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PRODUCTIVITY IN THE JAMAICAN ALUMINA INDUSTRY
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JAMAICA

Technical Report

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ABSTRACT

The competitive position of Jamaican alumina refineries exceeds that of all other bauxite/refinery combinations currently operating in the world with the possible exception of those operated by Alcoa in Western Australia.

The main advantages for Jamaican refineries lie with their favourable bauxite costs and lower labour costs.

Higher than average caustic consumption (both intrinsic and avoidable), higher energy costs and higher administration and maintenance expenses tend to erode the above advantages.

The older design of the Jamaican refineries compared with present day standards make efforts to control these costs more difficult.

The penalties imposed by older design are:

- higher kiln operating and maintenance costs;
- poorly optimized heat recovery;
- smaller vessels leading to higher heat losses and labour requirements;
- poorer recovery of soda values from red mud;
- high soda losses arising from equipment descaling operations and mud disposal arrangements.

The age of the plants has financial implications that they are effectively depreciated. Thus the profits which they generate are not as tax effective as with newer plants.

Measures to reduce costs for Jamaican refineries and to improve their competitive position vis-a-vis refineries elsewhere should include:

- update alumina calcination kilns to retrofitted rotary or fluid bed;
- reduce dependence on one grade of fuel oil;/
- improve performance of mud washing trains and extend the use of dry mud stacking;
- ensure larger size process trains are used to replace multiple smaller trains;
- provide for training of key operating personnel to complement the foregoing item;
- introduce a higher level of automation and instrumentation.

Extension of existing specialty alumina product range should be considered as a means of increasing the value added of production from Jamaican refineries. The prospects for producing gallium metal from a side stream from an alumina refinery should be considered.

The data presented in this report has been arrived at both directly and indirectly by way of interpretation and derivation from trade, technical and other information in the Public Domain.

The Author accepts no responsibility for the accuracy of this nor for the consequences of any action by others as a result of placing reliance on same.

15 July 1992 Ronald W Moyle.

SECTION 1

INTRODUCTION

1. INTRODUCTION

1.1 Significance to Jamaica of the Bauxite/Alumina Industry

Bauxite for alumina production represents a net cash flow of hard currency to the Jamaican economy in the form of levy, income tax and local cost expenditures of US$270 million per annum.

This is second only to tourism as an earner of hard currency.

The stability of the industry within Jamaica and its continued viability is vital to the economy of Jamaica as any disruption to operations will have serious implications for hard currency cash flows. This in turn will be likely to have a strong influence on the value of the Jamaican dollar, particularly in the current climate of currency exchange deregulation.

The effect of disruption to the industry that was experienced following the closure of the Alpart refinery in 1985, was stated (1) to be equivalent to US$30 million (1985 dollar terms) and the temporary closure of the Jamalco plant in February of that year. These events underline the importance to the Jamaican economy of the bauxite/alumina business.

The Jamaica Bauxite Institute has a key role in encouraging, shaping, improving the stability of the country's bauxite/alumina industry.

(1) - Daily Gleaner 2/8/85

Structure of the Industry

The ownership and control of alumina refining activity within Jamaica is distributed among the companies listed in Table 1 who also have bauxite/alumina facilities located in other locations throughout the world. It is important that the JBI have an understanding of these operations in order to be able to follow and where necessary predict the strategies that these companies choose to follow in the conduct of their affairs in the bauxite/alumina business so that JBI may plan effective strategies to shape and control the industry so as to produce a favourable outcome for Jamaica.

The companies which are active in the industry in Jamaica are as in Table 1.

It is seen from Table 1 that each of the companies active in Jamaica has alumina capacity greatly in excess of that in Jamaica, located in other bauxite producing countries throughout the world.

It is important to the industries continued viability that the bauxite-alumina operations within Jamiaca are maintained on a competitive basis with those facilities located in other countries and that diversification and vertical and horizontal integration occur in order to maximize the interdependence and cohesiveness of the industry in the region.

SECTION 2

PRODUCTIVITY ANALYSIS

2. PRODUCTIVITY ANALYSIS

Elements making up the Base of Production of Alumina

The following are the key specific cost elements in the production of alumina:

A) Bauxite into refinery;

B) Energy;

C) Caustic Soda;

D) Labour; and

E) Other

It is proposed to examine the performance of the Jamaican refineries and to endeavour to rank them in world cost context in relation to each of the above.

Advice will be provided on ways in which operations may be improved so as to reduce these operating costs.

2 A. BAUXITE COSTS

The operation for all Jamaican bauxite mines are summarized in Table 8.

The estimated costs have been derived for comparison purposes using the Jamalco Performance Reports together with data supplied to the JBI from the companies (Regulation "58") and via Mr. Dennis Morrison of the JBI.

The costs of mining are generally of the same order as for those bauxites mined in Australia. In general, the higher cost of wages in Australia and the more efficient mining methods that are used with the larger deposits there contrast with lower cost of labour and the need to build feeder haul roads and mine simultaneously several small pockets of bauxite.

Advantages as far as cost of bauxite delivered to the refinery are concerned occur where refineries are located adjacent to the mines as in Jamaica. In this way, the cost of trans-shipment of bauxite are avoided and it becomes economic to consider using lower grades of bauxite. A further penalty of shipping bauxites is the need to reduce moisture as much as possible to reduce freight costs. Some key refineries affected by this requirement are in table 10.

Apart from the Alcoa refineries located in Australia and a prospective alumina plant to be located at Weipa, the Jamaican plants are among the few plants possessing the advantage of low bauxite freight charges.

Royalties

Royalties on bauxite/alumina processed are levied by governments of all countries for the purposes of regulating the industry, setting aside funds to carry out long term plans associated with the areas affected, including the environment, and as an indirect form of taxation.

The rate for Jamaican bauxites of US$0.5/tonne of dry bauxite equivalent in the tonnes of shipped alumina has been included in the calculations in Table 12.

No coherent pattern exists between countries which levy Royalties because of the varying needs and priorities arising from the above. Also royalties tend to become enshrined for each mine during its project negotiation stage with at least an ambit rate being lock-in at this stage.

It is therefore not proposed to present any comparison between countries as regards Royalties. They do need to be recognized as a cash cost of doing business to the alumina refining companies.

2 B. ENERGY

Energy cost is related to the rate of energy consumption and to the cost of a unit of energy. The latter depends on principally the type of fuel used. In Jamaica, there is universal reliance on fuel oil having a sulphur content of less than 2.2%.

The energy consumptions for Jamaican alumina plants and the costs of energy are given in Table 2.

Jamaican Alumina Kilns

In order to maintain a competitive position in relation to world plants, there is a need for Jamaican plants to consider updating and modifying kiln operations to reduce energy consumption.

The current status of alumina kilns currently in operation is as in Table 3.

Type of Fuel

Alternative sources of energy for process steam and for calcination are:

Process steam	-	oil
		gas
		coal
Calcination	-	oil
		gas
		coal gasification

The problem with oil has been the fluctuation in price which has resulted in those refineries dependent on it and with high energy consumptions to be candidates for closure during periods of sustained high oil prices.

Refineries tied to a deposit of gas or coal are able to negotiate long term contracts which are while they may not be entirely independent of oil price, nevertheless serve to considerably smooth the rate paid for energy over time.

Conversion from oil to coal involves significant additional capital expenditure and further conversion to coal gasification for kiln operation, a considerably higher level of capital expenditure again.

Energy Summary for Jamaican Plants

Process Energy -

The introduction of a sweetening stream in to the high pressure Alpart plant in line with practice in high temmperature plants located elsewhere has reduced boiler energy consumption.

There are two other factors which work against the Jamaican plants being able to achieve the higher energy efficiencies of more modern plants:

1) the size of vessels which is relatively small and from which higher rates of heat losses per unit of volume can occur;

2) the age of the plants and the standards to which it is practical to maintain them i.e. frequency of cleaning of heat transfer surfaces and the extent to which lagging replacement is cost effective.

Kiln Energy

The rotary kilns used on Jamaican plants are less energy efficient than the current level of fluid bed calciners. (See Table 4). Retrofitting of existing rotary kilns offers a major energy reduction and is being implemented by Alcan as kilns come up for relining.

