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PROCESSING OF ALUMINIUM ONES WITH HEIGHTENED CONTENT OF Si AND/OR Fe^{1/}

by

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^{1/} The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO.

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SUMMARY

The following study involves low-grade bauxites with Al_2O_3/SiO_2 ratios lying between the values 8 to 3; industrial scale methods have been given preferred consideration and laboratory methods only brief mention. Characteristic signs of interest to those who are planning industrial development have been emphasized.

In the introduction the problem of high capital input and technical and economic risk in low-grade bauxite processing is emphasized. Good results can be expected only if the designed technology fully coincides with all local economic and technical factors. In complicated situations perspicuous planning has been recommended, including flexible technology design and location of a plant where there is a possibility of supply of both low-grade domestic and high-grade imported bauxites. In the first stage of planning a maximum effort should be given to start production at a profit enabling future growth and development. Mention was made of step-by-step planning to decrease technological risk.

Consideration has been given to the influence of heightened silica and iron content in the electrothermal, acid and alkalic extraction methods and classification of low-grade bauxites from this standpoint. Low-grade bauxites have been classified on the basis of bauxite silica module. Here a total alumina/total silica weight ratio was taken because for low-grade bauxites more energetical extraction means must be used. Electrothermal methods of molten corundum production and the processing of AlSi 65/35 intermediate alloy by total reduction have been considered. The Pederson and Haglund processes have not been described because they do not seem to be of economic interest.

The acid methods with characteristic main technological problems of acid extraction are described. As a prospective method the Australian BAS process has been briefly cited. A prospective of acid processing has been admitted for the production of aluminium sulphate, special alumina modifications for catalysis and alumina salts for the chemistry. For large-scale alumina production the acid methods have been refused because they represent heavy technological risk, fully unbalanced by economic advantage. The alkalic extraction methods, namely the Bayer method in low-grade bauxite processing, the self-reliant sinter process, parallel Bayer-sinter process, combination method, high-pressure digestion, the Ponomarev process and variations of the desilication methods are also described.

For an illustrative comparison of three fundamental processing methods, i.e. Bayer, sinter and the combination method, there was chosen an identical scale of bauxites with decreasing silica module from 8 to 3. Illustrative data characterizing alumina and soda recovery, red mud and sinter quantity and total heat consumption as a function of decreasing bauxite quality for each of the above-mentioned methods have been evaluated. For each of the alkalic extraction methods a brief technological description was given together with characteristic advantages and critical processing problems. Improvements have been cited, for example, the Montecatini improvement of sinter process, Kaiser method of reduction and sodalite bulk, and the special importance of high pressure digestion in low-grade bauxite processing. The desilication methods have not been recommended for industrial application. A detailed comparison of Bayer parallel and combination methods and two variations of desilication methods on the basis of data of one bauxite type with silica module above 6 has been cited. The author's opinion of various alkalic extraction methods is summarized in the conclusions.

Technical conclusions

From the given survey and data, it is evident that for economical alumina processing, the Bayer line represents a fundamental production unit; the sinter line an auxiliary and complementary unit. The trend shows that the bauxite under-quality

order is gradually being replaced by improvement of the Bayer processing technique in the direction of decreasing silica module of bauxite. The under-quality border of bauxite, to which the Bayer line can be economically processed, must in each individual case be estimated by the combination of technological experiments and economic calculations.

The bauxite quality-border where the technological and economic possibilities of wet digestion end and where it is necessary to apply a self-reliant pure sinter process, cannot be decided today with certainty. The reason lies in the fact that for the low-grade bauxites all technological and economic applications of the high pressure digestion technique have not yet been fully examined. It is now evident that in heat consumption the dispute has been definitely decided for high-pressure digestion, because for the sinter process a heat consumption of 750 kcal/kg sinter represents extreme construction possibilities and cannot be further substantially reduced. The same can be said for comparing the equipment extent of high-pressure and sinter attack. In such a situation a decision without risk can be made only in cases where natural and economic conditions allow for the installation of the Bayer line as a fundamental processing unit. The decision about the installation of the classic combination method and the pure self-reliant sinter process is problematic and a satisfying answer is expected in the next few years.

Installation of the auxiliary sinter unit remains fully entitled for causticisation of soda for/or from Bayer process, and this method cannot be replaced, especially for bauxites with heightened carbonates and organic matter content, and where there is cheap calcined soda.

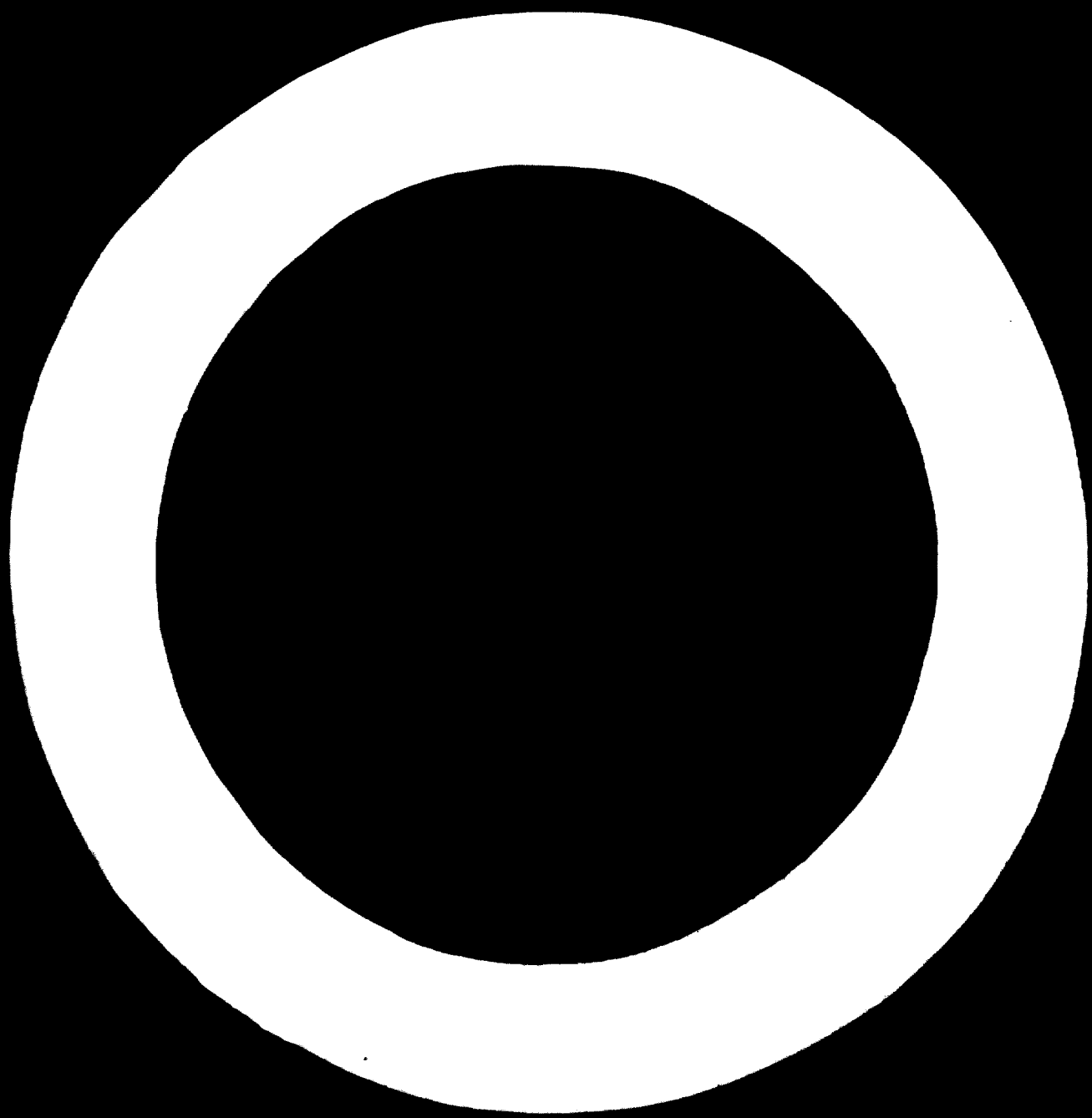
Planning conclusions

The complexity and number of factors influencing good economic results in processing alumina from low-grade bauxites shows that the right decision cannot be made in a few days, but only after a thorough study and analysis of all important questions, for which a minimum of two-years time is needed before design is started. The study and analysis of problems mentioned should therefore be started in actual cases without loss of time by a small group of domestic qualified engineers. This group should have an opportunity to consult all investigated questions with a neutral specialised organization, further to learn the practice of alumina producers, which work under similar conditions to realize at specialized institutes model and pilot-scale technological experiments, and to report the results and conclusions to a group of neutral specialists at a higher level.

