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RESTRICTED

9 December 1993
ORIGINAL:ENGLISH

REPORT ON THE MISSION

DP/IND/88/015/11-08/B
INDIA

of Dr. K. Solymar, expert in alumina process engineering to India between 13 September and 24 November, 1993

for the

Jawaharlal Nehru Aluminium Research Development and Design Centre, Nagpur

about

Guidance in the preparation of pre-investment studies for the modernisation / expansion of alumina plants of BALCO, HINDALCO and NALCO at JNARDDC.

Backstopping officer : Dr. T.Grof, Subsistance officer

UNIDO, Vienna

TABLE OF CONTENTS

ABSTRACT

The mission was organized by UNIDO Vienna in the framework of the Project to assist the Government of India in setting up a functioning Aluminium Research Development and Design Centre (Project No. DP/IND/88/015/11-08).

The objective of the mission was guidance in the preparation of pre-investment studies for the modernisation/expansion of alumina plants of BALCO, HINDALCO and NALCO. All the three studies have been prepared in a form of Draft during the mission (13 Sept. - 24 Nov.).

The recommended options are based on the processing of gibbsitic (low-boehmite) bauxite at medium pressure digestion (at 145 - 150°C) and adaptation of up-to-date precipitation process with high liquor productivity. The studies confirm the adequate capability of the related experts team of JNARDDC, Nagpur. They are valuable contributions to the development strategy of alumina production in India.

The presentation of the studies at companies by JNARDDC, the urgent recruitment of further staff members (completion of the personnel), collection and evaluation of representative bauxite samples, lab simulation tests and preparation of feasibility studies on request are recommended.

Nagpur, 20 November, 1993

Dr. K. Solymar
UNIDO Consultant

INTRODUCTION

The mission was organised by UNIDO Vienna and by the Jawaharlal Nehru Aluminium Research Development and Design Centre, (JNARDDC) Nagpur in the framework of UNIDO project "Assitance to the Government of India in setting up a Functioning Aluminium Research Development and Design Centre" (Project No. DP/IND/88/015/11-08).

This report has been written by Dr. K. Solymar, expert in alumina process engineering as a result of his mission. The related job description is enclosed as **Annexure - I**. The activity was started on 13th September and terminated on 24th November. The main objective of the consultant was providing guidance in the preparation of pre-investment (case) studies for the modernisation/expansion of alumina plants of BALCO, HINDALCO and NALCO. The studies have been prepared by the staff of JNARDDC with the involvement of international experts (Mr. L. Varga, Ms. E. Molnar and Mr. A. Molnar for durations of 2.0, 1.75 and 0.75 months respectively from the International Subcontractor (ISC), Aluterv-FKI Ltd. based on Contract No. 89/153 and Ammendment No. 1 to the contract). The whole work has been directed, organised and co-ordinated by Dr. T.R. Ramachandran, Director and Dr. J. Zambo, Chief Technical Adviser.

The main activity of the consultant was covered by the guidance/assistance offered in the preparation of the above listed pre-investment studies with the support/ consultations from the staff members of the Centre, international experts and representatives/experts of the alumina plants.

The pre-investment studies were elaborated in draft version and the objectives of the mission were attained.

On the request of JNARDDC the consultant participated in the Workshop on Production and Applications of Special Alumina Chemicals held in Bangalore between 27 and 29 October and presented a paper on "Present Status of the World Alumina Industry and Main Strategies to Produce Speciality Alumina Chemicals".

As a final activity a visit to Renukoot Alumina Plant of HINDALCO was undertaken to hand over the Draft Pre-investment Study and to conduct explanatory and preliminary discussion on the main findings of the study.

ACTIVITIES

The activity of the consultant was based on the job description and on the detailed programme for preparation of pre-investment studies for alumina plants elaborated on the site. The final version of this programme is enclosed as **Annexure - II.** The related activity of the consultant has been interrupted between 24 and 31 October due to his participation in the Workshop in Bangalore.