FUEL

Because of the absence of gas and the lack of an indigenous coal deposit in the region, there appears little opportunity for Jamaican plants to develop an alternative energy source.

A summary of relative energy consumption rates for current oil prices is given in figure 1 and for oil prices +/- 30% of those current in tables 5A and 5B. It can be seen how a low oil price is favourable to Jamaican plants, whereas a higher oil price places these plants at a disadvantage.

2 C. CAUSTIC SODA

Caustic soda consumption is in part a characteristic of the intrinsic properties of bauxite which determines the amount of desilication product. The balance of caustic soda losses are avoidable and comprise losses from the process in the liquor of the red mud, in the product alumina, and as losses from the release of liquor from plants during descaling and from pump seals.

The anticipated soda consumptions for Jamaican plants compared on an equitable basis against world standards are shown in Table 6.

2 D. LABOUR (Refinery Only)

The competitiveness of Jamaican alumina refineries as regards labour is a function of the productivity of labour based on a tonnage output of alumina per employee together with the average annual rate of pay attaching to that labour. For the purposes of comparison with other alumina plants, the mine labour has been excluded. It is assumed to be included in the cost of bauxite, which has been assumed to be provided on an "arms-length" basis.

The costs for Jamaican refineries have to be taken from the "Regulation 58" data as supplied by the refinery operators for 1990.

Productivity Comparison

A comparison of labour productivities for Jamaican versus selected world refineries is given in Table 7. The range of productivity values obtained follows a predictable pattern based on economies of scale, i.e. the larger plants have a higher output of alumina per man employed than the smaller ones. The Jamaican plants fall within the higher range of the more modern plants in other countries with Alpart with its higher capacity plant being superior to Ewarton/Kirkvine at which the ability to share key staff enables some advantage to be enjoyed in this area.

The smaller Clarendon plant is inferior is this regard.

Wage Cost Comparison

The main advantage to Jamaican refineries arises from the relative rates of pay in Jamaica compared to other countries shown.

The rates are based on relativities provided by the US Department of Labour together with exchange rate data for the period concerned.

Recent movement of the J$ against US$ during the period of the study will further serve to increase the competitiveness of Jamaican plants in this regard.

2 E. OTHER COSTS

Falling into the category of "other" costs are: maintenance materials, processing supplies (including flocculant and limestone purchase/production cost) insurance, office expenses. Depreciation, interest on borrowed funds and other capital charges are not included.

The headquarters of the operators of Jamaican alumina plants are located in the continents of North America or Europe. Provisioning of these plants is undertaken from two separated offices; one for purchasing of materials which is done mostly in North America, the other for receival of goods at the port in Jamaica and for transport of these to the refinery site. Consequently higher overhead costs are incurred as well as probably higher working capital requirements. These factors contribute to higher "other" costs than for refineries located in US and Europe or Australia.

For the case of refineries in Australia, an intermediate situation exists where the provisioning is done through the local infrastructure but major spares etc, are purchased overseas.

A further factor affecting these costs is economy of scale both in mining and refining and the degree to which refineries have been modernized.

Both of the factors work to the disadvantage of the Jamaican plants.

A suggested comparison between selected Jamaican and other plants is provided in Table 11.

2 F SUMMARY

Based on refineries costs of operation in Jamaica in 1990, a comparison with other major low cost-of-production refineries located outside Jamaica show that Jamaican refineries fit into a ranking by cost category as follows:

Bauxite Costs (including freight, Royalties and levies)

On the basis per dry tonne of bauxite mined, Jamaican mines deliver bauxite to refineries in Jamaica at costs on a par with the lowest cost producer outside Jamaica. The Worsely refinery in western Australia is believed to have costs which are higher because of costs associated with their 51 km cable belt from mine to refinery (compared with Alpart's 14 km cable belt).

When considered on the basis of cost of bauxite per tonne of alumina produced, Jamaican bauxites/refinery combinations are lower cost than Australian bauxite refineries on the basis of a more advantageous bauxite to alumina ratio. The margin of cost advantage on this basis is perhaps of the order of 0- 15% of alumina production cost based on costs applying during 1990.

Energy Costs

Jamaican refinery average unit energy consumptions based on a gigjoule per tonne of alumina basis is one of the highest by world standards. The Alpart refinery has been particularly disadvantaged in this regard and whereas an expansion of alumina kiln capacity using lower energy consuming fluid bed calciners would be expected to lower the rate somewhat, this refinery is expected to remain inferior to many others in this regard.

The practice of Jamaican refineries of calcining their own limestone using small kilns does not assist their competitive energy positions. The prospect of one calcination kiln to service two or more refineries is a possibility, however there are difficulties associated with the transport of quicklime that would need to be overcome.

The main reasons for high energy consumption appear to be:

1) Retention of high energy consumption rotary kilns for the calcination of alumina. Retrofitting of rotary kilns reduces energy consumption but not the level achieved by fluid bed calciners);

2) The small size of vessels in the Jamaican plants relative to more modern plants means that the opportunity for heat loss is greater;

3) The changes that have taken place since the plants were designed in the compositions of process streams, means that heat exchange equipment is no longer optimally sized as in more modern plants designed with a greater emphasis on heat recovery. In this regard, the plants are understood from time to time to have difficulty with process control arising in part from changes in feed bauxite composition.

4) Management policy and practice as regards heat retention and recovery in the context of the fixed plant design/layout is probably the result of an operator's cost/benefit analysis which comes down on the side of not preventing minor heat "leaks".

The Jamaican plants rely exclusively on the purchase of fuel oil as an energy source. They are therefore subject to a greater or lesser extent, depending on owners of oil purchase contracts, to fluctuations of oil prices. By comparison, plants located in Australia and elsewhere have been able to negotiate long term contracts for natural gas and for coal whereby a high degree of long term stability has been achieved in energy costs.

The foregoing contributes to a higher "risk profile" of Jamaican refineries.

Caustic Soda Consumption

The rate of consumption of caustic soda used in processing of Jamaican bauxites is significantly higher than would be anticipated from consumptions in some similarly sized refineries worldwide (see table 6).

Caustic soda consumption is heavily dependent on the characteristics of the bauxite processed. Jamaican bauxites processed locally suffer from a higher volume of mud compared to say Boke bauxite

However there is some evidence to indicate that mud from some Jamaican bauxites is easier to dewater than some elsewhere. The progress being made toward dry mud stacking may effect both a higher recovery of caustic soda as well as present a viable alternative to ponded mud disposal systems.

Jamaican plants do not recover as much of the avoidable caustic losses as plants in other countries. This is due to :

1) the capacity and design of mud washing facilities which are less than would be deemed adequate by modern standards;

2) the loss of excessive amounts of soda during descaling activities; losses of process liquor during malfunction of evapourating equipment, and the dilution effects of water losses from water sealed glands in process pumps.

The direct cost penalties faced by Jamaican plants as a result of avoidable plus unavoidable losses relative to the best elsewhere appears to be of the order of US$15 - 25 per ton alumina compared to a refinery based on Boke bauxite. These are principally due to aged and non-optimized plant design and inadequate instrumentation leading to intermittent plant malfunction.

Delivered price for caustic soda is relatively low in Jamaica compared to Australian refineries due to the proximity of US producers and low freight rates in the region. Actual prices in each case however, will depend on existing negotiated contracts.

Labour Costs

Labour productivity in Jamaican refineries is lower than that in other leading world refineries. This is due to the smaller size of some of the equipment in Jamaica arising from its old design and the lesser reliance on automated operation.

The labour productivity in Jamaican refineries is between 50 and 65% of that in Australian refineries. However, this is more than compensated for by the relatively low wage rates in US$ terms paid to Jamaican nationals.

In 1990, wage rates were about 20-25% of those paid in US$ and 25-30% of those in Australia.

The net effect is that labour costs in Jamaican refineries are among the lowest in the world. After allowing for US expatriate salaries labour costs appears in 1990 to be on par with the best Australian plants in this regard.

Recent exchange rate movements September/October 1991) have effectively moved Jamaican labour costs down below those of Australia. The ensuing months will determine to what extent wages increases may erode this competitive advantage.