Even in the case where alumina processing from domestic low-grade ores will not be realized, a remarkable effect for development planning can be gained, because the data necessary for the evaluation of alumina processing possibility are valid and of interest for the chemical, ceramical and metallurgical industries.

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Foreword

The purpose of the study is to present information to facilitate the orientation of alumina processing methods from low-grade bauxites. Due to the lack of a survey, the following limitations appeared to be necessary: (a) The low-grade bauxites involved here have $\text{Al}_2\text{O}_3/\text{SiO}_2$ weight ratios between 8 to 3; (b) Industrial scale methods are preferred over laboratory and pilot scale methods and are mentioned only where they represent advances for the future; (c) An attempt was made to emphasize characteristic signs of interest to persons who are planning industrial development.

I. INTRODUCTION

1. The foundation of an alumina industry processing low-grade bauxites should be estimated as a high capital investment influenced by a number of complicated relations. If we compare relative capital input between two plants processing high-grade and low-grade bauxites, the relative capital input in the first case will mostly not exceed the sum of \$200 per metric ton alumina. In the second case, up to double the amount of relative capital input per ton, year production, can be expected. This relative capital input increases with the decreasing Al_2O_3/SiO_2 weight ratio. The increment of capital input must not be critical above the value Al_2O_3/SiO_2 5 or 6.
2. Under the value Al_2O_3/SiO_2 5 it is in most cases necessary to build two plants or lines. The second one processes high-grade from low-grade bauxites (desilication method), or recovering soda and alumina from rich waste red mud leaving the Bayer extraction (combination method). A heightened number of technological steps necessary in low-grade bauxite processing means at the same time an increased input in the form of amortization, manpower and energy consumption. A combination of all these influences has bearing on elevating production costs. There does not exist any miraculous technological recipe for lowering relative production costs, if compared with processing of high-grade bauxites. Suggestions about revolutionary improvements in low-grade bauxite processing should be subject to a most critical examination. In fact, the majority of significant improvements in low-grade bauxite processing can be applied at the same time with good technical and economic effects for high grade bauxites.
3. In spite of all these disadvantages, there are a number of chances for countries - owners of low-grade bauxite deposits - to produce alumina at a profit. The world's big producers of alumina and aluminium, the United States, Canada, the Union of Soviet Socialist Republics, Germany (Federal Republic) and Japan, have local sources only in low-grade bauxite, or they do not have any at all. The advantage of simplicity and high effectivity of processing high-grade bauxites is often eliminated by long-distance transportation costs. If we compare the structure of production costs between the United States and Japan, both highly industrialized countries in similar conditions, with the alumina industry based on imported bauxites and classical Bayer technology, we can ascertain remarkable varieties:

	<u>Energy</u>	<u>Raw material</u>	<u>Amortization</u>	<u>Loans</u>	<u>Total</u>
United States	18%	40%	22%	20%	100%
Japan	35%	38%	21%	6%	100%

4. In the case of processing low-grade bauxite of various composition by different technologies under various local conditions, this variety can become, if examined carefully, a main source of economic reserve. The chances are good of the possibility of technical and economic errors with long-lasting consequence, if such an evaluation is neglected. This fact cannot be emphasized enough, when planning low bauxite processing.
5. A thorough examination of all brighter economic aspects influencing the choice of special technology represents a primary condition of success. For example, a decision to build a technologically reliable combined method with guaranteed high yields of alumina and low soda consumption can be unwise if there are low mining costs of low-grade bauxite and good possibilities to gain cheap domestic soda. The capital input in a sintering part of the combined method does not differ substantially from the input in a middle-scale soda plant or NaCl electrolysis.
6. This can be taken as an example that a processing method fully suited from the technological standpoint for a certain ore cannot alone guarantee the desired economic effect. Good results can be expected only when the designed technology fully corresponds with all local technical and economic change. This is not simple to accomplish. Local conditions might be geologically, technologically or economically evaluated incorrectly and a number of important factors substantially influencing results may not be known at the planning stage.
7. An exact evaluation of all influencing factors is, in most cases, a long-term project requiring not only geological and technological investigations and the necessary capital and time, but also a substantial proportion of experience gained only through practical participation. Such complicated questions arise, for example, when the quality of alumina ore is extremely low or fluctuating, if poor surface mining and transportation conditions exist and the low quality ore is then unbalanced, or if production requires very complicated technology and expensive equipment. In such situations perspicuous planning is recommended to let the doors open for more eventualities in the future. In some cases a plant can be situated in a place permitting a supply of both domestic low-grade and imported Bayer bauxites. Imported Bayer bauxites or a mixture of domestic and imported bauxites can represent temporarily the main economic production basis and the domestic bauxites an auxiliary strategic basis.
8. Technological equipment should be projected universally, corresponding to the possibility of necessary technological arrangements. Such flexibility can be realized by relatively little increased capital input for a limited amount of technological equipment. For example, to realize autoclave digestion at elevated temperatures and using for the causticisation of soda the parallel sintering line.

9. The capacity of a parallel sintering line will usually not exceed 15 per cent of the plant's total capacity. Such practical solving gives opportunity for an exact technological and economic examination of domestic low-grade bauxites together with the possibility of a temporary processing of imported Bayer bauxites with good economic results. The capital increment can be neglected in comparison with the risk and long-term financial losses, which may originate from a decision based on some primarily wrong or unverified assumption.
10. In the first stage of planning alumina production a maximum effort should be made to start production at a profit which would provide for further growth of the industry in the future. The above example illustrates the fact that there are means existing to solve complicated problems. It may happen that sound economic analysis will be suppressed by transitional strategic considerations. Alumina production in each big industry does not allow for such a solution, and for those who are not industrially great powers, it is best to have neither the economy nor the strategy.
11. Knowledge of the problems mentioned is not less important than knowledge of special technological and engineering matters. It is important because, especially in this sphere, often lie the source and possibility of great error. The technology and economy of processing alumina from low-grade bauxites can be done by means of known engineering principles with very effective improvements if a plant is based at the right place and has flexible equipment. No substantial improvement without high capital loss can be expected if the primary decisions have been wrong.

