of fuel cost on gross profit of plant using Grade '85' feedstock

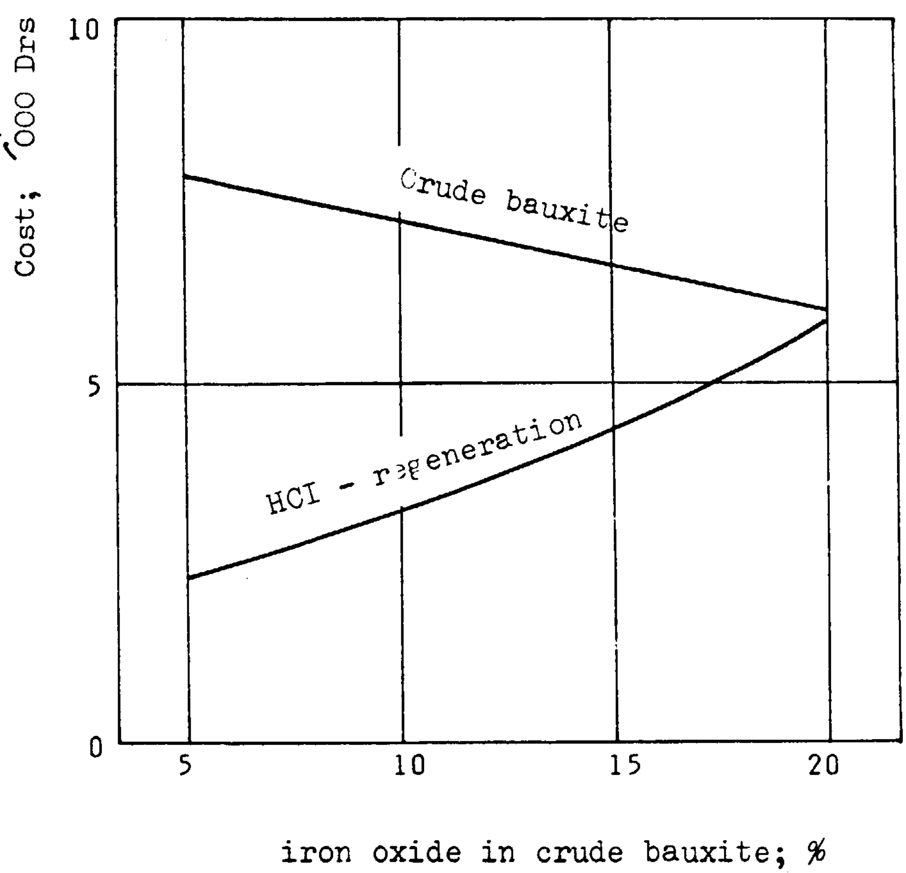


Figure 8/3

Cost of feed and cost of HCI regeneration vs iron oxide content of feed.

