PROCESSING OF DIASPORE BAUXITES

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Diaspore bauxites of different origin were processed in tube digestion systems.

The influence of temperature, retention time, concentration of the caustic liquor and addition of lime on digestion efficiency were tested.

The results obtained prove that the tube digestion process allows an almost complete digestion of diaspore even at low caustic liquor concentrations.

Introduction

More than 90 % of the world's alumina production is extracted from bauxites by the Bayer-process. The term "bauxite" comprises the variety of sediments in which aluminium of either hydroxide or oxide form is found. Table I shows the geographical distribution of world-wide bauxite resources amounting to 37.500 million tons (1,2).

Table I. Estimated World-wide Bauxite Resources (in million metric tons) (1)

DEPOSITS	Resources				
	Developed		Undeveloped		Total
	Minable Reserves	Potential Ores	Reserves	Potential Ores	
Total Australia	1,215	1,800	830	2,180	6,025
Guinea	1,430	4,000	2,950	1,000	9,380
Cameroon	-	-	680	1,200	1,880
Other Africa	60	-	650	830	1,540
Total Africa	1,490	4,000	4,280	3,030	12,800
Brazil	70	-	1,350	1,900	3,320
Jamaica	2,000	-	-	1,000	3,000
Surinam	200	-	200	1,570	1,970
Colombia	-	-	115	905	1,020
Other America	200	250	50	1,535	2,035
Total America	2,470	250	1,715	6,910	11,345
India	50	-	1,010	1,495	2,555
Indonesia	40	40	-	1,000	1,080
Other Asia	35	5	100	845	985
Total Asia	125	45	1,110	3,340	4,620
Total Europe	840	350	-	280	1,470
Total Western world	6,140	6,445	7,935	15,470	36,260
Total Eastern countries					1,965
World Total					38,225

Bauxites are generally classified under aspects of bauxite origin, geological age of the deposit or mineralogical composition (3,4). Depending on origin, chemical-mineralogical properties and in this connection of course the values of bauxites vary to a considerable degree (1,5).

Criteria for the economical evaluation of bauxites are bauxite prices, transportation charges and alumina production cost. Alumina production cost is decisively influenced by the chemical-mineralogical composition of raw material processed.

A classification of bauxite deposits into cost categories has been made under aspects of economy (1). The majority of the presently world-wide processed bauxite qualities are of the lowest cost category. However, only 12 % of the total bauxite reserves can be assigned to this cost class. In the decades to come low cost bauxites will presumably be in short supply. Thus more and more high cost class bauxites will have to be processed.

Alumina in bauxites is mainly found in three crystalline forms:

gibbsite (γ-$Al(OH)_3$)
boehmite (γ-$AlOOH$)
diaspore (α-$AlOOH$)

Bauxites may be classified under mineralogical aspects as gibbsitic, boehmitic and diaspore bauxites. A great number of mixed types do exist.

Of the three aluminium hydroxides, gibbsite thermodynamically has the less stable and diaspore the most stable lattice. The hydrothermal, caustic digestion of gibbsitic bauxites is mostly without problem. The caustic extraction of diaspore bauxites, however, is only possible using more drastic digestion parameters. Processing of diaspore bauxites requires, therefore, additional technological expenditures, however, will become of increasing interest as low-cost bauxites run short.

General Survey

1. Diaspore Bauxite Deposits

Major diaspore bauxite deposits are found in Greece, USSR, China, Vietnam, Iran, Turkey and Yugoslavia. They amount to about 20 % of the karst bauxite type which again comprises about one third of the world-wide bauxite deposits (6).

2. Diaspore Bauxite Processing

The highly stable lattice of diaspore results in poor digestibility and a low Al_2O_3 equilibrium solubility. The hardness of diaspore causes abrasion problems during the digestion process. Despite these problems considerable amounts of diaspore bauxites are processed in various production plants of different countries (7 - 9).

Process variations to improve diaspore bauxite digestion are dealt with in a number of publications (10 - 17). In particular mineralogical peculiarities and the heterotypism of diaspore bauxite, entailing major differences in the digestibility, were thoroughly investigated (16, 18 - 20). Satisfactory diaspore extraction rates are generally possible only if lime or CaO-containing additives are used during the digestion process. Different mechanisms are discussed as being responsible for the improved yield rates experienced when using lime in the extraction process (10, 15).