Other Costs

Current policies of Jamaican refinery management places heavy reliance on provisioning their operations from bases in the USA. This comes with an administrative cost penalty.

The markedly different nature of mining operations together with the smaller scale of operations and older plants in Jamaica as against Australia imposes significantly higher costs for Jamaican operations. Thus it is estimated that "other" costs for Jamaican plants are 40 - 70% higher than those for Australian plants.

The policy of provisioning directly from USA also tends to deprive the Jamaican economy the flow-on effect of hard currency expenditures on-shore and provides little encouragement for the growth of Jamaican infrastructure to provide these goods and services where practicable.

SECTION 3

PROSPECTS FOR INCREASING PRODUCTIVITY

3A - ENERGY

Improved energy efficiencies would be one of the outcomes that would accompany the modernization of existing plants along the lines covered in 3 C.

These measures may be summarized as follows

- upgrading/retrofitting alumina kilns
- increasing vessel size where appropriate
- improve insulation to reduce heat loss
- reduce volumes of hot waste discharge
- improve heat exchange of waste streams

Some improvement in caustic soda consumption rates and water balances would also be accompanied by a reduction in energy consumption.

The development of an alternative and cheaper energy source to oil (ie gas or coal) would reduce energy costs.

3B - EQUIPMENT AND INSTRUMENTATION

For a discussion of equipment requirements the reader is referred to also in section 3C, Process Technology.

Introduction

Comprehensive and well selected instrumentation and control systems are pivotal to maintaining tight process conditions within alumina plants. This in turn reflects not only on being able to maintain product within specification, but in more economical use of resources and in the avoidance of pollution problems.

As regards Instrumentation the writer did not have the opportunity to view any of the refineries in sufficient detail as to pass comment on the level or degree of modernity of their instrumentation, however the impression was gained that instrumentation and control was consistent with the practice common at about the time the plants were constructed.

The writer believes that updating of instrumentation and control systems would be part and parcel of a revamp of the process to take account of changing bauxite grades fuel costs and increasing environmental constraints. The following general comments are applicable in the field of instrumentation amd control.

General Principles

The following will provide an indication of the general concepts governing the choice and application of the instrumentation installed in alumina plants together with some insight into the operation of certain complex control loops essential to satisfactory and smooth operation. A list of the types of physical measurements common to all plants is given in table 15.

Continuity and Reliability

The instrumentation must provide for uninterupted continuous operation. Instrument sensors on severe process applications require special facilities for maintenance without shutdown and in certain critical applications are duplicated.

Arrangement of Controls

Instrument and control valves should allow for local and remote operation. Most of the recording and controlling instruments together with alarm annunciators should be located in operating centre control rooms, where operators stationed continuously are able to monitor operation and make key decisions for corrective action

Protection in scaling service

Certain process liquors form precipitates during processing. These precipitates deposit as hard scale on equipment surfaces and will plug small openings such as instrument impulse lines and valve and pump shaft bearings. Plugging is avoided by forcing treated water through small openings into the process. provision is made to allow a probe to be forced through process connection openings to to clear away any scale which may restrict or block the openings.

Control Valve Operating Characteristics

Proportional type automatic controllers are used to actuate throttling type control valves in response to process demand signals.

Butterfly and globe control valves in which the logarithm of the flow rate is proportional to the valve opening are used. These valves provide the greatest span between max and min flows and cause least upset due to loss of valve pressure drop when line resistance increase occurs.

Globe control valves pass 110% max design flow with full stem travel. Butterfly valves are designed to pass max flow with a max angular shaft rotation of 60 degrees. This avoids continuous operation in the range of torque instability at angles exceeding 72 degrees.

Control Valve Rangeability

Valve rangeabilities for stable controlled flow under clean conditions and with constant pressure drop are selected as follows:

Type	Control Range
Butterfly	15 to 1
Globe single seat	25 to 1
Globe V pup	50 to 1
Globe angle	25 to 1
Globe two seat	50 to 1
Globe three way	25 to 1
Ball	100 to 1

However because of the desire to minimize pumping costs and the restrictive effect of scale buildup in the piping, the pressure drop across control valves may be one-sixth or less of the system pressure drop. In such systems this reduced rangeability may have the following effects;

Slow response to change of control point setting at high flow rates.

Long recovery time after process upset at high flows.

Wandering control record at high flow rates, requiring reduced proportional band setting.

Unstable control record at low flow rates, requiring increased proportional band setting.

Specialized Integrated Control Loops

Some important circuits which have been developed to facilitate control in Alumina plants are as follows

Digester Feed Rate

Bauxite feed rate to grinding mills is controlled to maintain desired alumina/caustic ratio. The main spent liquor flow includes the spent liquor which is diverted to the bauxite mills. Responsive interlinking of the bauxite feed rate and liquor flow controls is necessary.

Digester Pressure

Static pressure of the digester train is sensed at the discharge head and control achieved by regulation of the effluent tail valve. A duplicate control loop from the transmitter through the control valve is usually provided.

Digester Level/Temperature Control

Digester operating levels are maintained manually by adjusting the non-condensible gas bleed from the top of the vessel.

Two separate temperature control loops are generally used. The first controls a relatively large amount of steam injected into the first vessel. The second is arranged to control the first and to provide the desired discharge temperature from the digester train.

Spent Liquor Pump Controls

Multi-stage pumps transfer spent liquor from test tanks through heaters to digestion. Control seeks to achieve the following;

Regulate the flow at the required rate

Maintain pressure such that the liquor does not flash

Provide transfer from one pump to its alternative without upsetting the flow.

First Stage Liquor/Booster Charge Pumps

The rate of flow is controlled at the first pumping stage of the spent liquor charge. In addition booster pumps receive spent liquor which has been pumped by the charge pumps less that quantity of liquor which is bled off to bauxite grinding for slurry mix. Control at this point is predicated upon adjusting the pump speed to hold the desired suction pressure.

Injection Pump Pressure Control

The pressure control system is similar to that for the booster pumps. There is the added problem of temperature control at the suction of the pumps following the injection heaters. To avoid the danger of flashing at the pump suction during startup or transfer it is necessary to either reduce the set point of the temperature controller or use hand control.

The foregoing is provided in order to indicate the degree of complexity and the potential for things to go wrong in the operation of alumina plants. The frequent consequences of malfunction are:

loss of product

environmental discharges exceeding those permitted

out of specification product

higher energy and caustic soda usages.

higher maintenance costs

loss of effective production hours/reduced plant capacity

In addition it can be seen that a plant is designed to operate optimally on a specific grade of bauxite, and if significant variations occur in this then there is a strong potential for the foregoing consequences to occur.

The operation of alumina plants is at best a compromise of a number of competing factors. In the case of the Jamiacan Plants operation is made all the more difficult by the age of the plants and the variation in Bauxite feed quality they sometimes have to cope with. Such difficulties may be overcome to some extent by more skiiled manual operation (see comments under 3D on workforce skills and training).

Table 15

INSTRUMENTATION AND CONTROL - ALUMINA REFINERY

Summary of Physical Measurements and Summary of Devices Used

conductivity	
	flow through cells insertion cells
flow measurement	
	positive displacement meters variable area meters velocity head meters magnetic flow meters mass flow measurement
level measurement	
	buoyancy type hydrostatic type bin level switches
pressure measurement	
	pressure indicators (dial type) transmitters, bourdon tube type transmitters, differntial type pressure switches
temperature measurement	
	temperature transmitters, filled system thermocouples
dry solids flow measurement	
	continuous belt scales weigh feeders

3.C. - PROCESS TECHNOLOGY

As long as good quality bauxites are available in the world, there is not on the horizon at this time any cost efficient alternative process for the production of metallurgical grade alumina than the established Bayer process.

There are a number of improvements to the process and more cost effective ways of carrying out operations which are being implemented in many existing and new plants throughout the world. The refineries which currently operate within Jamaica have the origins and histories as detailed in Table 14.

The following are some ways in which alumina production costs are reduced in modern plants. Some of these factors are readily applicable to older plants, others may not be technically feasible or economically viable.

Size of unit plant stream

Alumina plants have always been conceived of as being constructed in multiples of a single process stream. The initial plant usually being just one of these streams with space allowed for the addition of up to perhaps another five units.