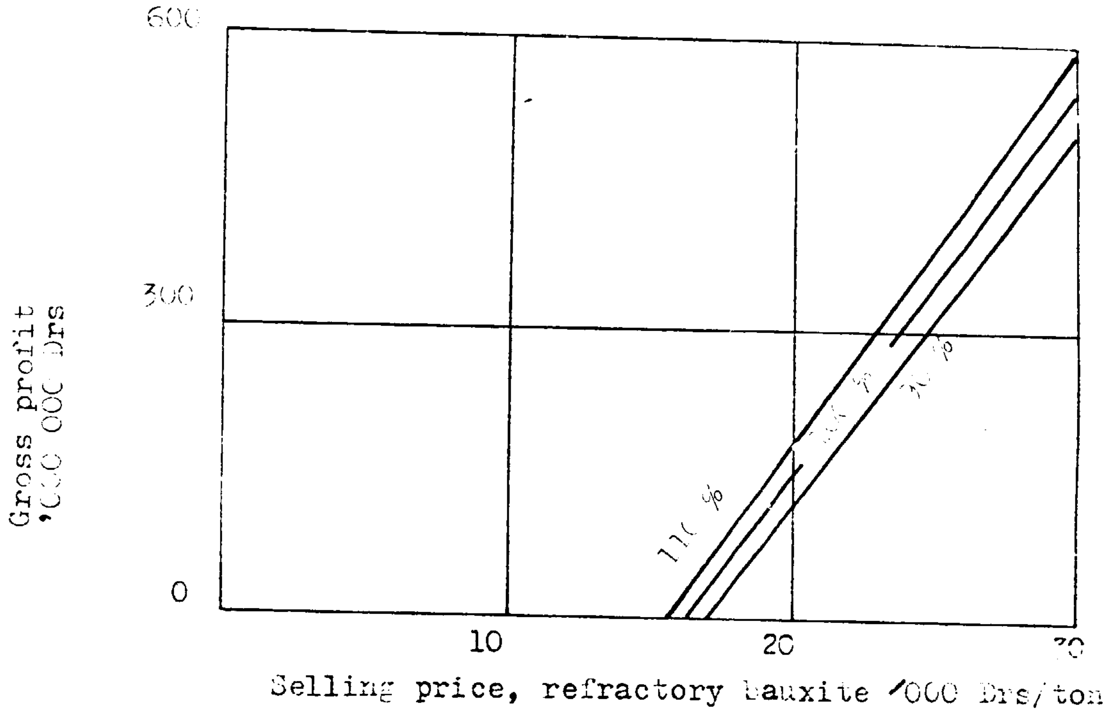


Figure 8/4 The effect of the selling price of the calcined refractory bauxite and of the level of production on the gross profit of the 40/35 plant

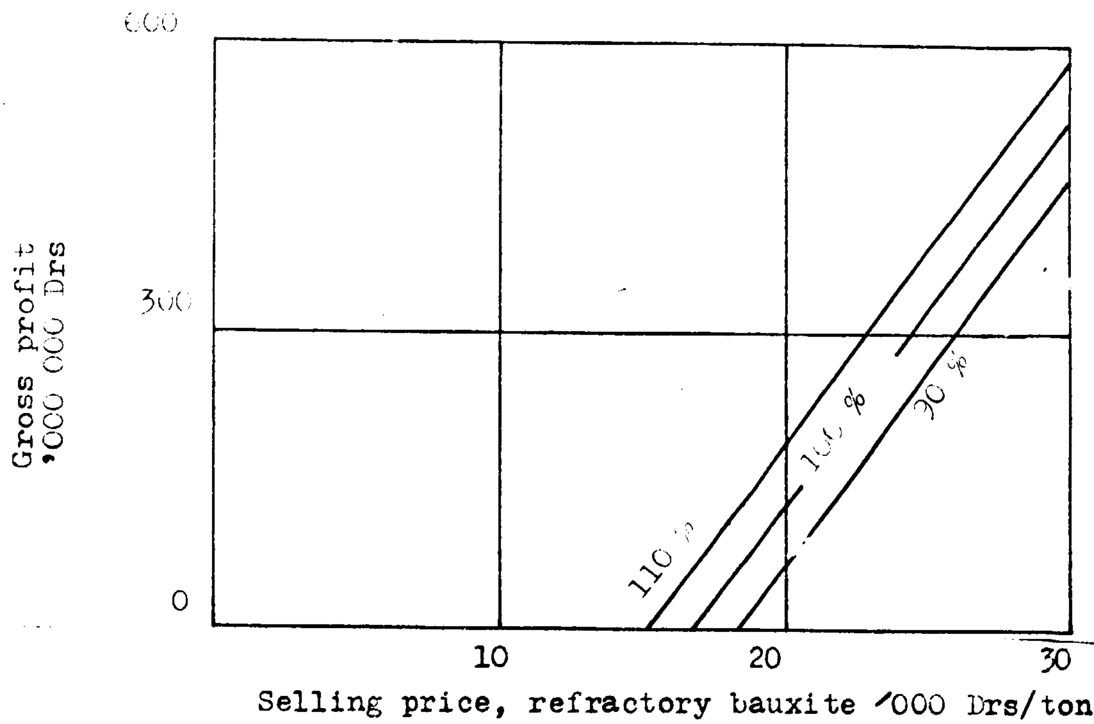


Figure 8/5 The effect of the selling price of the calcined refractory bauxite and of the level of production on the gross profit of the 40/33 plant

Figures 8/6 and 8/7 show at what level of production the 40/85 and 40/83 plant break even, respectively.