There are three major procedures used for digestion of diaspore bauxites:

a) digestion in autoclave systems
   digestion temperature: 220 - 255 °C
   liquor concentration: > 200 g Na_2O caustic/l
   retention time: up to several hours

b) pyrogenic lime-soda-sinter process
   This process is disadvantageous on account of the high energy consumption.

c) tube digestion technology

The aforementioned tube digestion technology is applied to a major extent by "Vereinigte Aluminium-Werke" (VAW). The advantages of the tube digestion process have been reported on in detail already (21, 22). The characteristics of this technique are summarized in Table II.

Table II. Characteristics of the Tube Digestion Technology

Characteristics of the Tube Digestion Technology
1. Digestion temperatures up to 300 °C
2. High turbulence of the ore suspension in the tube reactor
3. Optimum retention time
4. Bauxite specific adaption of retention time
5. Application of low concentration liquors (140 - 150 g Na_2O caustic/l)
6. System availability of up to 90 %
7. Low energy consumption (no liquor evaporation)

Pilot plant tests for the digestion of different grade diaspore bauxites were performed in the tube digestion system.

Digestion Tests of Diaspore Bauxites

Digestion tests of diaspore bauxites were performed in pilot plant tube digesters of different size. Test materials were a middle-grade diaspore bauxite (A) and a pure diaspore bauxite (B).

Table III shows the chemical analysis of bauxites.

Table III. Chemical Analysis of Bauxites

(%)	Bauxite A	Bauxite B
Al_2O_3	55,5	65,0
SiO_2	5,5	12,5
Fe_2O_3	21,0	4,0
TiO_2	2,5	3,0
CaO	0,6	0,4
LOI	14,2	14,0

Table IV shows the mineralogical composition of the Al_2O_3-compounds.

Table IV. Mineralogical Composition of the Al_2O_3-Compounds

(%)	Bauxite A	Bauxite B
Diaspore	35	85
Boehmite	55	-
Gibbsite	6	-
Kaolinite	4	15

The bauxites were prepared for the digestion by common use grinding technique.

The bearing of parameters such as

digestion temperature
retention time
lime additive
liquor concentration
molar ratio after digestion

on the digestion yield was investigated in a model test for bauxite A by varying extensively said parameters. The results obtained made it possible to limit parameter variations to a significant range when testing bauxite B.

Definitions

The digestion yield was calculated as follows:

$$\text{yield [\%]} = 100 - \frac{[\%\ Al_2O_{3\,RM} - (\%\ SiO_{2\,RM} \cdot 0{,}85)] \cdot \%\ Fe_2O_{3\,B} \cdot 100}{[\%\ Al_2O_{3\,B} - (\%\ SiO_{2\,B} \cdot 0{,}85)] \cdot \%\ Fe_2O_{3\,RM}} \qquad (1)$$

(RM = Red Mud, B = Bauxite)

The molar ratio is defined as follows:

$$MR = \frac{Na_2O \text{ caustic [Mole/L]}}{Al_2O_3 \text{ [Mole/L]}} \qquad (2)$$

1. Digestion of Bauxite A

The following digestion parameters were used for the processing of bauxite A:

digestion temperature:	250, 260, 270, 280	(°C)
retention time:	0, 5, 10	(minutes)
lime additive:	0, 3, 5	% CaO related to bauxite feed
liquor concentration:	140 - 150 g Na_2O caustic/L and 220 - 230 g Na_2O caustic/L	
molar ratio after digestion:	1,45 - 1,75	

1.1 Digestion Yield as a Function of Digestion Temperature and Retention Time

Figure 1 shows the digestion yield of bauxite A as a function of digestion temperature and retention time.