II. CLASSIFICATION OF LOW-GRADE BAUXITES AND THE INFLUENCE OF IMPURITIES

12. Classification of low-grade bauxites may be done from several standpoints. With respect to alumina, there is the known Bayer scale of hard and heavy soluble alumina monohydrates, diasporite and boehmite, and the easily soluble alumina trihydrate, and gibbsite (hydrargilite).
13. With respect to the ferric oxide content, there are normal, low iron white, and high iron ferritic bauxites. The content of Fe_2O_3 in white bauxites is 1 to 5 per cent, often occurring with a high silica content. In some cases it can be seen that the iron content decreases with increased silica content, but this is not a rule of general validity. The Fe-content in ferritic bauxites rarely exceeds 25 per cent in the form of Fe_2O_3 and its influence depends on the kind of technology used.
14. The electrothermic production of alumina as molten corundum represents Fe solvent for removal of other impurities Si, Ti etc. in the form of metallic FeSi alloy and therefore sometimes Fe compounds are added. There is one exception, if total

electrothermic reduction of white bauxites to Al 60-65 Si 40-34 intermediate alloy is processed, an Fe content is not desirable. In the acid-extractive metallurgy of alumina processing, the elevated Fe content is the source of trouble influencing the quality and a source of loss in acid radicals in the form of basic salts; therefore it is not desirable.

15. In the alkaline extraction the presence of Fe_2O_3 does not cause direct alumina and soda losses in chemical compound form, but is responsible for indirect losses in the moisture of red mud and causes serious complications in the settling, washing and filtration equipment. Finally dispersed colloidal hydrates in the form of limonite and goethite are more dangerous than the absolute Fe content, and they often occur with good soluble alumina trihydrate in bauxites of the tropical type. Much effort has been exerted to overcome such complications, and there exists a bright scale of technological means for handling bauxites with bad settling and filtration characteristics. Of more importance can be cited bauxite roasting, coagulants (dextrins and polyarylamides), addition of good settling bauxites, elevated digestion temperatures, special milling, settling and filtration equipment. Therefore for contemporary technological means the elevated Fe content in alkalic extraction does not represent a critical problem where necessary technological investigations have been realized.

16. In the sinter process (sintering bauxite with soda and limestone) some content of Fe_2O_3 (molar ratio to alumina 0.2-0.25:1) is needed, for sintering originated sodiumferrite causticizes the liquor and prevents alumina hydrolysis loss. But the elevated Fe content in the presence of other easy melting components causes gluing of sintering kilns and decreases the leaching yields of alumina and soda from sinter.

17. The economy and technology of processing alumina is determined by the alumina and silica content in the ore. Therefore this characteristic is of primary importance for the classification of low-grade bauxites.

18. In the praxis of world alumina producers processing the imported (and therefore with maximum quality desired) bauxites are those with reactive silica content above 5 per cent designated as lower grade. In the praxis of European producers are domestic bauxites with silica content 6 to 7 per cent processed by classical Bayer process at good economic result. (Note relativity in the term "lower grade" bauxites.)

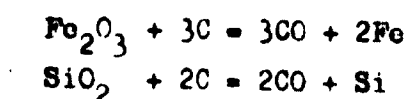
19. For low-grade bauxite classification, it is reasonable to introduce the term silica modulus of bauxite (MSi) as the weight ratio of total alumina to total silica present. (Bauxites with 48 per cent Al_2O_3 and 8 per cent SiO_2 will be classified as MSi6.) Total silica content should therefore be involved in the classification because for low-grade bauxites more energetical extraction means must be used.

20. Bauxites with $MSi < 8$ can then be designated as lower and low-grade. Bauxites with $MSi < 3$ are rarely processed. The world's bauxite deposits in the industrial category are estimated at 6,000 million metric tons and therefore processing of bauxites with $MSi < 3$ under normal conditions is an economic abnormality.
21. The influence of silica content in low-grade bauxites depends on the type of process applied. In the electrothermical processing of alumina, silica is removed by reduction to ferrosilicon and the energy for reduction needed raises the stream consumption from 1,300 kWh/t for pure alumina to 3,300-4,000 kWh/t for alumina in the presence of elevated Fe and Si content. In the total reduction of white bauxites to AlSi intermediate alloy silica in the form of pure quartzite or low iron kaolinite must be added to 35 to 40 per cent Si in alloy present, reduction of alumina in presence of lower Si content being impossible.
22. In the acid methods silica does not react with the acids, but it is responsible for indirect losses of acids in the form of filtration cake moisture. Colloidal forms of silica sometimes make the acid process impossible. In the Bayer process silica represents the main source of alumina and soda loss in the form of sodalite. The chemical composition of sodalites formed depends on the ore character and the processing conditions and formulae for the practical evaluation of chemical losses of soda and alumina should be in each special case experimentally verified. Preliminary rough calculation is for 1 kg SiO_2 present 1.1-1.2 kg Al_2O_3 and 0.65-0.70 kg Na_2O loss is used mostly. Of practical importance is the ion exchanging character of sodium aluminosilicates in sodalite. The sodium group can be replaced by calcium-hydrate, but in economically interesting conditions (under 2 moles of 2 CaO to 1 mole Na_2O) the recovery of Na_2O rarely passes over 40 to 45 per cent, sodalites originated at elevated digestion temperatures being in most cases less reactive.
23. In sintering bauxite with soda and limestone, silica is bound in the insoluble form of dicalcium silicate, $2CaO \cdot SiO_2$. Here the heightened content of silica influences the yield of alumina and recovery of soda is substantially less than by Bayer. In the absence of heightened Fe content, decrease of one MSi unit will be connected with a decrease of 0.5-0.6 per cent in alumina yield. In the presence of heightened Fe content this decrease per MSi unit will be 1 per cent and sintering, cooling and leaching conditions will be very important. The form of silica content is not without practical importance. In the presence of little reactive coarse grains of quartz silica, an attempt to wash the grains out is reasonable. The presence of silica in the form of crystalline alumino-silicate is exploited in the desilication process. By roasting the ore at 600 to 1,050°C the alumina becomes less, silica more reactive;

therefore, the substantial part of silica can be washed out by dilute caustic and heightened MSi of bauxite results (desilication method). As a result it can be said, that the absolute content of silica influences the technological process chosen more substantially than the silica form.

III. ELECTROTHERMIC EXTRACTION OF ALUMINA

24. Description: Crushed bauxite is melted in electric arc furnaces in the presence of coke. A reducing agent is added in the stoichiometric proportion



with necessary increments for reduction of other impurities. FeSi solves other impurities and settles at the hearth bottom. If worked periodically, alumina from FeSi is mechanically separated by crushing the cooled content. If larger melting capacity is used, the process can be continual with decantation of the FeSi in an arc-heated forehearth.

25. The product is brown corundum with maximum 96 to 97 per cent alumina content. The Si and Fe are above 1 per cent each, however the corundum is unsuitable therefore for the production of aluminium. It is used for production of abrasives and refractories of common quality. The Fe content can be lowered by means of spraying the alumina melt by overheated steam and leaching the grains by dilute acids.

26. Heightened alumina quality with Fe and Si content of 0.05 per cent each is cited in the patented Pechiney process. A reducing agent is added in two steps. After the first step mentioned above is added 0.2-0.3 stoichiometric excess of reducing agent and the finely dispersed metallic impurities in molten alumina are precipitated by the addition of iron metallic scrap without iron oxide content. Refined alumina melt is sprayed by compressed air, some portion of aluminium carbides being destroyed.

27. Characteristics: The electrothermic method is characterised by maximum simplicity of equipment and it is influenced little by the ore character, the electric arc furnace representing the main capital item.

28. The process can be started with little electric arc furnaces of a capacity less than 1,000 kVA and a minimum of equipment if manpower is not expensive. Consumption:

electric energy	3,300-4,00 kWh/t alumina
electrodes	20-35 kg/t alumina
coke	70-120 kg/t alumina

High energy consumption indicates that the process can be applied if steam power is not expensive. Hearth energy consumption evaluated for a middle steam power station represents 9 to 10 million kcal/t alumina. Together with the fact of unsuited quality this makes the product application for aluminium reduction problematic. For the production of abrasives and refractories the method is suitable, which is proved by its parallel existence with the big classical Bayer plants. The same precaution is necessary in the price evaluation of the ferrosilicea by-product, which must not even correspond to the rigorous requests of steel producers.