At the time of construction of the Jamaican plants, the size of the unit process stream was 250 - 300,000 tpa capacity. At the present time, the minimum size of a plant that would be built is of the order of 800,000 tpa.

The key advantage of plants is in the reduced capital cost of their construction as the following table from Hiscox (Alcan) demonstrates.

ALUMINA PLANT CAPITAL COSTS

Size MT/yr	Size Factor	Cost $m	Cost Factor	Cost per Annual MT $/MT
400,000	0.50	236	0.766	592
600,000	0.75	271	0.877	452
800,000	1.00	309	1.000	386
1,600,000	2.00	473	1.533	296

This table is taken from a paper entitled "Economics of Scale in Alumina Plant Design" by B.A.Hiscox, of Alcan International Ltd, which was included in the proceedings of the All India Aluminium Conference (date not supplied)

For existing Jamaican plants the normal method of increasing the capacity of the plant by the addition of a second process stream would merely perpetuate the poor economies of scale of the original plant.
Thus expansion of these plants will tend to occur by a gradual debottlenecking within the existing plant and by encorporating process and technological improvement. This would be the most cost effective way for these plants to be brought up to date.

The above study also examines the effect of plant stream size on operating cost. Here the effect is less dramatic but economies of scale apply to labour productivity. This is significantly lower in smaller plants. Also the rate at which repair and maintenance materials are used is significantly higher for plants based on small unit stream sizes.

In addition to the above operating cost item, the financial structure of the companies that operate them is based on a proportion of capital funds being borrowed. Depending on the individual debt/equity ratio of the company involved there will be an interest bill for a proportion of capital investment which will be higher for the smaller plants and extensions thereto than for plants based on larger unit sizes.

Pretreatment for Improved Desilication

With some bauxites it is advantageous to react bauxite with liquor prior to digestion at an elevated temperature less than that required for digestion. This permits the formation of a desilication product seed whereby desilication can be improved with reduced levels of silica in the extract and a reduced rate of scaling in the hotter liquor heaters.

Such pretreatment smooths the bauxite charging rate which is important for an efficient digest and smooth downstream process operation. It is understood that measures along these lines have been introduced in all existing Jamaican refineries.

Liquor Filtration

The use of Kelly filters on all plants except that of Jamalco is out of step with modern industry practice. Also the lime slurry which is used to assist filtration by keeping the filter cake porous is subsequently disposed of to the red mud waste steam thereby unnecessarily increasing the solids disposal burden. Reclycing of this stream to the digesters would reduce the mud volume and would reduce lime calcination requirements.

Filtration using sand as the filter medium has replaced Kelly filters in a number of refineries.

Well maintained sand filters operating with efficient fluidized backwashing of the sand bed enable operating costs to be reduced markedly over Kelly's in which the leaves must be separated to enable cake discharge and cloth cleaning. The capital cost of sand filters is also considerably lower.

It is understood that with Jamaican bauxites at high A/C ratios that difficulties have been experienced with the use of sand filters because of crystalization of aluminium hydroxide on the filter bed.
The filter bed is made up of bauxite derived minerals which act as a nucleating agent. A bed comprising a crystal form which is morphologically disimilar to aluminium hydroxide may reduce this problem.

Optimization of Precipitation Tank/Time

Studies into the cooling profile during precipitation have enabled rates of precipitation to be increased while still meeting alumina size specifications.

To conserve energy it is important to achieve a high yield for each pass of liquor so that by introducing an intermediate interstage cooler in the precipitation train, both yield and energy efficiency may be increased.

Precipitation times may thereby be reduced markedly over those which were provided at the time the Jamaican plants were designed.

To what extent the benefits of research into precipitation has been implemented on Jamaicans plant is difficult to determine.

Alternative Sources of Soda Values

The imbalance in demand levels between caustic and chlorine (both co-products of the electrolysis of sodium chloride) has continued to increase during the 80s. This has resulted in the price of caustic soda increasing disproportionately to its apportioned cost of production.

If the imbalance were to continue there will be a price for caustic soda at which alternative routes for its production would become commercially viable.

In the USA the original base of soda values for alumina refining were derived from Solvay produced soda ash converted to caustic soda.

Subsequently, a surplus of Gulf Coast and Japanese soda led to low caustic prices. The gradual erosion in caustic/chlorine balance which has been occurring now for some years to the detriment of caustic soda prices is causing alumina plant operators to re-evaluate soda ash as an alternative to caustic soda.

It is understood that the refineries currently operating in Jamaica do not possess the ability to generate caustic soda by causticization of soda ash at the present time. However, the process of causticization involves a number of inputs which every alumina refinery possesses for its normal process requirements.

These inputs and their requirement in the causticization process are as follows:

Input	Usage per Tonne Soda Ash *
Process/ Evapourisation Steam	4.95 million BTU
Power	85.8 KWH
Oil/gas/coal	4.33 million BTU
Calcined limestone marl	1.64 tonne (as limestone)

* (1.325 tonne soda ash is equivalent to 1 tonne of 100% caustic soda)

An alumina refinery that has excess capacity in steam and power generation and in lime calcination capacity, is more likely to be a candidate to use soda ash to replace caustic soda because of the absence of additional capital investment in these areas.

The sodium carbonate raw material need not be of the same purity as that for glass manufacture and is therefore less expensive.

On the basis of a most favourable scenario for the above route in which spare steam and power capacity is available without further capital expenditures the marginal cash cost of producing a tonne of caustic soda from purchased soda ash is madeup of the sum of:

- tonnes of purchased soda ash equivalent to 1 tonne of soda ash after allowing for conversation losses = 1.37

- marginal cash cost of conversion of soda ash to caustic soda - say US$60 /tonne

- capital dependent charges (interest, return to capital) - say US$60/tonne.

Based on the delivered cost of a tonne of soda ash of US$160/tonne this implies a continuous future price for caustic soda in excess of $294/tonne would be necessary in order that such an investment could be justified. This should set a cap on an average caustic soda price to alumina refineries given stable soda ash prices based on unlimited supply of impure soda ash.

Recovery of Soda values from Red mud

This established process procedure is not currently practised and is not considered economically feasible unless its benefits are combined with an improvement in mud disposal techniques.

The process involves sintering mud to recover soda and alumina values. Energy consumption is high and has only ever been considered for use with mud from high silica bauxites.

3D - LABOUR

The cost of labour in alumina production is the product of the number of men employed times the average rate per man. The number of men employed will depend to an extent on the level of technology/instrumentation built into the refinery. The higher this is, the lower may be expected to be the number of men employed in plant operation.

The level of skill that the workforce is able to bring to bear on the job also affects productivity. It is in the interests of both management and workers that this be raised to so that overall economies can be effected within the operation of the plant and for the workers to achieve higher rewards. This can be improved by the implementation of a comprehensive program of workforce education and training, supported as necessary by a Government incentive scheme applicable to both the Company and to individual workers.

The development of work trade skills applicable in the plant maintenance and support areas would assist in bringing more of this kind of activity onshore to Jamaica rather than have it carried out in the USA and elsewhere.

The prospect of the setting up a joint initiative between industry and government for the purposes of developing appropriate training courses and acreditation schemes should be given serious consideration.

The rate of pay which the average Jamaican worker currently receives is quite low by international standards and appears to be declining in line with the recent past devaluation in the Jamaican dollar. Whereas one view is that this may be seen as bringing to the industry in Jamaica a competitive edge, it is not on the other hand a desirable or sustainable state of affairs in the long term.

The degree to which real wages may become depressed before an unacceptible level of social discontent is reached is beyond the scope of this report. However in the interests of keeping the industrial evironment of Jamaica attractive to industry, it is important maintain a high level of political stability.

The maintenance and improvement of real wages and living standards is a positive step towards retaining this stability and the improvement of skills and the retention of those people with such skills is the means by which this can be achieved.

3E - WASTE DISPOSAL

The general principles with regard to waste disposal apply to alumina refinery operation: namely that which can be recycled should be, and that which cannot should be contained.

Detailed comments are available as regards waste disposal in that section of this report dealing with the environment. Other references appear in this part of the report under sections 2C, 3A and 3C.