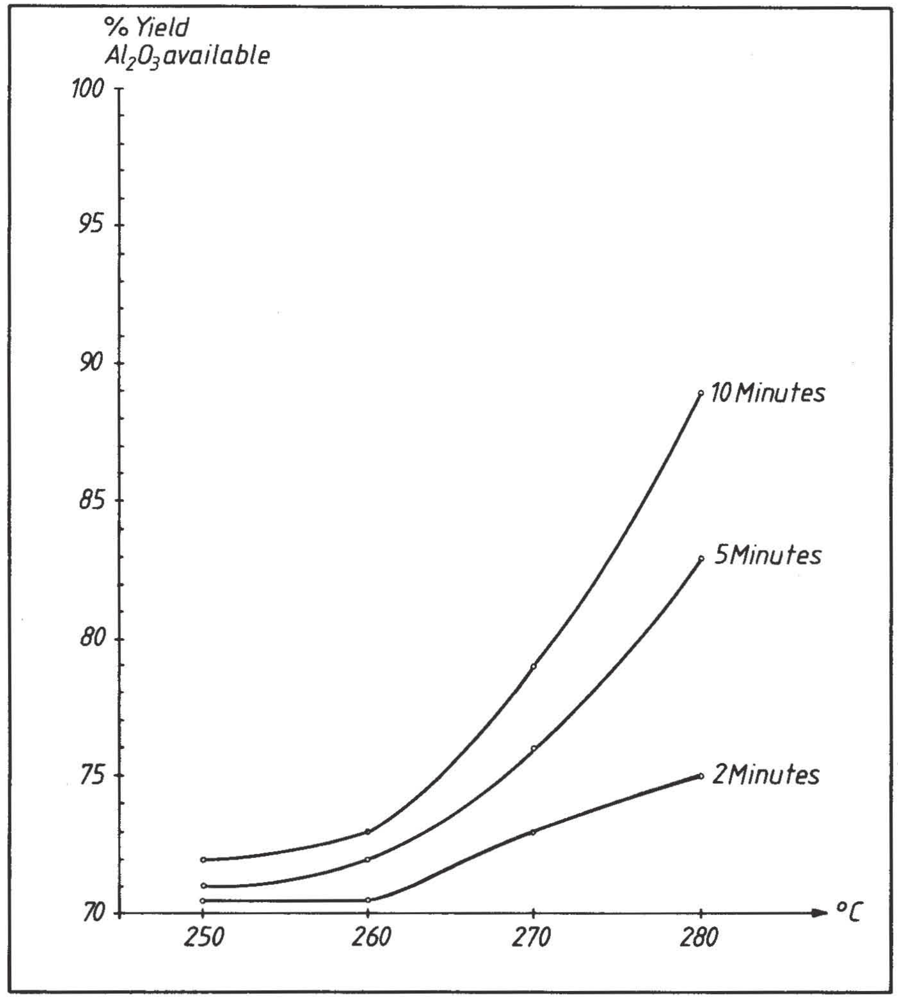

Figure 1 - Digestion Tests of Bauxite A
Digestion Yield as a Function of Temperature
140 - 150 g Na_2O caustic/L, MR 1,6 - 1,8
2 - 5 - 10 Minutes Retention Time.

Digestion tests were performed using a liquor concentration of 140 - 150 g Na_2O caustic/L. In the low temperature range of 250 - 260 °C temperature effects on the digestion yield remain negligible even at retention times of up to 10 minutes. Increasing temperatures of 270 - 280 °C yield a considerable improvement of the extraction rate. The bearing of extended retention times on the extraction rate is significant in the higher temperature range.

Even though high temperatures and extended retention times do not result in sufficient high extraction rates to indicate industrial processing of diaspore bauxite A. Therefore, further digestion tests were made with lime additive.

1.2 Digestion Yield as a Function of Lime Additive

Lime was added using a special dosing device in the high temperature range of the digester.

Basing on the established positive effect of a 10-minute retention time, most of the tests with lime additives were performed at this optimum retention time using a liquor concentration of 140 - 150 g Na_2O caustic/L.

Solubility of diaspore increases considerably with growing amounts of CaO additive. Using a 5 % CaO additive as related to bauxite feed no further extraction rate improvement can be achieved by raising temperatures beyond 270 °C (maximum digestion yield = 97,5 %).

Figure 2 shows the digestion yield as a function of lime additives at varying temperatures.

Figure 3 shows the digestion yield as a function of temperature and varying amounts of CaO.

Table V shows digestion yields of bauxite A as a function of retention time at varying digestion temperatures and 5 % lime additive.

Table V. Digestion Yield of Bauxite A as a Function of Retention Time at Varying Temperatures

Temperature (°C)	Yield (%) 5 Minutes	Yield (%) 10 Minutes
260	89,0	96,0
270	93,0	97,5
280	97,0	97,5

(140 - 150 g Na_2O caustic/L, 5 % CaO, MR 1,55 - 1,80)