IV. ELECTROTHERMIC REDUCTION OF WHITE BAUXITES TO Al65Si35 ALLOY

29. Description: Milled dry white bauxite with low Fe_2O_3 <2 to 2.5 per cent is mixed with necessary SiO_2 substance (dry milled kaoline or quartzite) and stoichiometric portion of reducing agent (high reactive low ash <6 per cent washed lignite) and briquetted 0.85 to 0.90 of carbon with respect to the reaction $Al_2O_3 + 3C = 3CO + 2Al$ and $SiO_2 + 2C = 2CO + Si$ being added. A removal of Fe excess from the charge by addition of NH_4Cl and grinding at $400^\circ C$ is possible. The briquettes are melted in an electric arc furnace where reduction takes place. The tapped intermediate alloy Al65Si35 is mixed with molten aluminium, cooled to $630^\circ C$, impurities in the form of by-product Si 16 to 30%, Fe 5 to 10%, Mn 7 to 17% being in crystalline form from eutectic silumine AlSi13 are filtered. Presence of Fe before filtration is compensated by Mn addition. Instead of ammonium chloride, a removal of Fe_2O_3 excess by gaseous chlorine inlet directly on the briquettes before the melting zone is cited.

30. Characteristics: Consumptions for one ton of Al65Si35 intermediate alloy:

el. energy	11,500	kWh/t
bauxite + quartzite	3.9	t/t
lignite	0.9	t/t

for one ton of final product AlSi13 foundry alloy:

intermediate alloy	0.5	t/t
aluminium	0.69	t/t
el. energy	0.5	MWh/t
by-product	0.21	t/t

Filtration wastes Si 16 to 30%, Fe 5 to 10%, Mn 7 to 17% Al rest as deoxidant suitable for steel industry. Relative capital input represents 70 per cent of them, if AlSi13 foundry alloy by pure aluminium and pure silicium metal is produced, processing costs being 80 to 85 per cent the same. The process is ruled good on one-phase furnaces, which means asymmetric stress of the power system, three-phase melting not fully ruled. Some prudence is necessary at the filtration rest price evaluation.

31. Total electrothermic reduction of white bauxites represents a very compact and perspective process, which gives to low iron white bauxites with high silica content higher value than other low-grade bauxites. Therefore this method was involved.

32. Other electrothermical methods, especially designed to produce alumina for Al electrolysis as the Pederson and Haglund process are not described, because they do not have any economic perspective.

V. THE ACID PROCESSES OF ALUMINA EXTRACTION

33. Improvement of acid attack by means of HCl, HNO₃, H₂SO₄, H₂SO₃ on low-grade alumina ores has been subject to many attempts and to numerous patents. Until now acid processing has not been able to compete in technical or economic spheres with the alkalic methods of alumina extraction. In economic evaluations of acid processing data from the German and Japanese industries during the Second World War there are data cited with production costs two to five times higher than in the case of Bayer production.

34. There are more serious difficulties complicating acid processing:

- (a) High corrosivity of acid solutions and gases is connected with the need of expensive special materials and short service life of equipment;
- (b) The good solubility of iron and other impurities in acids complicates the purification of alumina intermediate products;
- (c) The recycling of reagents, especially from the calcination stage, is very difficult and is connected with high heat consumption,
- (d) The extraction efficiency is, in most cases, lower than the efficiency of the alkalic processes;
- (e) In the presence of colloidal silica forms the processing can fail because of bad filterability of the mud.

35. To overcome the problems mentioned, in many cases technological means have been recommended. In recent years there have been some sound ideas, verified in model scale among which the basic aluminium sulphate process designated CSIRO Melbourne should be mentioned.

36. The process performs double steps countercurrent leaching the ore in diluted sulphuric acid at 180 and 130°C, by means of which the ore excess in the second step, the aluminium sulphate, is converted into the basic form. A ferric sulphate is converted to ferrous by reduction with SO₂ and hydrolysis of basic aluminium sulphate gives therefore a low iron intermediate product. Main problems are represented by the equipment for calcination.

37. The arrangement of the process consists of six technological steps in closed circuit modelling, in general the Bayer idea. Cheap sulphur and energy sources are needed. The method is unsuited for ores with alkalic and alkalic earth carbonate content; white bauxites with a low iron content are preferred.

38. The future of reasonably designed acid processes cannot be excluded, especially in the sphere of aluminium salts production and for the preparation of special modifications of alumina for catalysis and chemical purposes. Here the suitable acid production methods could be fully entitled.

39. But for the large-scale alumina production of today and for the future the acid methods of alumina production represent a heavy technological risk, absolutely unbalanced by corresponding economic advantages.

VI. ALKALIC EXTRACTION METHODS

40. Two fundamental methods from which all other processes for low-grade bauxites are derived are the Bayer method and the sintering process. If two qualities of bauxite can be mined the better one can be utilized in the Bayer process and the other one in the sinter process. This is the parallel method which can be converted gradually into a combination method, if the rich red mud from the Bayer is processed by sintering with limestone and soda. If we replace the normal Bayer autoclave vessels by tubes, enabling digestion to perform at temperatures above 250°C, preferably at 290-320°C, we have high pressure digestion.

41. If we substitute in processing of gibbsitic bauxites the influence of elevated digestion temperatures by high content of Na₂O caustic (300-400 g/litre) to dissolve all the silica present, working without pressure, we have the Ponomarev method. If we roast the grinded bauxite at 600-1,050°C, silica being then more, alumina less reactive, remove the reactive silica with diluted caustic, and resulting heightened grade bauxite utilized by normal Bayer, we have desilication method.

VII. THE BAYER IN LOW-GRADE BAUXITE PROCESSING

42. Description: The Bayer process, as already known, consists of the alkaline digestion of bauxites, wherein the alumina is extracted, the separation of the alumina enriched liquors from the residues of digestion, the autoproccipitation of Al hydrate from supersaturated caustic aluminate liquors, and finally the calcination of the hydrate. After the precipitation of Al hydrate the liquor spent in this process is recycled in the digestion phase, the excess of water is removed by evaporation.

43. Characteristics. To give a better imagination about the influence of bauxite quality on Bayer process data, we will examine the scale of bauxites with MSi decreasing from 8 to 3. The same scale of bauxites will be used for numerical comparison of sinter and combination process data. It should be emphasized that the following illustrative examples can in no case replace special experimental investigations necessary in each concrete case, but they are useful to compare dynamic characteristics of the mentioned processes, dependent upon bauxite quality change. The data of heat consumption refers to alumina in trihydrate form. The data of alumina chemical yields are not to be changed by mistake with alumina plant yields, the last ones are 3 to 6 per cent lower.