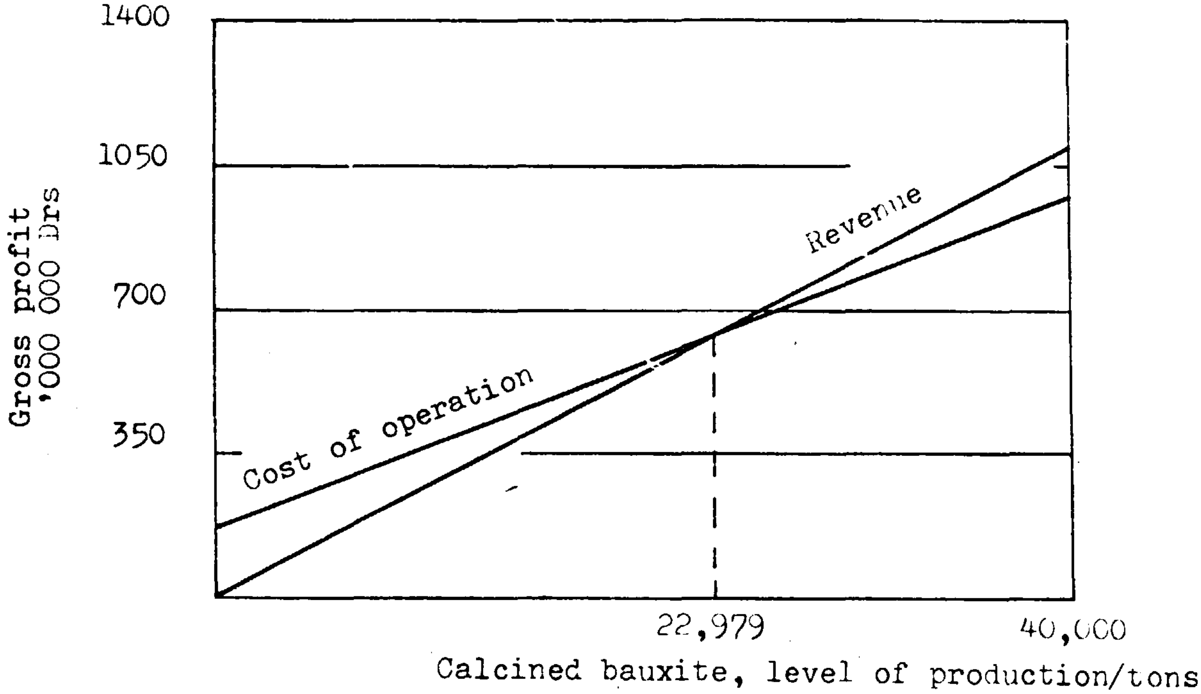


Figure 8/6 Break even point for the 40/35 plant

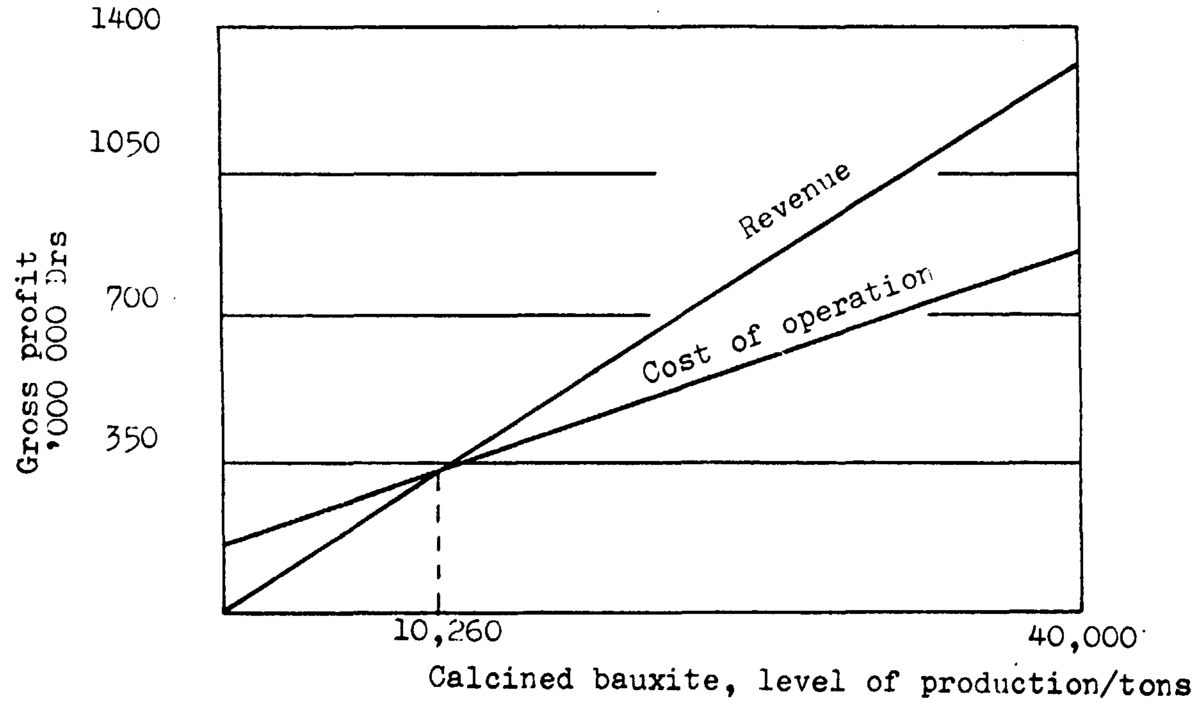


Figure 8/7 Break even point for the 40/83 plant

8.3. Financial evaluation

As apparent from the section 8.1 plants having an output capacity of 40, 60 and 80,000 tons show a gross profit when the products are sold at the maximum projected prices. Only the largest plant considered shows a net profit, however, under the same price conditions. The use of the medium grade bauxite to feed a beneficiation plant can therefore not be recommended unless fuel price and bauxite cost are significantly reduced.

In an attempt to demonstrate the level of economic viability to be expected from using the high grade feed, two financing models are considered. In one it is assumed that promoters and collaborators will provide 75 % of the capital requirement of the project, 25 % coming from a Government Grant. In the other model 35 % foreign loan is assumed, 40 % is brought in by the promoters/collaborators and 25 % is covered by Government Grant. The use of Greek loan is not considered because of its high interest cost.

Working capital is financed from a short term loan subject to 21.5%interest.

Net cash-flow and total net present value analyses for the first model appear in Tables 8/3 and 8/4, for the second model in Tables 8/5 and 8/6.

Table 8/3

Projected income statement for the plant 40/83; financing model No. 1*

/values in '000,000 Drs/