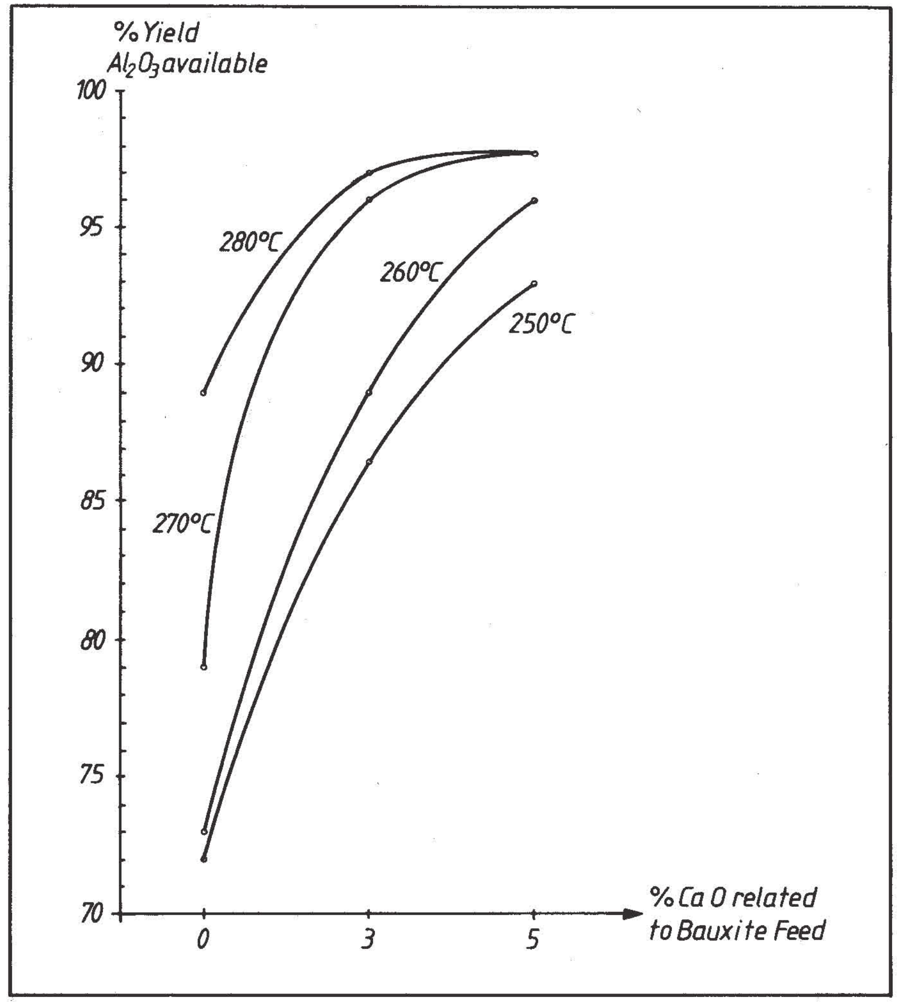

Figure 2 - Digestion Tests of Bauxite A
Digestion Yield as a Function of Lime Additive
140 - 150 g Na_2O caustic/L, MR 1,55 - 1,8
10 Minutes Retention Time.