The schedule of the mission is given below :

Arrival Delhi (from Budapest)	Sep. 13
Visit UNDP Delhi office (Meeting with Mr. Vivek Rae, Mr. Sat Pal and Mr. D. Kumar)	Sep. 14
Arrival Nagpur (from Delhi)	Sep. 15
Guidance/assistance in preparation of pre-investment studies for alumina plants at JNARDDC, Nagpur	Sep. 16 - Oct. 23
Travel from Nagpur to Bangalore (via Hyderabad)	Oct. 24 - Oct. 25
Participation and presentation of a lecture on the Workshop on "Production and Applications of Special Alumina Chemicals" in Bangalore, discussions with the participants and experts of alumina plants.	Oct. 26 - Oct. 30
Travel from Bangalore to Nagpur (via Hyderabad)	Oct. 31

Guidance/assistance in preparation of pre-investment studies for alumina plants at JNARDDC, Nagpur	Nov. 1 - Nov. 20
Travel to Renukoot Alumina Plant from Nagpur (via Delhi - Varanasi)	Nov. 21 - Nov. 22
Handing over the study and explanatory, preliminary discussion with the experts of HINDALCO	Nov. 22 - Nov. 23
Travel to Budapest (via Varanasi - Delhi - Zurich)	Nov. 23 - Nov. 24

A. Guidance in the preparation of pre-investment studies

This activity has been performed in close co-operation with Dr. T.R. Ramachandran, Director, Dr. J. Zambo, Chief Technical Advisor, the international experts of UNIDO and the Staff of the Jawaharlal Nehru Aluminium Research Development and Design Centre (JNARDDC), Nagpur. The list of the experts participating in the preparation of the studies is enclosed as **Annexure - III**.

The preparatory work relating to the data basis and main objectives of the expected pre-investment studies was in good progress at the time of arrival of the consultant. The material and heat balances concerning the existing operations of all the three alumina plants were available already (Calculated by the experts of JNARDDC trained by the experts of ISC before on the site and at Aluterv-FKI Ltd. in Hungary). Other experts were familiar with the COMFAR programme used for economic evaluation (preferred by UNIDO).

The main duties marked under points 1 to 3 in the job description of the consultant have been fulfilled by the direct joint daily work with the staff members of JNARDDC and accordingly no series of lectures on preparation of feasibility reports has been delivered. This kind of activity would be more meaningful in the future when the technical personnel in the given field will be recruited completely.

Three pre-investment studies were prepared in draft form, during the mission of expert as follows :

1. Intensification of the production process and improvement of alumina quality at Korba Alumina Plant of BALCO.

2. Intensification of the production process and modernisation of precipitation at Renukoot Alumina Plant of HINDALCO.

3. Intensification of the production process and expansion of producton capacity of Damanjodi Alumina Plant of NALCO.

The preparation of these studies has two main objectives, namely.

- Provide training to Scientists of the Centre in order to enable them to carry out such activities in the future with a limited contribution/assistance of international and domestic experts.

- Provide the companies (alumina plants) with valuable documents/information relating to the economic expansion of their alumina production capacity and quality improvement if necessary.

The selection/finalization of the proposed variants of technology was agreed with the representatives of BALCO between 27 and 29 September, that of HINDALCO between 29 September and 1 October at JNARDDC.

Meeting on process engineering was held with BALCO-team only between 18 and 20 October while further meeetings with the experts of HINDALCO, BALCO and NALCO were possible during the Workshop held in Bangalore. The consultant has participated at all these meetings.

B. <u>Participation and lecturing at the Workshop</u>

The consultant participated in the Workshop on Production and Applications of Special Alumina Chemicals held in Bangalore between 27 and 29 October, 1993, and delivered a paper on "Present Status of the World Alumina Industry and Main Strategies to Produce Specialty Alumina Chemicals".

The actual topics of the pre-investment studies under preparation have also been discussed with the experts of the related companies at the time of the Workshop.

The evaluation of the Workshop is available in a separate document prepared by Aluterv-FKI Ltd.