Appended to this report are copies of :

"Guidelines for an Environmental Study for an Alumina Refinery in North Queensland" published by the Government of the State of Queensland, Australia.

Report and Recommendation of the Environmental Protection Authority of the State of Western Australia with regard to the Wagerup Alumina Refinery Expansion - Dec 1989, together with relevant explanatory documentation.

3F - PORT/STORAGE

No inspection of the Port facilities of the various alumina refineries was carried out (with the exception of the bauxite exporting operation by Kaiser at Discovery Bay), however the following general comments regarding storage apply.

The situation as regards the storage of bauxite for use in the Jamaican Alumina refineries is influenced by the peculiarities of mining the relatively small pockets of bauxite experienced in Jamaica and of the need to maintain numerous stockpiles of mined bauxite in order to be able to exercise a reasonable degree of control in the grade of bauxite sent to the refinery.

Bauxite mining operations in Jamaica vary considerably in this regard, the mining operations supplying the Alpart refinery are notably inferior to the others in this regard.

Broadly speaking there are three or four kinds of bauxite stockpile maintained by each mine/refinery.

The first is located at the source pit where the bauxite is mined. Generally this is quite small the bauxite being transported on as quickly as it is mined.

The second kind of stockpile which may be located at the railhead or central mining station is used for blending to achieve a uniform grade.

The third stockpile is located adjacent to the mode of transport used for carrying the bauxite to the refinery and is frequently the same stockpile as that used for blending.

The fourth stockpile is located at the refinery and is generally kept under cover to ensure a uniform a mosture content as possible is maintained in the feed bauxite to the refinery.

Two of the issues that arise in relation to stockpiles (both bauxite and alumina) are -

(1) the amount of working capital tied up in them

- and

(2) the wastage of mined material lost in tranferring between stockpiles.

Clearly the value per tonne of material in the alumina stockpile exceeds that in the bauxite stockpile by perhaps a factor exceeding 10, and the alumina companies recognize this fact by giving the majority of their attention to the efficient management in the alumina area.

However there is room for some improvement in performance in dealing with bauxite stockpiles. While it is recognized that special problems exist with regard to grade control, and that the small size and large number of mine pits being operated may require that larger than normal stockpiles be held, there does appear room for improvement in this area.

The assessment of the amount of bauxite mined based on the amount of alumina shipped multiplied by a negotiated conversion factor permits the companies to indulge in excessive wastage of bauxite in their stockpiling and processing procedures without being penalized by Government levy on the amount wasted.

As regards size of bauxite stockpiles, an estimate of the number of weeks of production held between minesite and refinery might be as high as 6 months. This is perhaps not excessive when applied to a bauxite which has to be shipped overseas as in the case of some of the large bauxite mines elsewhere, however it is excessive when applied to mines which have refineries adjacent to them. Here the advantages of "just-in-time" delivery should be realizable.

3 G - PROSPECTIVE BY-PRODUCTS

I - Alumina hydrates and Specialty Grade Aluminas

Terminology

Alumina hydrate - is aluminium hydroxide trihydrate which has been produced by precipitation from sodium aluminate liquors (usually Bayer plant).
Its most important property is its chemical reactivity derived from its hydrated form. It is mostly shipped in dried form. Hydrate is classified under the heading of non-metallurgical alumina (as anhydrous tonnage). It should be distinguished from other products in this category such as calcined aluminas for abrasives and refractories. A small amount of hydrate is used in refractories.

No significant amount of hydrate finds its way into the metallurgical alumina market.

A summary of current world non-metallurgical grade alumina capacity/production is given in table 13.

Uses

The major uses of aluminium hydrate are in the following areas:

1) fire retardant for carpets and smoke suppressant filler for plastics and rubbers;

2) a raw material for manufacture of aluminium chemicals, notably aluminium flouride, aluminium sulphate, sodium aluminate and aluminium chloride;

3) a filler, extender and coating for paper;

4) a minor ingredient for refractories and glazes;

5) raw material for catalysts production

6) washing agents (zeolites) and other.

Consumption Patterns

Fire Retardants

Plastics - growth at about at 5 - 6% p.a is predicted based on hydrate being currently the cheapest fire retardant filler for plastics which meets flammability regulations.
A major drawback is that it cannot be used where curing temperatures exceed 2000 C.

Carpet backing - US legislation requiring fire retardancy in carpets was the reason for a dramatic period of growth in the 1970's. Since then, the proportion of total used for this purpose has fallen because of reduced stringency in enforcement of the above legislation. The grades sold for this purpose are the coarsest and lowest value of all hydrates.

Rubber - The non-contaminating nature of hydrate as a flame retardant is lost in rubber products for which chemical flame retardants have tended to displace it.

Other - Hydrate induces arc resistance and di-electric strength in epoxy adhesives for construction use, a unique property.

Aluminium Chemicals

Chief amongst these are aluminium flouride and cryolite. Progressively more stringent environmental legislation has forced aluminium smelters to reduce fluorine emissions. Scrubbing systems now are designed with fluorine recovery in mind. Demand for fluorine chemicals by smelters has consequently decreased.

Paper

The growth of koalin products for paper over the past decade has tended to displace hydrate in paper coating and filling applications. Calcined koalin and precipitated silicates, in particular have displaced hydrate as a titanium dioxide extender.

Refactories

A small input of hydrate is needed for production of refractories, however the bulk of alumina for this purpose has been pre-calcined. The abrasives and refractory market reflects the level of activity in the steel, foundry and automotive sectors. US production has been affected by European imports. Continued market expansion in the refractories area is envisaged however.

The trend has been for smaller Bayer plants to switch part or all of their production to higher value hydrate. However, several of these have not continued to operate (Bauxite and Baton Rouge in US and MacKenzie in Guyana)

3 G - PROSPECTIVE BY-PRODUCTS

II - Gallium Production from Bauxite Ore

The following data may be useful in assessing the potential for manufacture of gallium metal from Jamaican bauxites.

Markets

Annual consumption of gallium has risen dramatically because of its presence in in many new technologies, including integrated circuits, magnetic bubble memories, and infra-red diodes for communications purposes. In the long run gallium usage is likely to increase perhaps even more dramatically, because of its demand in the form of gallium arsenide for application in photovoltaic energy conversion.

Technology

Currently the worlds most important source of gallium is bauxite in which gallium concentration ranges from 0.002 to 0.008 percent. The richest gallium bearing bauxites occur in Surinam, India, Arkansas (USA). Gallium is present in bauxite as as Ga2O3 along with oxides of vanadium and chromium.

Because of the low concentration of gallium in bauxite there is no satisfactory method of recovery directly therefrom, although there is one process which makes a claim to a possible recovery by a direct chlorination method.

At present gallium is commercially extracted from Bayer plant liquors by two major processes,

The carbonation (Beja) process

The direct electrolysis (La Breteque) process.

The carbonation process used by Alcoa to extract gallium from Bayer liquor, involves treating aluminate solution with carbon dioxide in two controlled stages.

Alusuisse using the La Breteque process produces gallium by direct electrolysis of concentrated Bayer liquor. Gallium concentration is allowed to build up by repetitive recycling of Bayer liquor in the main alumina plant until a portion of it is passed to the gallium recovery circuit. This liquor is further concentrated by cyclic evapouration. Direct electrolysis takes place in the cells using a strongly agitated mercury cathode and nickel anode. The cells are operated bathwise.

When gallium in the amalgum reaches about 1% it is leached out with caustic soda and the solution further electrolysed to produce gallium metal. Spent mercury is purified and returned to the La Breteque cells. A diagram of this process is shown in fig 2.

Construction and Operating Cost Data

Process data for the La Breteque process is given below. The figures have been adjusted to apply to a plant conforming to the following basic profile.

Alumina plant capacity	200,000 tpa
Bauxite feed rate	400,000 tpa
Gallium content in bauxite	20 ppm
Gallium recovery potential	60 %
Prospective gallium production	4.8 tpa

Total capital construction cost when this process is applied applied to a suitable alumina plant would be of the order of US $30 million, plus the cost of the mercury inventory.

Mercury losses must be carefully controlled, a consumption of about 20 gm per kgm of product would be expected.