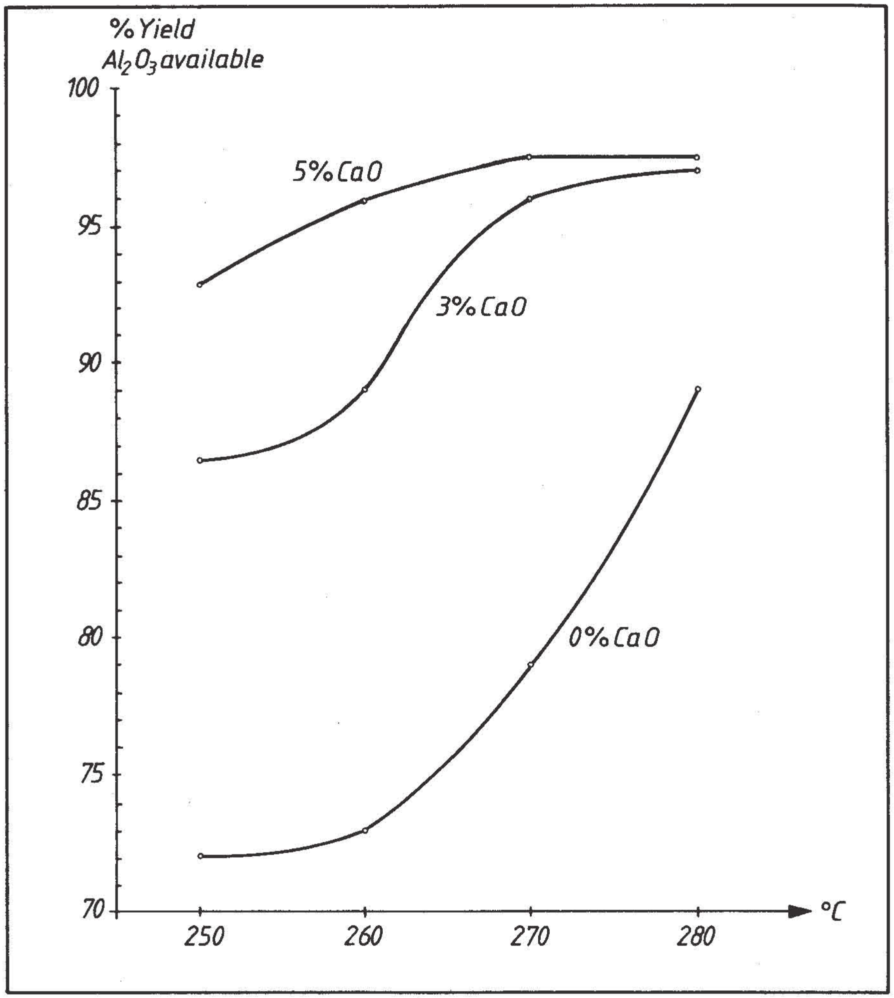

Figure 3 - Digestion Tests of Bauxite A
Digestion Yield as a Function of Temperature
140 - 150 g Na_2O caustic/L, MR 1,55 - 1,8
10 Minutes Retention Time, 0 - 3 - 5 % CaO.

1.3 Digestion Yield as a Function of Caustic Liquor Concentration

Diaspore bauxites of type A were processed at digestion temperatures of 270 - 280 °C and at a retention time of 10 minutes, using 3 - 5 % lime additives as related to the bauxite feed. It was found that in this case caustic liquor concentration (140 - 150 g Na_2O caustic/L and 220 - 230 g Na_2O caustic/L) has no bearing on the extraction rate within the tested range.

In absence of lime additives, high concentration liquor will - other than liquor of low caustic concentration - yield increased extraction rates in the high temperature range. Table VI shows digestion yields as a function of varying liquor concentrations in absence of lime additives.

Table VI. Digestion Yield of Bauxite A as a Function of Liquor Concentration

	Yield (%)	
Temperature (°C)	140-150 g Na_2O caustic/L	220-230 g Na_2O caustic/L
250	72,0	73,0
270	79,0	90,5
280	89,0	98,0

(retention time 10 minutes, MR 1,6 - 1,8)

1.4 Digestion Yield as a Function of Molar Ratio after Digestion

Figure 4 shows the digestion yield as a function of the molar ratio after digestion at digestion temperatures of 270 °C and 10 minutes retention time, using 5 % CaO as related to bauxite feed and a liquor concentration of 140 - 150 g Na_2O caustic/L.