Bauxite scale:

MSi	Al_2O_3/SiO_2	8	7	6	5	4	3
	Al_2O_3 %	50	50	50	50	45	45
	SiO_2 %	6.25	7.14	8.33	10	11.25	15
	Fe_2O_3 + imp. %	28.75	27.86	26.67	25	28.75	25
	Fe_2O_3 + SiO_2 + imp. %	35	35	35	35	40	40
	L.O.I. %	15	15	15	15	15	15

44. For this illustrative scale of bauxites let us evaluate the chemical yield of alumina and the chemical loss of Na_2O in red mud by means of the molar ratio formulas:

- (a) 1.0 Na_2O :1.0 Al_2O_3 :2.0 SiO_2
- (b) 1.2 Na_2O :1.3 Al_2O_3 :2.0 SiO_2
- (c) 1.4 Na_2O :1.3 Al_2O_3 :2.0 SiO_2

It means that from 1 kg of SiO_2 will be bounded in the case

- (a) 0.85 kg Al_2O_3 and 0.52 kg Na_2O
- (b) 0.94 " " 0.62 "
- (c) 1.11 " " 0.72 "

45. With the decreasing quality of bauxite the results will then be:

MSi		8	7	6	5	4	3
Al_2O_3 yield %	(a)	89	88	86	83	79	72
	(b)	87.5	86.5	84.5	81	76.5	69
	(c)	86.5	84.5	81.5	78	72.5	63
Na_2O loss kg/t Al_2O_3	(a)	73	84	100	126	164	242
	(b)	88	102	122	152	203	300
	(c)	104	123	148	185	248	370

MSi	8	7	6	5	4	3
Dry red mud quantity kg/t Al_2O_3						
(a)	980	1,010	1,040	1,180	1,560	1,780
(b)	1,020	1,070	1,140	1,250	1,680	2,050
(c)	1,080	1,140	1,240	1,375	1,830	2,260

46. We can evaluate the approximate total heat consumption if we assume at MSi heat consumption 2.5 million kcal as a basis, from what 1.3 million kcal will be linear

function of red mud quantity. Then for MSi:

	8	7	6	5	4	3
mil. kcal/t Al_2O_3 :	2.5	2.6	2.7	2.9	3.4	3.9

47. From this example some conclusions can be deduced:

- (a) Of significant importance is the molar ratio of sodium aluminosilicate. It can be noted that this is equivalent to a change in bauxite quality of 1-2 MSi. The formula (a) is theoretical. Alumina yields corresponding to formula (b) have been experimentally reached with the high pressure digestion. Yields corresponding to formula (c) are reached with good technology at autoclave leaching;
- (b) The negative influence of decreasing MSi has its inflexion point at M5; from here the alumina and soda loss is increasing progressively. At the same time the quantity of red mud is increasing to a doubled value, which is connected with a duplication of the capacity of the evaporators and washing tanks. A good sedimentation of red mud is necessary; hence the high pressure leaching should be preferred;
- (c) A good imagination is given that for a low-grade bauxite Bayer processing, the price of soda is of principal importance. The chemical loss of soda represents 70-75 per cent of total soda losses, if not causticized with lime. Therefore sources of high quality limestone are of substantial importance. The reaction of red mud sodium aluminosilicates is a typical reversible process. Therefore before causticisation the red mud must be thoroughly washed and divided from free caustic. The causticization has a negative influence on V_2O_5 recovery, and the loss of alumina is somewhat increased.
- (d) The chemical loss of alumina in sodium aluminosilicate represents 80 per cent of total losses at MSi 6, 20 per cent being due to hydrolysis and causticization. The plant yields will be at MSi 7-6 lower of circa 4 per cent than the chemical yields, at M5-4 this difference can be above 6 per cent.

VIII. THE SINTER PROCESS

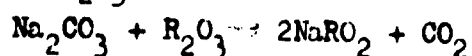
48. Description: Bauxite, limestone and soda together with concentrated soda liquor from evaporators are wet milled to a size of 175 mesh in a slurry with maximum 40 per cent free water content corresponding to following chemical composition: limestone to silica is calculated -

for stoichiometric composition $2\text{CaO}:\text{SiO}_2$

soda to alumina and ferric oxide:

for stoichiometric ratio $1\text{Na}_2\text{O}:1\text{Al}_2\text{O}_3$ and $1\text{Na}_2\text{O}:1\text{Fe}_2\text{O}_3$.

49. The slurry is sprayed by pumping at 15-25 ata into the cold end of the rotary kiln and sintered at 1,200-1,300°C. Silica is bounded in the form of little soluble dicalcium silicate. Soda reacts with Al_2O_3 and Fe_2O_3 present in the form



50. Sodium aluminates being in hot water better, sodium ferrites less soluble. The cooled sinter is crushed to a size of 6 mm and leached by hot water in countercurrent. The leached rest containing CaO , SiO_2 , Fe_2O_3 is as a waste "brown mud" pumped to deposit.

51. Fresh liquor with alumina content 130-160 g/litre and caustic mol ratio $\text{Na}_2\text{O}/\text{Al}_2\text{O}_3$ 1.6-1.7 is desilicated in autoclaves from silica content 8-10 g/litre to 0.4 - 0.7 g/litre, the white mud of sodalites is removed by control filtration. Clear liquor is precipitated by washed gas from rotary kilns corresponding to the reaction $2\text{NaAlO}_2 + 3\text{H}_2\text{O} + \text{CO}_2 = 2\text{Al}(\text{OH})_3 + \text{Na}_2\text{CO}_3$.

52. The "carbonised" alumina hydrate is filtered, the filtrate representing the soda solution thickened in evaporators and recirculated to sinter charge preparation.

53. Characteristics: The process is little depending on the bauxite character, diasporitic bauxites have advantages in slurry preparation, gibbsitic bauxite tends to a gelatinous slurry with elevated water content and decreases the rotary kiln capacity. The decrease of alumina yields with decreasing MSi is substantially slower than at Bayer.

54. High quality limestone with minimum silica and MgO content is necessary. MgO forms insoluble alumina spinels and has decreasing alumina yields. High quality fuel or coal with low ash content and sulphur content of 1 per cent is necessary. The presence of sulphates complicates sintering by gluing the rotary kilns, at the same time the soda loss is elevated.

55. If alumina is only desilicated by autoclaves, a high silica content in the final product, 0.20-0.25 per cent SiO_2 must be expected. To produce an alumina of Bayer

quality, i.e. with 40.06 per cent SiO_2 , a second desilication step by means of stirring with lime or limestone addition must be performed. Vanadium present in the bauxite is lost in brown mud in the form of calcium vanadate. The total heat consumption among the different special technologies for low-grade bauxites. Skilled personnel for the supervision of rotary kilns, turbo-compressors etc. are needed.

56. Improvements: The process economy is deeply influenced by the specific heat consumption per ton sinter and by the character of sinter granules for leaching, parallel existence of the particles; for example, 6-10 mm size and dust makes the conditions of leaching unequal. The coarse grains are unleached; at the same time the fine particles are a source of unwanted side reactions.

57. The Montecatini Company published an improvement of the sinter process in which the dry sinter charge is pelletized to a uniform size of 1-3 mm, sintered under addition of 3 mm carbon particles on grid or DW belt. The sintered pellets are leached without grinding by agitation in hot caustic and desilication is realized under normal pressure by means of stirring with Bayer red mud. The brown mud from the leaching step has a Na_2O content less than 0.8 per cent. The extraction yields of alumina represent 90-92 per cent for ores with a medium content of SiO_2 , and 87-89 per cent for ores with silica content of 10-14 per cent. The authors insist that the total Na_2O losses will in no case exceed 45-50 kg/t Al_2O_3 .

58. Total heat consumption per ton of alumina in trihydrate form represents 3.75 million kcal, distributed: 0.25 million kcal for ore drying; 1.24 million kcal for evaporating the water used in sinter leaching and washing, and 2.25 million kcal for sintering. The heat consumption per ton of sinter at this process is 0.80-0.85 million kcal. For a daily production of 100 t alumina, two Greenawalt pans of 30 m² are needed.

59. The equipment is suitable for a middle-size production. The capital costs are reduced to 60 per cent if compared with Bayer and to 40-45 per cent if compared with the classical sinter process based on rotary kilns. With European bauxites the cost of alumina in the pyrogenic aluminates should be 20 per cent less than for Bayer process of alumina, if causticization costs are taken into account.

60. There can be some critics on the consumption data and the simplified technology because the Montecatini process does not work as a self-reliant pure sinter plant, but parallel to the Bayer process. In spite of all that, the published Montecatini report contains a number of reasonable improvements, important for the further development of the sinter process.