Steam would be rquired for:

heating aluminate liquors	5,200 tpa
evaporation of added water	1,370 tpa
total	6,570 tpa

Soda is required for makeup purposes at the rate of 86 tpa as 100% caustic soda.

Vanadium in the bauxite impairs gallium recovery efficiency. Methods to remove it are disruptive and costly (they involve cooling the aluminate liquors or adding calcium hydroaluminate).

TABLE 1

STRUCTURE OF THE INDUSTRY - 1990

SUMMARY OF OWNERSHIP OF CAPACITY IN JAMAICAN ALUMINA REFINERIES
TOGETHER WITH OWNERSHIP OF REFINING FACILITIES IN OTHER COUNTRIES

COMPANY	JAMAICAN ALUMINA REFINERY ENTITLEMT CAPACITY ktpa (1)		ALUMINA ENTITLEMENT VIA EQUITY IN OTHER MAJOR ALUMINA PRODUCING COUNTRIES country	refinery 1 equity	entitlmt ktpa	refinery 2 equity	entitlmt ktpa	refinery 3 equity	entitlmt ktpa	total non-Jamaican ktpa
Alcoa	Jamalco	275	Australia	Kwinana	1500	Pinjarra	3000	Wagerup	1070	5570
	50%		Brazil	Sao Luis	570	P de Caldas	208			778
			USA	Pt Comfort	1740					1740
			Surinam	Suralco	908					908
			EEC	Ludwigschafen						0

										8996
CAP	Jamalco	275								
	50%									
Alcan	Jamalcan	977	Canada	Vaudreuil	1140					1140
	93%		Australia	Gladstone	825					825
			Brazil	Saramenha	150					150
			EEC	Aughinish	920	San Ciprian	239	Burntisland	120	1279
			Japan	Shimizu	100					100
			India	Belgaum	71	Muri	34			105

										3599
JBM	Jamalcan	74								
	7%									
Kaiser	Alpart	767	Australia	Gladstone	947					947
	65%		USA	Gramercy	1000					1000
			EEC	Eurallumina	141					141

										2088
Norsk Hydro	Alpart	413								
	35%									

NOTES

(1) CAPACITIES ARE "NOMINAL" AS PER KING REPORT ON ALUMINA AVAILABILITY - APRIL 1991

TABLE 2

ENERGY CONSUMPTION IN JAMAICAN ALUMINA REFINERIES

REFINERY	TYPE OF DIGEST	PROCESS ENERGY GJ/T	TYPE OF KILN	CALCINATION ENERGY GJ/T	ELECTRIC POWER USED GJ/T	TOTAL ENERGY CONSUMED GJ/T	ENERGY COST (BASED ON OIL AT US$15/BBL) US$/T ALUMINA	ENERGY COST (BASED ON "REG 58" DATA US$/T ALUMINA
JAMALCO	LT	7.87	FB	3.8	0.05	11.72	26.6	26.4
JAMALCAN								
EWARTON	LT	10.53	R	4.96	(2)	15.49	35.2	33.2 (5)
KIRKVINE	LT	10.53	RR (1)	4.2	(2)	14.73	33.5	33.2 (5)
ALPART	HT SWEET	13	R (2)	5.28	(2)	18.28 (3)	41.6 (4)	42

NOTES

(1) hydrate prodn of 35,000 tpa not calcined

(2) additional calcination capacity of 920,000 tpa to be Lurgi fluid bed existing 1,200,000 tpa calcination capacity to be retrofitted and

(3) as a result the calcination energy consumption is expected to fall to 3.5 GJ/T and overall consumption to 18.9 GJ/T and

(4) energy cost will fall to US$44/T alumina

(5) ·· for Ewarton & Kirkvine

TABLE 3

SUMMARY OF ALUMINA CALCINATION KILNS IN OPERATION AT JAMAICAN ALUMINA REFINERIES

PLANT	NUMBER OF KILNS	CAPACITY EACH KILN TPA	TYPE	TOTAL CAPACITY TPA
JAMALCO	3	350,000	ALCOA MKIII	1000,000
JAMALCAN				
EWARTON	3	200,000	ROTARY	600,000
KIRKVINE	3	200,000	RETROFITTED ROTARY	600,000
ALPART	3	400,000	RETROFITTED ROTARY	1,200,000
	2	460,000 (1)	LURGI FLUID BED	920,000

NOTES (1) PART OF PROPOSED EXPANSION

TABLE 4

INDICATIVE UNIT ENERGY CONSUMPTIONS

FOR ALTERNATIVE ALUMINA CALCINATION KILN DESIGN

KILN TYPE	ENERGY CONSUMPTION GJ/T ALUMINA
ROTARY	4.6
RETROFITTED ROTARY	3.45
ALCOA (MKII)	3.5
ALCOA (MKIII)	3.18
LURGI	3.14
FL SMIDTH	3.18

TABLE 5

SUMMARY OF ENERGY REQUIREMENTS FOR

SELECTED WORLD ALUMINA REFINERIES

REFINERY	BOILER ENERGY SOURCE	BOILER ENERGY GJ/T	CALCN ENERGY SOURCE	CALCN ENERGY GJ/T	ELECTRIC ENERGY GJ/T	TOTAL ENERGY GJ/T	ENERGY RATE US$/GJ (1)	ENERGY COST US$/T ALUMINA
Pinjarra	gas	8.95	gas	3.5	0 (3)	12.45	2	24.9
Kwinana	gas	7.95	gas	3.5	0 (3)	11.45	2	22.9
Wagerup	gas	8.95	gas	3.19	0 (3)	12.14	2	24.3
Worsley	coal	7.62	gas	3.37	0 (3)	10.99	2	22.0
Gladstone	coal	9.8	oil (2)	3.5	2.2	13.3	2.2	29.3
Gramercy	oil	14.2	oil	3.5	0 (3)	17.7	2.4	42.5
Aughinish	oil	7.2	oil	3.2	2.5	10.4	2.4	25.0
Interallumina	heavy oil	9.6	oil	3.2	0 (3)	12.8	2.3	29.4
San Ciprian	oil	7.2	oil	3.2	2.5	10.4	2.4	25.0

Notes (1) assumed rates (see text)

bunker C oil - US$2.4/GJ
coal/heavy oil - US$2.2/GJ
gas - US$2.0/GJ

(2) recent announcement that a contract had been signed for the use of gas to replace oil for calcination

(3) self generation of electric energy

TABLE 6

ANTICIPATED CAUSTIC SODA CONSUMPTION IN JAMAICAN ALUMINA REFINERIES

REFINERY	DIGESTION TEMP	TOTAL ALUMINA %	TOTAL SILICA %	REACTIVE SILICA %	T BX/T ALUMINA	ANTICIPATED SODA USE T/T ALUMINA (2)	ACTUAL SODA USE T/T ALUMINA	ACTUAL COST SODA US$/T ALUMINA
EWARTON	140	43.04	2.47	2	2.4552	0.071	0.077 (1)	24.3
KIRKVINE	140	43.9	1.81	1.8	2.4552	0.064	0.077 (1)	24.3
ALPART	230	46.39	1.13	1.1	2.3194	0.037	0.098	30.9
CLARENDON	170	42.59	1.36	1.44 1.75	2.6363	0.052	0.148	46.6

NOTES (1) average for both plants

(2) based on average performance of similar sized plants elsewhere

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TABLE 7

PRODUCTIVITY AND LABOUR COST OF JAMAICAN REFINERIES TOGETHER WITH SELECTED WORLD ALUMINA REFINERIES - 1990

REFINERY	PRODN KTPA	WAGES	NUMBER EMPLOYED (1) SALARY	CONTRACT	TOTAL	LABOUR PRODCTVTY TONNE/ PERSON	AV WAGE US$/MAN /ANNUM	LABOUR COST US$/T
JAMAICAN REFINERIES (2)								
Ewarton/ Kirkvine	975	710	259	0	969 (4)	1373	14600	10.6
Alpart	1188	555	392	0	947 (4)	2141	16000	7.5
Clarendon	706	533	345	0	878 (4)	1325	14600	11.0
SELECTED WORLD REFINERIES								
Alcoa (Aust)								
Pinjarra	2400	990	220	240	1450	2424	30000	12.4
Wagerup	650	390	110	120	620	1667	30000	18.0
Kwinana	1400	900	200	200	1300	1556	30000	19.3
Gove	1160	559	306	0	865	2075	30000	14.5
Worsley	1000	360	240	0	600	2778	30000	10.8
Gladstone	3000	870	440	100	1410	3448	30000	8.7
Gramercy	1000	440	260	130	830 (3)	2273	50000	22.0
Aughinish	1000	500	240	20	760	2000	25000	12.5
Interallumina	1000	800	380	190	1370	1250	15000	12.0
San Ciprian	1000	560	240	50	850	1786	22000	12.3