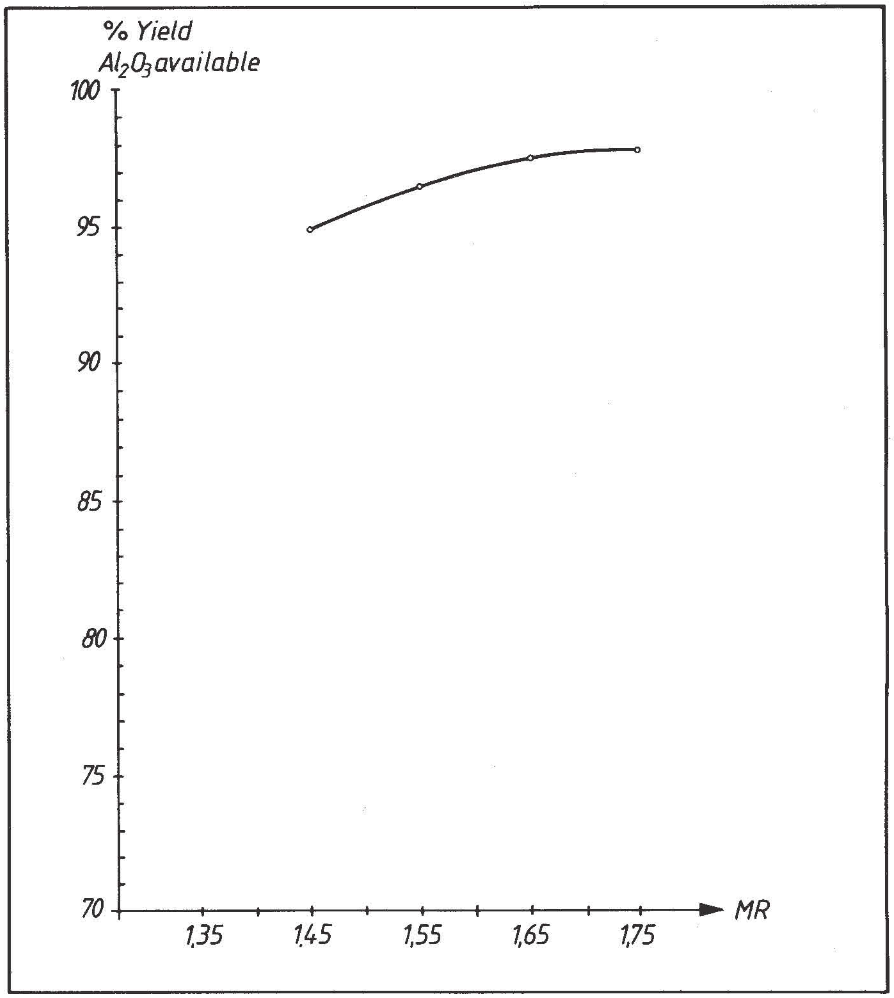

Figure 4 - Digestion Tests of Bauxite A
Digestion Yield as a Function of Molar Ratio after Digestion, 140 - 150 g Na_2O caustic/L, 270 °C, 5 % CaO, 10 Minutes Retention Time.

2. Digestion of Bauxite B

Basing on the test results obtained for bauxite A, digestion parameters, namely:

lime additive:	3 - 7 % CaO as related to the bauxite feed
digestion temperature:	265, 270, 275 °C
molar ratio after digestion:	1,45 - 1,75

were optimized for the digestion of the pure diaspore bauxite B.

At given test conditions no significant influence of the liquor concentration with view to extraction rates obtained could be observed.

2.1 Digestion Yield of Bauxite B as a Function of Lime Additive

Figure 5 shows the digestion yield as a function of CaO-additive at digestion temperatures of 270 °C, 10 minutes retention time using liquor of low caustic concentration. The aforementioned test conditions warrant good digestion yields (95,5 %) when using CaO-additives of approximatively 5 %.

2.2 Digestion Yield of Bauxite B as a Function of Temperature

Table VII shows extraction rates as a function of varying digestion temperatures.

Table VII. Digestion Yield of Bauxite B as a Function of Temperature

Temperature (°C)	Yield (%)
265	93,0
270	95,5
275	96,5

(retention time 10 minutes, 5 % CaO as related to bauxite feed, 140 - 150 g Na_2O caustic/L, MR approx. 1,5)

As can be seen digestion temperatures of approximatively 270 °C will result in a good digestion yield.

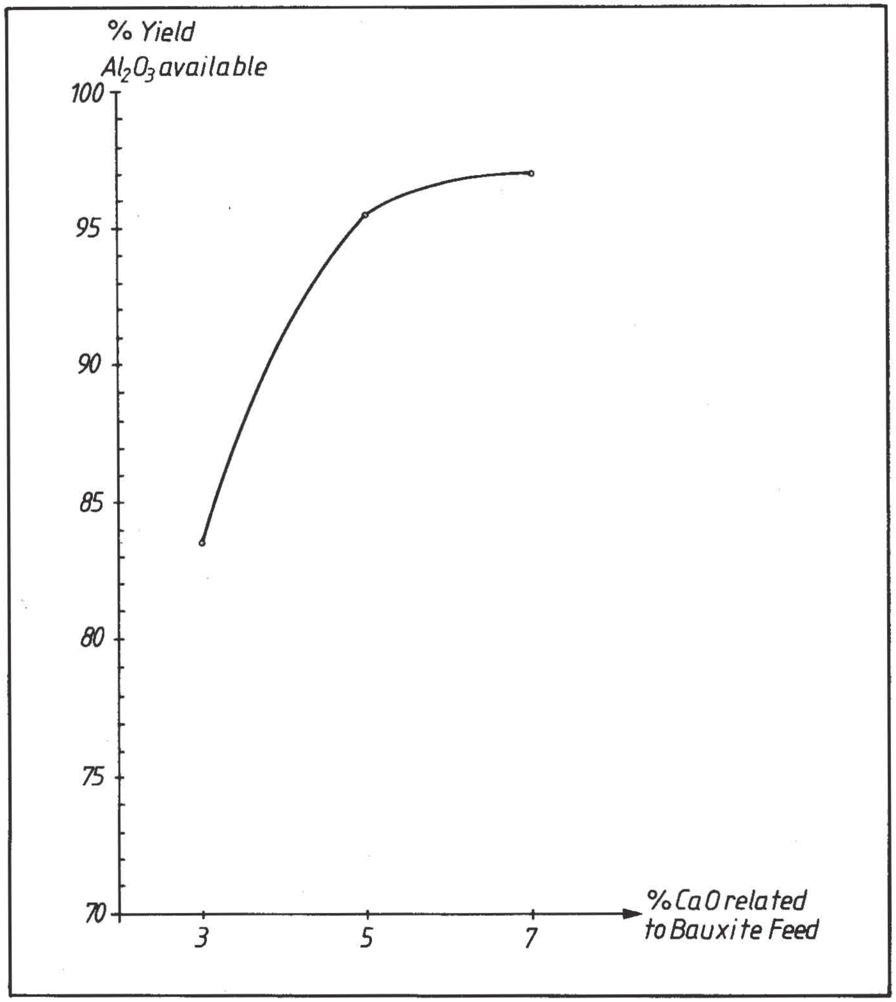

Figure 5 - Digestion Tests of Bauxite B
Digestion Yield as a Function of Lime Additive
140 - 150 g Na_2O caustic/L, 270 °C, MR 1,5 - 1,6
10 Minutes Retention Time.