61. Let us evaluate some characteristic data for the classic sinter process, working as a self-reliant circuit with rotary kilns for illustrative scale of bauxites with decreasing quality from MSi 8 to MSi 3, identical with that of Bayer. In the example we put the heat consumption per ton of sinter 1.3 million kcal. (The latest improvements of cement works rotary kilns publish the heat consumption <0.8 million kcal per ton of sinter.)

62. We will calculate with molar ratios: $2CaO:SiO_2$
and $/Al_2O_3 Fe_2O_3/:SiO_2$

and we will take into account that 15 per cent of the sinter weight is recirculating in the form of reversible wastes (desilication sodalites, sulphates, dusts etc.).

Then:

MSi	8	7	6	5	4	3
Al ₂ O ₃ chemical yield %	86	85	84	83	81.5	80
Na ₂ O cons. kg/t Al ₂ O ₃	83	87	91	100	120	140
sinter t/t Al ₂ O ₃	3.8	3.9	4.0	4.1	4.5	4.9

63. Taking into account that the heat consumption of the sinter process wet line does not substantially differ from Bayer and therefore taking for total heat consumption the sum of heat necessary for sintering and for the wet line:

Heat for sinter million kcal	4.95	5.1	5.2	5.3	5.8	6.4
Heat for w. line " "	2.5	2.5	2.5	2.5	2.5	2.5
Total million kcal/t Al ₂ O ₃	7.45	7.6	7.7	7.8	8.3	8.9

IX. THE COMBINATION METHOD

64. Description: Low-grade bauxites are digested with caustic soda as in the normal Bayer process. The red mud from Bayer process is washed in two to three steps and filtered, part of the red mud dried. The red mud with corresponding reduced humidity content is processed after adding limestone of lime and calcinated soda in sintering process. The sinter from the sinter process is leached in ball mills, the aluminate liquor is connected with liquors from Bayer digestion and alumina precipitated by decomposition. The sodium carbonates from Bayer are causticised in sinter process.

65. The main part of alumina (75-85 per cent) is produced in the Bayer line; the sinter line is installed in order to avoid alumina and soda losses in the red mud. The high recovery of alumina and soda is a result of two gradual steps. If in the first Bayer step, for example, the recovery will be 70 per cent and the loss 30 per cent, in the second sinter step with the recovery 70 per cent (from 30 per cent = 21 per cent) we can reach a total chemical recovery of 91 per cent.

66. Characteristics: For better imagination let us evaluate data for bauxite scale identical with that of the Bayer and sinter processes:

MSI	8	7	6	5	4	3
Total alumina yields	94	93.5	93	91.5	90	88
kg Na ₂ O/t Al ₂ O ₃	45	48	52	58	75	90
Sinter bulk t/t Al ₂ O ₃	1.2	1.3	1.4	1.6	2.0	2.4
heat cons. total mil. kcal per t Al ₂ O ₃	4.1	4.2	4.3	4.5	5.1	5.7

for 1.3 mil. kcal/t sinter and 2.5 mil. kcal for Bayer line.

67. Heat consumption is between that of the Bayer and sinter processes; the recovery of alumina and soda is less influenced by the bauxite quality decrease. The advances are paid by high number of technological steps, which means expensive equipment. The sedimentation and filtration properties of Bayer red mud are very important. In a positive case the number of washing steps can be substantially reduced, or practically eliminated. The filtration is expensive. For a normal red mud filtration a drum filter with an efficiency of not more and 50-80 kg dry cake/m². hour can be expected, which means for example at MSI 5 a specific filtration surface of 30 m² for one ton alumina hour capacity. The presence of elevated iron content does not complicate only the filtration, at the same time the lowered melting point of the charge for rotary kilns makes troubles in processing them. Sometimes the charge of rotary kilns must be re-freshed by addition of bauxite to the red mud (at weight ratios 1:3 or 1:2). Therefore the sinter bulk per ton of alumina can increase to 140-180 per cent and results in a material flow not different from pure sinter process.

68. The leaching of sinter with low alumina and soda content at heightened bulk of silica and iron oxides must be accomplished under energetic conditions. The combination method is, in comparison with other processes, characterized by high technological flexibility. The gradual combination can be, with relatively little capital increment, converted to parallel Bayer-sinter process with the production increase of 20-50 per cent due to the red mud bulk, which was converted from two steps to one step processing and replaced by fresh bauxite for sinter process. For this reason, under normal conditions if good quality bauxites are available, the combination method is applied as a parallel system.

69. Improvements: The Kaiser Company has patented a process with special Bayer digestion equipment, allowing for concentrated sodium aluminium silicates in the form of pellets, decreasing the sinter bulk. The main part of iron oxides remains in the Bayer red mud in fine suspension, which is not subject to two-step gradual processing. Further advantages in the filtration and drying of pellets are evident. Replacement

of the filtration of red mud by settling and drying in open basins under suitable meteorological conditions has been recommended. Improvements of the sinter process described by the Montecatini Company and the improvements of rotary kilns design are also of interest.

X. THE PARALLEL BAYER-SINTER PROCESS

70. Description: The process consists of two parallel production lines, the Bayer and the sinter line. The Bayer line is designated for good quality bauxites, the sintering line processes low-grade bauxites by pyrogenic attack with sodium carbonate and limestone. Sodium carbonates from Bayer are added to the fresh soda portion necessary for compensation of losses and hereby causticized. The aluminate liquor from the sinter line is connected with the liquors from Bayer and decomposed to alumina hydrate.

71. Characteristics: The parallel Bayer-sinter process as a whole is simpler than Bayer and sinter processes working individually. The causticization of sodium carbonates generated in Bayer is replaced by sinter process. Wet causticization in the pure Bayer process by lime addition is connected with an alumina loss in the form of insoluble calcium aluminate. In the causticization by the dry method of sintering there is no alumina loss.

72. The proportion of alumina flow in sinter process aluminates to Bayer line aluminates is determined by the quantity of sodium carbonates to be worked up and represents mostly 1.5-2:10. Because the ratio of aluminates from sinter process is relatively low, they can be precipitated by decomposition; hence the expensive carbonisation and pressure desilication is not necessary.

73. At the same time the existence of parallel Bayer and sinter line enables reliable experiment in processing low-grade bauxites by the combination method without excessive capital risk. But if the combination process will be realized, it must be calculated with a capacity loss in alumina in rotary kilns (Al_2O_3 content in sinter will decrease from 35 per cent to 10-15 per cent) and capital increment in the red mud filtration and for brightened capacity of rotary kilns, which must be able to process all the red mud. The parallel process should also be preferred if the calcined soda is cheaper and more easily attained than the caustic, and if the bauxites show an increased content of carbonates and organic matter.

XI. THE DESILICATION PROCESS

74. Description: The desilication process consists of three lines. In the first line from low-grade bauxite after roasting at temperatures 600-1,050°C (for activation of silica and inactivation of alumina) silica is leached by diluted caustic or aluminate liquor. In the second line the filtered cake of desilicated bauxite, which is now high-grade, is treated by the normal Bayer method. In the third line from the dissolved sodium silicate soda is regenerated by means of precipitation di calcium silicate with lime addition, or if silica dissolved in caustic sodium aluminate, sodium aluminium silicate is precipitated by sodalite mud addition. The temperature of bauxite roasting depends on the form of regeneration of caustic from sodium silicate.

75. If regenerated only in wet process by lime addition, the loss of alumina dissolved in the desilication step is irreversible and therefore the roasting is performed at temperatures 1,000 to 1,050°C to make alumina in bauxite less soluble. In the second case, if desilication has been performed by caustic sodium aluminate, alumina is precipitated with sodalite inoculation, sodalite filtered and processed by sintering with limestone. Here is minimum alumina loss and therefore the bauxite roasting can be performed at temperatures of 600 to 650°C.