NOTES

(1) - Total number of employees including contract and indirect

(2) - Derived from regulation 58 reports for year ending Dec 1990

(3) - Kaiser News notes gave number employed as 1000 for Gramercy and 950 for Baton Rouge in Dec 1982

(4) - derived from reg 58 "data"

TABLE 8 - BASIS OF ESTIMATION OF MINING COSTS FOR JAMAICAN BAUXITES

MINE	SCHWALLENBURGH		MANCHESTER PLATEAU		
REFINERY	EWARTON	KIRKVINE	ALPART	CLARENDON	KAISER
OVERBURDEN M	0.3	0.3	0.3	0.6	0.5
MINE EQUIPT	DOZERS/ POWER SHOVELS BACKHOE DRAGLINE	DOZERS/ POWER SHOVELS BACKHOE DRAGLINE	DRAG LINE DOZER	BACKHOES 2 D9 DOZERS 5 D8 DOZERS 4 DRAGLINE	DOZERS+ DRAGLINES GRIZZLES AT RAILHEADS(3)
TRUCK EQUIPT	2 X 100 T X 85 T X40 T			13 X 50T	50T+ CONTRACT SHT HAUL
RAIL EQUIPT	NA	NA	NA	18 WAG BLOCK 1 LOCO	2 WAG BLOCK 2 LOCO
DIST RD	4 K	4 K	3 K		3-5 MLS
DIST RAIL	NA	NA	NA	21.3 MLS	12 MLS
DIST CABLE/ ROPE	7 K	NA	9 MLS(1)	NA	NA
NO EMPLOYEES	100	97	15[illegible]	166	750(2)
SHIFTS /DAY	2	2	2 (1)	2/3	3
PIT SIZE RANGE	med-large	med-large	small	med-large	med-v large
NO PITS OPEN			10	4	20

NOTES (1) - Cable belt shuts at 11-00 pm because of noise
(2) - includes port facilities
(3) - Excludes port equipment of - "wobblers"
three dryers and ancillaries
conveyors
shiploader

TABLE 9 - ESTIMATED CASH MINING AND TRANSPORT COSTS FOR JAMAICAN BAUXITES
(excluding capital, depreciation and interest payments)

US$/T DRY BAUXITE

MINE	SCHWALLENBURGH	MANCHESTER PLATEAU		
REFINERY	EWARTON KIRKVINE (av for both sites)	ALPART	CLARENDON	KAISER
BAUXITE MINED MTPA	2.389	2.84	1.832	3.866
LABOUR NUMBER	197	168	166	250 (est)
LABOUR COST US$/T BX	1.48	1.06	1.63	1.15
MATERIALS				
FUEL	0.52	0.82	0.70	0.92
R & M	0.7	1.05	0.92	0.92
SUPPLIES	0.25	0.25	0.25	0.25
FEES (2)	0.69	0.69	0.69	0.69
LAND RECLMN	0.31	0.27	0.21	0.22
TRAIN RUNNING	0	0	1.35	1.65
FEEDER RDS	0.15	0.12	0.14	0.18
CABLE BELT	1.58	1.88	0.00	0.00
INSUR & TXS	0.02	0.02	0.02	0.02
TOTAL BX COST	5.70	6.16	5.91	6.00

(1) - yr ending Dec 1990 (2) - estimated at flat fee US$/t regardless of grade

TABLE 10 - COMPARISON OF BAUXITE FREIGHT COSTS FOR BAUXITES PROCESSED AT REFINERIES WHERE OCEAN FREIGHT

OVERLAND FROM MINE VS WHERE OCEAN FREIGHT COST PENALTY IS INCURRED

CASH COSTS ONLY

BAUXITE	ESTIMATED BX COST AT MINE US$/T BX	REFINERY LOCATED OVERLAND FROM MINE: REFINERY LOCATION	OVERLAND TRANSPORT MODE	OVERLAND TRANSPORT COST	ESTIMATED COST AT REFINERY US$/T BX	ESTIMATED COST AT REFINERY US$/T ALO	REFINERY INCURRING OCEAN FREIGHT PENALTY: REFINERY LOCATION	OVERLAND ,PORT TRANSPORT COST US$/T	OCEAN FREIGHT US$/T	ESTIMATED COST AT REFINERY US$/T BX	ESTIMATED COST AT REFINERY US$/T ALO
JAMAICAN											
SCHWALLENBURGH	5.7 (1)	EWARTON	(1)	0	5.7						
MELROSE	5 (1)	KIRKVINE	(1)	0	5						
CLARENDON	4.86	CLARENDON	rail	0.8	5.91						
MANCH PLAT	4.28	ALPART	belt	0.5	6.16						
TOBOLSKI	4.6		rail drying	1.4 0.5			GRAMERCY	1.2	4	11.7	
JARRADALE	6.5	KWINANA	rail	1.5	8						
MT WILLIAM	5.6	WAGERUP	belt	0.4	6						
HUNTLY/DEL PARK	6.1	PINJARRA	belt	0.4	6.5						
MT SADDLEBACK	7	WORSLEY	c belt	1.5	8.5						
WEIPA	5						GLADSTONE SARDINIA		8 15	13 20	
BOKE W AFRICA	8						EUROPE USA		5 5	13 13	
GOVE AUST	4.7	GOVE	c belt	0.5			EUROPE		12	16.7	
TROMBETAS	10						INTERALLUMINA		6	16	

NOTES (1) - overland transport from mine included in Bx mining cost

TABLE 11

COMPARISON OF "OTHER COSTS" FOR SELECTED ALUMINA REFINERIES WORLDWIDE

BASED ON "OTHER COSTS" FOR JAMAICAN REFINERIES BEING TAKEN = "100"

REFINERY	COUNTRY	COST FACTOR (JAMAICAN PLANTS = 100)
ALCOA	AUSTRALIA	60
QAL	AUSTRALIA	55
GOVE	AUSTRALIA	70
GRAMERCY	USA	60
	SARDINIA	75
	SPAIN	
	IRELAND	
	GERMANY	
FRIGUIA		150
ST CROIX		170
JAMAICA		100
VENEZUELA		110

(1) - "OTHER" COSTS INCLUDES: MATERIALS, SUPPLIES, INSURANCE, OVERHEAD

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TABLE 12 - COMPARISON SUMMARY OF ALUMINA PRODUCTION COSTS FOR SELECTED REFINERIES

REFINERY	BAUXITE COST US$/T Bx (1) (2)	BAUXITE UNIT USGE tBx/tAlO	BAUXITE COST US$/T ALUMINA	BAUXITE ROYALTY US$/T ALUMINA	ENERGY	CAUSTIC	LABOUR	OTHER	TOTAL
Jamalco	6.55	2.6363	17.27	1.32	28.1	42	18.2	28	134.89
Jamalcan									
Ewarton	5.7 (2)	2.4552	13.99	1.23	37.2	24	14.5	28	118.92
Kirkvine	5 (2)	2.4552	12.28	1.23	37.2	24	14.5	28	117.20
Alpart	6.7	2.3194	15.54	1.16	48.2	22.5	12.7	28	128.10
Alcoa Aust	7	3.5	24.50	1.54	25.4	21	19	17	108.44
Worsley	8.5	3.47	29.50	1.53	20	23	17	20	
Gladstone	13	2.15	27.95	1.42	30.6	30	15	15	119.97
Gramercy	11.7	2.3	26.91	1.15	35.4	18	42	17	140.46
Aughinish	13	1.8	23.40	10.00	40	10	23	21	127.40
Sao Luis	5	2	10.00	6.58	29.4	23	21	31	120.98
San Ciprian	13	1.8	23.40	10.00	25	107	24	21	103.40