2.3 Digestion Yield of Bauxite B as a Function of Molar Ratio after Digestion

Figure 6 shows the correlation of molar ratio and digestion yield. The tests were performed at digestion temperatures of 270 °C, at 10 minutes retention time, using 5 % CaO-additive and liquor concentrations of 140 - 150 g Na_2O caustic/L.

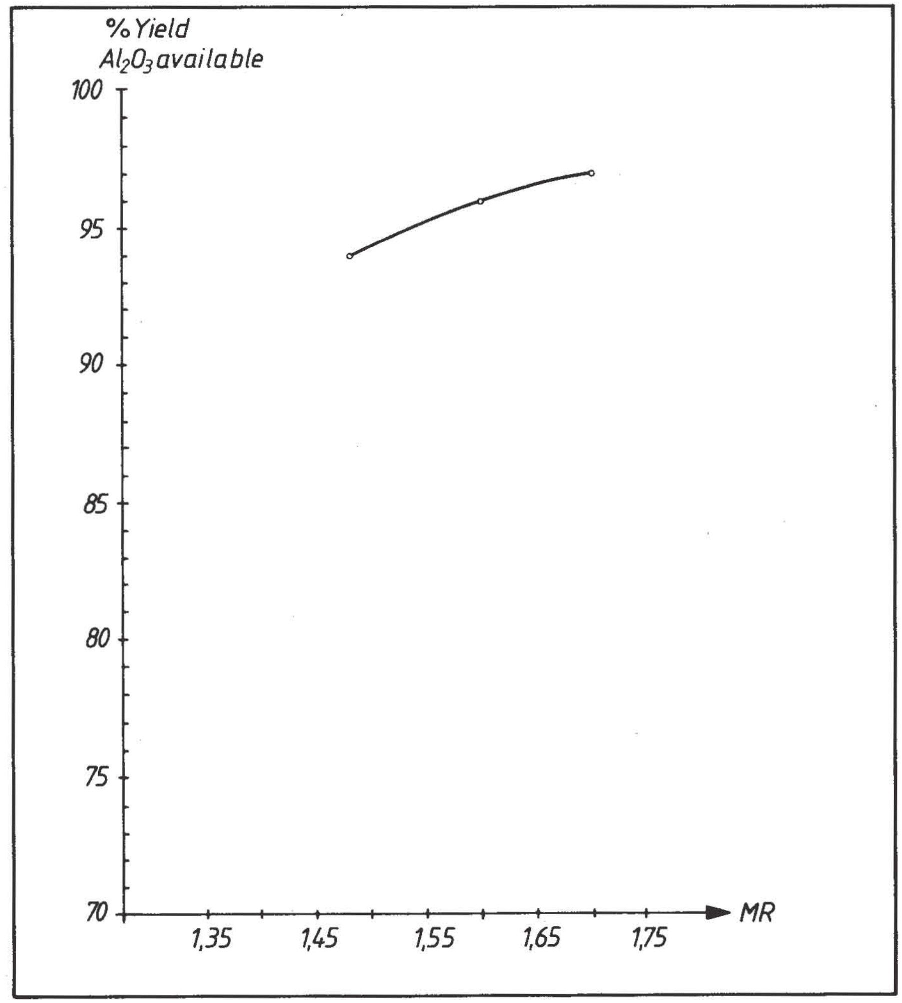

Figure 6 - Digestion Tests of Bauxite B
Digestion Yield as Function of Molar Ratio after Digestion, 140 - 150 g Na_2O caustic/L, 270 °C, 5 % CaO, 10 Minutes Retention Time.

3. Summary

Table VIII lists the optimum digestion parameters for the processing of bauxites A and B in the tube digestion system. The parameters indicated yield good extraction rates for the bauxites tested.