76. In both cases the caustic after filtering the calcium silicate or sodalite mud is recirculated to the desilication step. If roasting at temperatures under 1,000°C and higher is made, 65-68 per cent silica from low-grade bauxite can be extracted; if roasting is made at 600°C, the recovery of silica is higher and represents 75 per cent. In both technological modifications of desilication it is necessary to recover the silica by milling bauxite with caustic and by long stirring (5 to 6 hours) in diluted alkali.

77. Characteristics: The desilication method is subject to a number of patents which recommend different alkali concentrations, temperatures, stirring times, or two-step silica extraction with concentrated and diluted alkali. In spite of that, all the desilication method has not been applied for large-scale production, and some of the technologies recommended by patents have failed on experimental investigation because of bad filtrability of desilicated bauxite.

78. There are more serious complications in the principle of the desilication method. The material flow of bauxite roasting is the same, or greater, than sinter bulk in the combination method. The high roasted alumina must be digested at high pressures. The settling properties of red mud from desilicated bauxite after Bayer digestion will be a source of trouble if bauxite in the desilication step has been over-milled. The material flow of desilicated bauxite to filtration will be doubled compared with the

red mud flow in the combination method. In desilication performed by caustic soda, which is regenerated by lime, about 10 per cent of alumina present in the bauxite will be irreversibly lost as calcium aluminate. If soda is regenerated by sintering of precipitated sodalite with limestone, the bulk of the sinter will be reduced only to 50 to 60 per cent if compared with the sinter bulk in the combination method. This decrease cannot settle the complications connected with expensive equipment and the high number of previous desilication steps.

79. A comparison between desilication process, combination method, classical Bayer, and parallel Bayer-sinter processes has been made by Hungarian specialists. The comparison was based on a combination of laboratory tests, practical experience and calculations. The comparison was made for domestic bauxite with MSi 6.65 of following analysis: Al_2O_3 51.7%, SiO_2 7.77%, Fe_2O_3 22.8%, TiO_2 2.5%. It is useful to cite the results. The symbols used are:

- 1B - Normal Bayer process
- 2C - Combination method
- 3P - Parallel Bayer-sinter process
- 4DS - Desilication by aluminate solution and regeneration of soda from sodalite by sintering
- 5DL - Desilication by dilute alkali and wet regeneration of soda by lime

A comparison of processes

<u>Processing method</u>	<u>1B</u>	<u>2C</u>	<u>3P</u>	<u>4DS</u>	<u>5DL</u>
Consumption per t Al_2O_3 : bauxite t	2.95	2.52	2.57 ^a / 0.32 ^a	2.75	3.09
NaOH kg	139	-	-	103.5	97.7
Na_2CO_3 kg	-	71.5	170	-	-
CaO kg	196	129	120	-	160
$CaCO_3$ kg	-	972	153	430	-
Steam 70 (2ta) t	1.65	1.37	1.47	1.91	1.69
Steam (4 ta) t	1.25	1.62	1.50	2.07	2.49
Oil for b. roasting kg	-	-	-	102	152
Oil for sintering kg	-	216	78	71	-
Oil for Al_2O_3 calcination	113	113	113	113	113
Oil total kg	113	329	193	286	265
El. energy kWh	286	328	331	374	342
Alumina yields for plant %	78.7	92.2	80.4	84.5	75.2
Na_2O loss for plant kg	105.5	41.4	97.2	78.4	74.0

^a/ To sinter line

For Hungarian price level, production costs are increasing in this order: combination method, parallel Bayer-sinter process, classical Bayer, desilication methods.

XII. THE PONOMAREV METHOD

80. Description: The method was proposed especially for gibbsitic bauxites with high silica content. The bauxites are extracted with Na_2O liquors of the concentration 450-550 g Na_2O /litre under normal pressure and temperatures of 100 to 130°C for five to ten minutes. Total silica content is dissolved together with alumina, the filtration cake being rich in iron.

81. Desilication of aluminate liquors is proposed to be made by lime addition at temperatures of 220 to 250°C in molar ratio $\text{CaO}:\text{SiO}_2$ 1:1 for ten to twenty minutes. The purified liquor is evaporated to 500-550 g Na_2O /litre and the sodium aluminate crystallized in solid state. The solid sodium aluminate is dissolved in weak liquor and alumina trihydrate is precipitated by Bayer decomposition.

82. More detailed characteristics of this method cannot be given, because there are no data from large-scale processing available. The method is subject to laboratory improvements; the present short reaction times are interesting. It is not possible to say exactly if the advantages of this original method will balance the problems and troubles of processing equipment with extremely high caustic concentrations and liquor gradients among the different steps of the process circuit. The low saturation of caustic by alumina at digestion (caustic module $\text{Na}_2\text{O}:\text{Al}_2\text{O}_3$ 12) is also problematic from an economic standpoint.

XIII. THE HIGH-PRESSURE TUBE AUTOCLAVE DIGESTION

83. Description: This newest method is based on the fact that the reaction velocity of dissolving alumina in caustic is increasing exponentially with the digestion temperature so that at temperatures of 290 to 320°C a digestion time of only five to ten minutes is needed. The tube autoclave construction is based in the experience of the pipe-style process known in oil refineries, and on the experience of high-pressure pump construction. The technology is based on the thermal Bayer circuit.

84. The caustic-bauxite slurry with molar ratio $\text{Na}_2\text{O}:\text{Al}_2\text{O}_3$ 1.35-1.45 is piped at 100-110 ata into a tube in tube countercurrent heat exchanger, from here into the tube boiler which is heated to temperatures 290 to 320°C (depending on the solubility of the alumina form present) by means of direct heat or salt bath. After the necessary reaction time, the slurry returns to the heat exchanger and is cooled at 110 to 120°C, the pressure is reduced by a reduction valve. The cooled aluminate liquor with red mud suspension is adjusted by old liquor from decomposition to a necessary caustic modulo (1.6) to avoid hydrolysis in red mud settling and washing. Clear aluminate liquor is precipitated by decomposition. The V.A. Company replaced

the countercurrent cooling of autoclave slurry by direct expansion under normal pressure, the system functioning on an evaporator, which must then not be separately installed.

85. Characteristics: A high-pressure tube autoclave digestion brings into the processing technique a number of significant advantages, especially for bauxites with heightened iron and silica content.

86. The chemical loss of alumina represents 0.95-1.0 kg Al_2O_3 for each kg of silica content. For high-grade bauxites the alumina loss is somewhat higher and represents 1.1 to 1.2 kg. Diasporite is dissolved without special technological means by concentrating the caustic liquor.

87. The presence of an elevated ferric oxide content in limonite, goethite and hydrogoethite - dangerous iron modifications for classical settling and filtration equipment - is here neutralized by dehydration of ferric oxide hydrates at elevated temperatures of the digestion. Therefore the voluminous settling equipment can be replaced by washing in drum filters, which means economy in water consumption. Water consumption can be reduced to 50 per cent if compared with the water consumption for red mud washing in the classical Bayer process. Hence the economy of heat for evaporators results.

88. A further source of heat economy is the possibility to perform the bauxite digestion with low caustic concentrations of 140-150 g Na_2O /litre, against 230-280 g Na_2O /litre in classical Bayer. Because no concentration gradient between decomposition and digestion exists, evaporation is not necessary. The high saturation of caustic by alumina to ratios 1.35 to 1.45 in contrast to the 1.7 caustic module in the classic Bayer process reduces the bulk of liquors circulating in the digestion step to 65 to 70 per cent; a less liquor volume per ton of alumina must then be heated. Therefore, the total heat consumption was 0.4 million kcal per ton of alumina reached; at the same time a significant simplification of the technological equipment results (0.4 million kcal for high-grade Bayer bauxites).