NOTES (1) Bx cost is cif plant where ocean transport is involved

(2) for Jamaican supplied by Mr Dennis Morrison, Jamaicaan Bauxite Institute

TABLE 13

WORLD PRODUCERS OF SPECIALTY GRADE

(NON METALLURGICAL) ALUMINAS

TONNES OF AL2O3 EQUIVALENT (1)

COMPANY	REFINERY	LOCATION	ESTIMATED 1991 NON-MET GRADE ALUMINA PRODN MTPA	CURRENT CO-PRODUCED MET GRADE ALUMINA MTPA	1986 NON-MET GRADE ALUMINA PRODN MTPA
ALCAN	VAUDREUIL	CANADA	125	1015	250
	KIRKVINE	JAMAICA	15	1050	0
	AUGHINISH	IRELAND	20	920	0
	BURNTISLAND	SCOTLAND	110	0	120
ALCOA	PT COMFORT	USA	481	1300	170
	POCOS DE CALDAS	BRAZIL	160	160	130
	KWINANA	AUSTRALIA	200	1300	150
	BAUXITE	USA	0	0	150
	LUDWIGSCHAFEN	FRG	0	0	140
	SURALCO	SURINAM	50	1538	50
KAISER	GRAMERCY	USA	160	750	200
REYNOLDS	C CHRISTI	USA	50	1475	200
PECHINEY	GARDANNE	FRANCE	320	350	300
AOS	STADE	FRG	50	690	140
MARTINSWERK	BERGHEIM	FRG	350	0	250
VAW	SCHWANDORF	FRG	80	0	120

(1) SOURCE - JAMES F KING - WORLD CAPACITY AND MARKET REPORT - ALUMINA & BAUXITE. FEB 1991

TABLE 14

TECHNICAL HISTORY OF JAMAICAN ALUMINA REFINERIES

REFINERY NAME	DATE CONSTRUCTED	INITIAL CAPACITY KTPA	CURRENT CAPACITY KTPA	DIGESTION STREAMS TEMP	ENERGY SOURCE	HYDRATE FILTERS	ALUMINA KILNS	MAJOR MODIFICATIONS
EWARTON	1959	270	450	2/140	OIL	KELLY	3/ROT	all kilns to be retrofitted deep thickeners added 1980 separate sodium oxalate rem
KIRKVINE	1953	270	550	2/140	OIL	KELLY	3/ROT	all kilns now retrofitted
CLARENDON	1972	400	750	2/245 (1)	OIL	SAND	3/FB (ALCOA MK III)	(1) reduced to 140 additional sand filters
ALPART	1969	900	1200	3/230	OIL	KELLY	2/ROT + NEW LURGI	sweetening introduced 1985

FIG 1

ENERGY COSTS FOR SELECTED REFINERIES

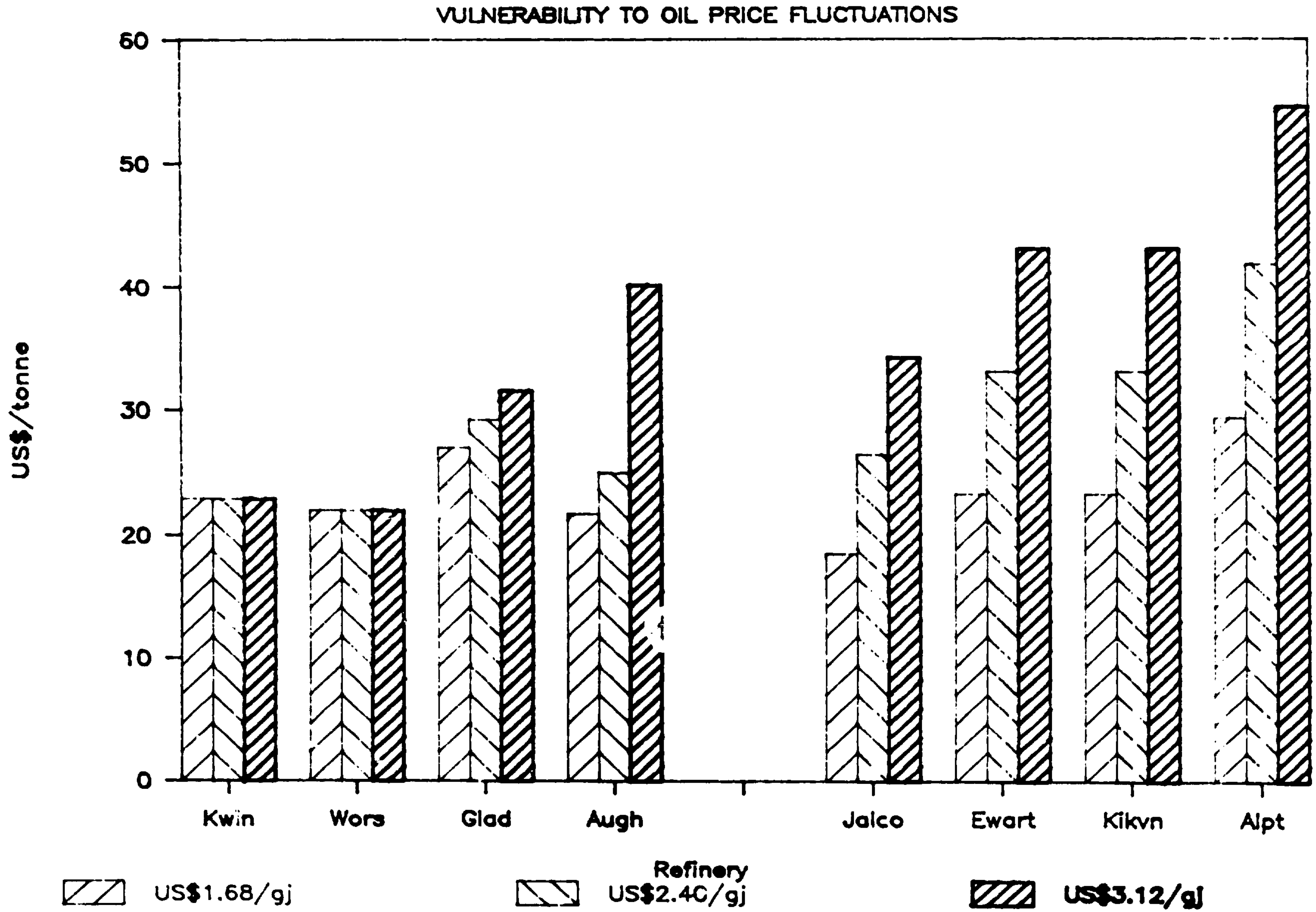

FIG 2

rwmr.wk1:a1		
GALLIUM RECOVERY FROM BAYER LIQUOR		
FEED COMPOSITION		
liquor rate 13 cub metres/hr		
caustic concn 250 gpl (carbonate)		
gallium concn 0.19 gpl		
	GALLIUM RICH LIQUOR	
	WET AIR OXIDATION	
	LIQUOR PURIFICATION	
	ELECTROLYSIS	RETURN LIQUOR
	RECOVERED GALLIUM	
gallium production 30 kgm/day		
gallium recovery 60%		
gallium purity 99.9%		

BIBLIOGRAPHY

The Europa World Year Book 1992 - Vol 1 - Europa Publications Ltd 1992, 18 Belford Square, London.

Experience with the Operation of the Alcoa Fluid Flash Calciner - Edward W Lussky - Manager Client Technology - Aluminium Company of America, Pittsburgh, Pennsylvania.

Energy Savings in the Bayer Process - D.J.Donaldson - Kaiser Aluminium and Chemical Corporation, Oakland, California - in Journal of Metals, September 1981.

Economics of Scale in Alumina Plant Design - B.A.Hiscox - Alcan International Ltd, Montreal, Canada - in Proceedings of All India Aluminium Conference. (undated).

Gallium Recovery from Bauxite - Translated and Summarized from "Etudes sur le Gallium" by Pierre de la Breteque - in Journal of Metals November 1956.