Table VIII. Digestion Parameters for Bauxites A and B

Parameter		Bauxite A	Bauxite B
Temperature	(°C)	≥ 270	≥ 270
Retention time	(min)	10	10
Lime additive	(%)*	3 - 5	5
Liquor Concentration	(g/L)	140 - 150	140 - 150
Molar ratio after digestion		1,45-1,6	1,5-1,6
Yield	(%)	95 - 97	95

(* lime additive as related to bauxite feed)

Good digestion yields can be obtained by processing middle-grade and high-grade diaspore bauxites in the tube digestion system. The favorable results were also obtained when using liquor of low caustic concentration and bauxite specific lime additives, at high digestion temperatures and at short retention times. The molar ratio achieved allows for a good productivity of the caustic liquor.

Processing of middle-grade and high-grade diaspore bauxites in traditional autoclave systems at digestion temperatures of 220-255°C and long retention times, using bauxite specific lime additives, will only yield equally favorable results if high concentration caustic liquors of Na_2O caustic > 200 g/L are applied.

Favorable energy consumption rates as well as technological advantages of the tube digestion system for the digestion of diaspore bauxites are thus evident. The fact that liquor of low caustic concentration is used for digestion renders set-up and operation of high cost evaporation plants unnecessary.

Comparison on Primary Energy Consumption in Autoclave Systems and Tube Digestion Systems

Basing on the test results and data available from diaspore bauxite processing in autoclave systems, primary energy consumption figures were calculated as shown in figure 7.

The favorable energy consumption figures of the tube digestion system are quite obvious. The comparison shows that primary energy consumption for the digestion of diaspore bauxites in autoclave systems is by approximatively 4 GJ/t Al_2O_3 or 60 % higher than in tube digestion systems.

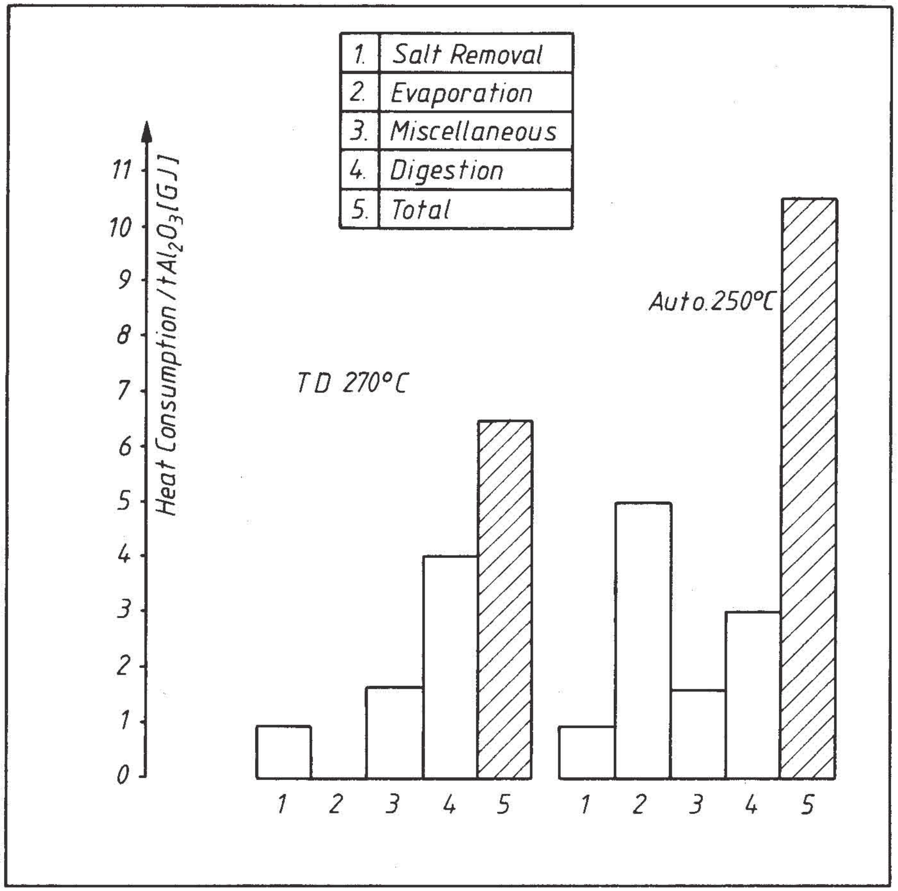

figure 7 - Energy Consumption in the Tube Digestion System and Autoclave System (without Calcination).

Conclusion

It was the objective of this report to determine optimum digestion parameters for diaspore bauxite processing in the tube digestion system.

Results obtained prove that processing of diaspore bauxites in the tube digestion system offers an optimum solution under technological and economical aspects as well.

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