89. The engineering technique of this new processing method is not fully ripe. There are problems with the service life of high-pressure pumps, reduction valves etc., but their removal is a question of experience and time. However, the relations:

low-grade bauxites = low alumina yields = high soda consumption

or

high alumina and soda recovery = high heat consumption

= high number of technological equipment,

valid for all precedent methods, are by high pressure digestion finding their solution by radical decrease of heat consumption and equipment simplicity. It can be expected, that in the future it will be possible to process alumina from low-grade bauxites with

satisfactory yields at heat consumption not exceeding 1.5 million kcal/t alumina, which represents the data of very good contemporary consumption of the classical Bayer process applied for high-grade bauxites.

Utilization of the red mud and digestion wastes from low-grade bauxites

90. There exists voluminous patent literature about the utilization of the red mud and digestion wastes. The main attempt is made for utilization of the iron substance. If we compare the metallic iron content in red muds or other digestion wastes (under 30 per cent) with the metallic iron content needed for effective iron and steel production (above 55-60 per cent), it can be noted that there is little or no chance to balance the total alumina producing economy with the red mud processing if the previous stages of the alumina production are economically unbalanced. The value of the red mud and digestion wastes can therefore be taken into calculation only in very rare cases, if a heightened content of valuable elements, for example, V, Ni or Co exists.

91. The same can be mentioned about the utilization of digestion wastes for cement production, where the presence of alkali, sulphates, iron content together with low hydraulic activity of the mono and dicalcium silicates make the application of these wastes problematic for cement works.

XIV. CONCLUSIONS

Technological conclusions

92. From the given survey and data it is evident that for economical alumina processing from low-grade bauxites the Bayer line represents a fundamental process unit, the sinter line an auxiliary and complementary unit. The borderline quality of bauxite, for which the Bayer line can economically be applied, must in each individual case be estimated by a combination of technological experiments and economical calculations. The trend shows that bauxite under quality limit is gradually replaced by the Bayer processing technique in the direction of decreasing silica modules of bauxite. The quality limit, being the limit for the technological and economic possibilities of wet digestion, and where it is necessary to apply a self-reliant pure sinter process, cannot today be delineated with certainty. The reason lies in the fact that low-grade bauxites have not yet been fully obtained and examined for all technological and economic applications of the high-pressure digestion technique.


93. At present it is evident that in the heat consumption zone the dispute is definitely determined by high-pressure digestion, because for the sinter process a heat consumption of 750 kcal/kg sinter represents extreme construction possibilities and

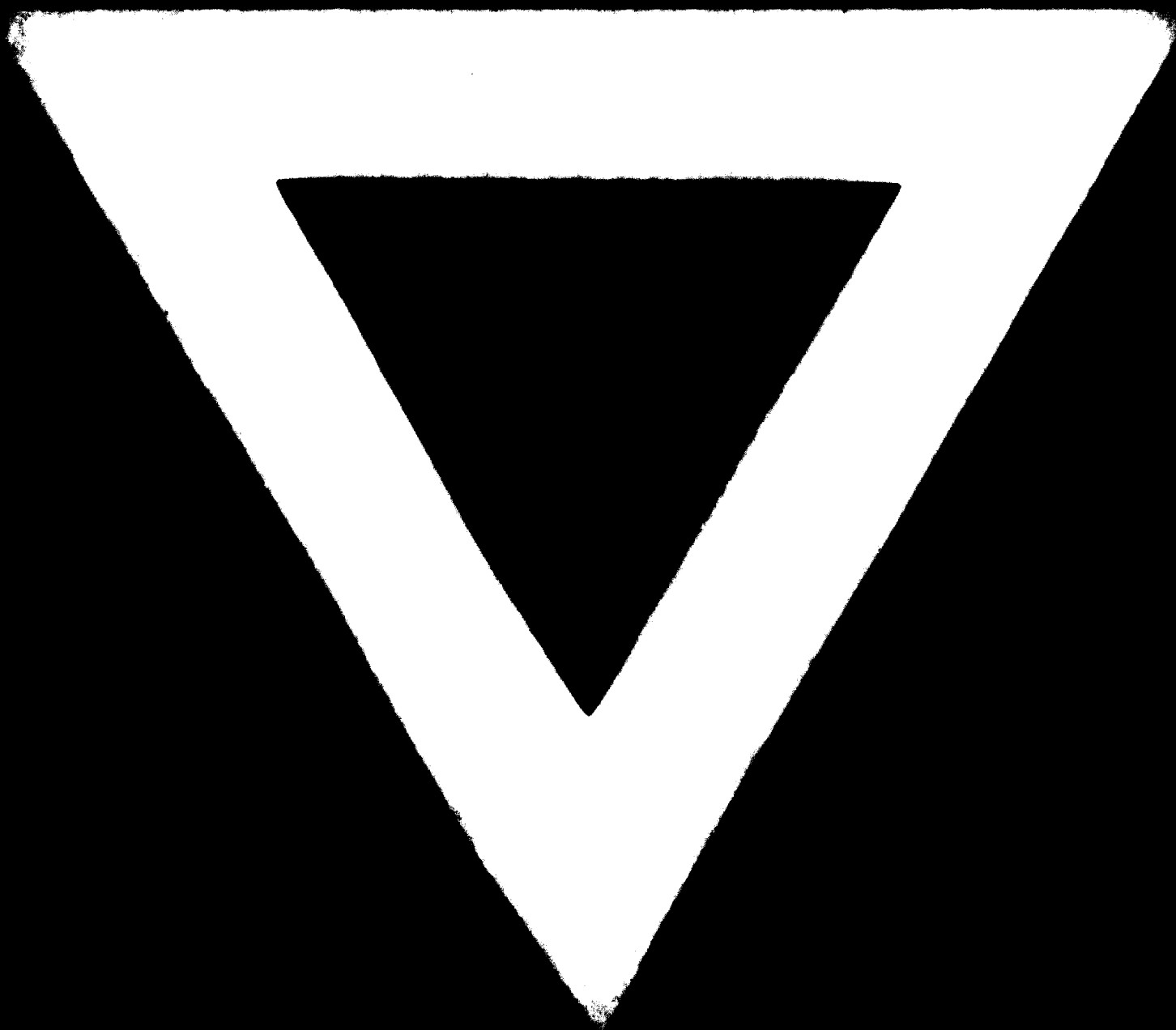
cannot be further substantially reduced. The same can be said if comparing the equipment extent of high-pressure with sinter digestion. In such a situation a decision without risk can only be made in the cases where the natural and economic conditions allow for the installation of the Bayer line as a fundamental processing unit.

94. The decision about the installation of the classic combination method, especially the pure self-reliant sinter process, is therefore problematic. A satisfying answer will be given in the next few years. The installation of the auxiliary sinter unit remains fully entitled for the causticization of soda for or from Bayer process, and this method cannot especially be replaced for bauxites with heightened carbonates and organic matter content, and where calcined soda is cheap.

Planning conclusions

95. The complexity and number of factors influencing good economic results in processing low-grade bauxites shows that the right decision can in no case be made in a few days, but after a thorough study and analysis of all important questions, for which a minimum of two years' time before design starts is needed. The study and analysis of the mentioned problems should therefore be started in actual cases without time loss by a few qualified domestic engineers. This group should have an opportunity to consult the completeness of investigated questions with a neutral specialized organisation, further to learn the practice of alumina producers, which work under similar conditions, to realise at specialized institutes the model and pilot scale technological experiments and to discuss the results and conclusions with a knowledgeable group of neutral specialists. Even in the case of alumina processing from domestic low-grade ores, a remarkable effect for the development planning can be won, because the data necessary for the evaluation of alumina processing possibility are valid and of interest for the chemical, ceramic and metallurgical industries.





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