Year	1	2	3	4	5	6	7	8	9	10	11	12	Residual value	Total
Sales revenues	-	-	344	1 299	1 299	1 299	1 299	1 299	1 299	1 299	1 299	1 299	-	
Cost of operation	-	-	600	847	847	847	847	847	847	847	847	847	-	
Gross Profit	-	-	244	452	452	452	452	452	452	452	452	452	-	
Depreciation	-	-	261	261	261	261	261	261	261	261	261	261	214	2 824
Taxable Income	-	-	/17/	191	191	191	191	191	191	191	191	191	-	
Taxes	-	-	-	84	92	92	92	92	92	92	92	92	-	
Net profit	-	-	/17/	107	99	99	99	99	99	99	99	99	-	882
Net cash flow	-	-	244	368	360	360	360	360	360	360	360	360	214	3 706

* Total Investment Outlay: 2 989 Mio Drs

Grant : 25 % = 717 Mio Drs

Equity: 75 % = 2 242 Mio Drs

Tax Rate: 48 %, no tax holiday

Net cash flow: net profit plus depreciation

Table 8/4

Calculation of present value and internal rate of return[1] on owners' equity /financing model No 1/ for plant 40/83

/values in '000,000 Drs/

Year	1	2	3	4	5	6	7	8	9	10	11	12	Salvage value[2]	Total
A. Cash inflow														
1. Sales revenue	-	-	844	1 299	1 299	1 299	1 299	1 299	1 299	1 299	1 299	1 299	-	
B. Cash outflow /1+2+3/	900	1 342	600	931	939	939	939	939	939	939	939	939	/750/	
1. Total inv. outlay	900	1 342	-	-	-	-	-	-	-	-	-	-	/750/	
2. Operating cost	-	-	600	847	847	847	847	847	847	847	847	847	-	
3. Taxes	-	-	-	84	92	92	92	92	92	92	92	92	-	
C. Net cash flow /A-B/	/900/	/1 342/	244	368	360	360	360	360	360	360	360	360	750	1 253
D. Present value[3]	/900/	/1 213/	200	273	242	220	199	180	163	147	133	121	227	-8

Notes; 1. Prices changes, appreciation not considered.

2. Salvage value: Land: 17, of buildings: 200, of plant equipment: 375, working capital: 165

3. Present value: discounted at the internal rate of return of 10.5 %

Table 8/5

Projected Income Statement for the plant 40/83; financing model No.2*

/Values in '000,000 Drs/

Year	1	2	3	4	5	6	7	8	9	10	11	12	Residual value	Total
Sales revenues	-	-	344	1 299	1 299	1 299	1 299	1 299	1 299	1 299	1 299	1 299	-	
Cost of operation	-	-	600	847	847	847	847	847	847	847	847	847	-	
Gross profit	-	-	244	452	452	452	452	452	452	452	452	452	-	
Interest on Forex loan	-	-	-	74.6	65	55.4	45.8	36.2	26.5	16.8	7.2	-	-	
Interest on short term loan	-	-	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	-	
Depreciation	-	-	261	261	261	261	261	261	261	261	261	261	214	2 824
Taxable Income			/52.2/	45.4	90.5	100.1	109.7	119.3	129.0	138.7	148.3	155.5	-	
Tax	-	-	-	21.8	43.4	43	52.7	57.3	62	66.6	71.2	74.6	-	
Net profit			/52.2/	59.1	47.1	52.1	57.0	62	67	72.1	77.1	80.9	-	522.2
Loan principal repayment	-	-	-	137.4	137.4	137.4	137.4	137.4	137.4	137.4	137.4	-	-	1 099.[illegible]
Net cash flow	-	-	208.8	132.7	170.7	175.7	180.6	185.6	190.6	195.7	200.7	341.9		2 247

*Total investment cost: 2 834 Mio Drs
Working capital: 165 Mio Drs

Grant: 25 % = 708 Mio Drs
Forex loan: 35 % = 992 Mio Drs
Equity: 40 % = 1 134 Mio Drs

Interest rate of Forex loan: 7 %, Repayment in 16 semesters; grace period of two semesters

Interest rate for short term loan: 21.5 %

Tax Rate: 4[illegible] %, no tax holiday

Net cash flow: net profit plus deprecia[illegible]

Table 8/6

Calculation of present value and internal rate of return[1] on owners' equity /financing model No 2/ for plant 40/83. /Values in '000,000 Drs/

Year	1	2	3	4	5	6	7	8	9	10	11	12	Salvage value[2]	Total
A. Cash inflow														
1. Sales revenue	-	-	844	1299	1299	1299	1299	1299	1299	1299	1299	1299	-	
B. Cash outflow /1+2+3/	400	734	635.5	1116.3	1128.3	1123.2	1118.4	1113.4	1108.4	1103.4	1098.4	957.1	/750/	
1. Investment costs													/750/	
a/ Equity funds	400	734	-	-	-	-	-	-	-	-	-	-		
b/ Forex loan principal repayment	-	-	-	137.4	137.4	137.4	137.4	137.4	137.4	137.4	137.4	-	-	1099
c/ Interest on Forex loan	-	-	-	74.6	65	55.4	45.8	36.2	26.5	16.8	7.2	-	-	
d/ Interest on short term loan			35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	-35.5	-	
2. Operation cost	-	-	600	847	847	847	847	847	847	847	847	847	-	
3. Taxes	-	-	-	21.8	43.4	48	52.7	57.3	62	66.6	71.2	74.6	-	
C. Net cash flow[4] /A+B/	/400/	/734/	209	183	171	176	181	186	191	196	201	342	750	1650
D. Present value[4]	/400/	/644/	160	123	101	91	82	74	67	60	54	81	155	[illegible]

Notes: 1. See Table 8/4
2. See Table 8/4
3. Discounted at the internal rate of return of 14.0 %
4. Rounded figures

Using the first model an internal rate of return of 10.5 % on the owners' equity results. Since the Greek system of investment promotion offers no tax holiday the profitability of the venture can be improved if outside capital available at relatively low cost is used. Under the selected financing model including outside financing the IRR calculated from the discounted cash flows is 14.0 %. This together with the pay-back period of 5 years appearing in Table 8/2 make the beneficiation of high grade Greek bauxite by the TATABÁNYA leaching/acid recovery technology an interesting idea to pursue.

The main reasons for the superior economic and financial performance of the 40/83 plant over 40/85 are as follows:

- leaching is more efficient as bauxite feed has more favourable minerology,
- less hydrochloric acid is lost as Ca+Mg level in feed is lower,
- material flows are lower,
- sales revenue is higher, despite lower pigment output, as top grade calcined refractory grade bauxite can be produced.

8.4. National economic evaluation

The production of calcined deironed bauxite from raw material available in Greece would have the following positive effects on the Greek national economy:

- Utilisation of local mineral resources for products with value added possible.
- Annual imports of some 10-15 thousand tons of refractory bauxite worth some 1.5 million US Dollars substituted by low import content local product.
- Exports potential of a few million US Dollars a year created for either refractory grade calcined bauxite, or refractory product made of it.
- Employment for 70 to 100 persons in a modern plant.

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9. Minutes of the tripartite discussions held in Hungary, 22-25 October 1986