C. **Providing the Centre with copies of relevant literature**

Copies of following relevant literature were submitted to the Centre :

a) Papers considered for the evaluation of the technical background of the recommended technological variants (Processing of gibbsitic bauxites, up-to-date precipitation technology).

b) MBR (Metal Bulletin Research) : The Aluminium Industry Review, December, 1992 Published by Metal Bulletin Journals.

c) Alumina Quality - Meeting Customer Needs - Proceedings of the Third International Alumina Quality Workshop. Hunter Valley, New South Wales, Australia October, 17-21, 1993.

d). Determination of the comparative export value and comparative processing value of the Vietnamese bauxite. Techno-economic study. (Techno-economic evaluation of the Tan Rai bauxite). UNIDO Case Study, Bien Hoa, Bauxite Research Centre, January, 1989.

CONCLUSIONS

1. The Draft Versions of all the three pre-investment studies have been prepared successfully due to the careful preparatory work, well organized acitivity of the staff members of JNARDDC and significant contributions of international experts in guidance/assistance, in spite of the very tight time schedule.

2. Executive Summary of each Pre-investment study is enclosed as **Annexure - IV, Annexure - V and Annexure - VI**. The recommended options are based on the processing of gibbsitic (low-boehmite) bauxite at medium pressure (145 - 150°C) digestion and the adaptation of the up-to-date precipitation technology developed by Alusuisse.

3. The preparation of the studies confirmed the high capability of the related experts-team of JNARDDC. These studies are valuable contributions to determine the development strategy of alumina production in India.

4. The finalization (completion/modification and final editing) of the Draft - studies can be performed by the Staff of the Centre successfully.

5. The Centre has a core of well trained experts in the fields of XRF and XRD analysis, Computer aided calculations of mass and heat balances, alumina production technology, bauxite geology and evaluation and techno-economic evaluation who are able to prepare similar studies with a limited assistance/guidance of international and/or domestic experts.

RECOMMENDATIONS

1. The presentation of the pre-investment studies by the experts-team of JNARDDC is recommended at the related companies in order to discuss them and to determine the follow-up actions.

2. To strengthen the activities in the Centre in the field of preparation of investment studies and engineering packages the following measures should be considered.

a) Acceleration of recruitment of the scheduled professional staff to enlarge the basis for such activities and to increase the number of experts trained in India and abroad in the frame of the project. One process engineer (electrical) one process engineer (mechanical/thermal) and a financial expert/economist are to be recruited for these tasks.

b) Urgent implementation and start up of all technological testing equipment and methods in the new technical complex in order to justify the design parameters by laboratory process simulation.

c) Collection and evaluation of processing value of representative bauxite samples and establishment of bauxite data bank at the Centre should be completed as early as possible for utilisation of this information in preparation and formulation of development strategies of alumina plants.

3. The continuation of the activity by preparation of feasibility studies is recommended according to the request of the related alumina plants with the adequate assistance/guidance of international and/or domestic experts.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

JOB DESCRIPTION

DP/IND/88/015/11-08*/B

J13207

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Post Title: Expert in alumina process engineering

Duration: 6 months split mission

Date required: First mission (3.5 m/ms) from August 1993
Second mission (2.5 m/ms) February/March 1994

Duty Station: Nagpur, India with travel in the country

Purpose of project: The immediate objective of the project is to assist the Government of India in setting up a functioning Aluminium Research, Development and Design Centre consisting of:

(a) Alumina Production Research Department
(b) Aluminium electrolysis Department
(c) Analytical Research Department
(d) General Services, instrumentation and Control Department (incl. Workshop and Maintenance)
(e) General Administration and Finance Department

The Centre will develop capability of carrying out the following main functions on behalf of and in cooperation with the bauxite processing/alumina production and aluminium smelter industries in the country:

(a) Assimilation and adaptation of available technologies
(b) Providing recommendations and ad hoc or applied and analytical research to local industries in process improvement, transfer of technology, etc.

(c) Setting up and operating a data bank

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*)

Applications and communications regarding this Job Description should be sent to:
Project Personnel Recruitment Section, Industrial Operations Division
UNIDO, VIENNA INTERNATIONAL CENTRE, P.O. BOX 300, Vienna, Austria

(d) Providing training of Indian engineers.

Duties: The expert will be required to advise on the improvement of alumina production technology and on basic engineering of alumina plants. He will assist in the setting up of the alumina production research department of the Centre and in mathematical modelling and preparation/application of energy and material balances of alumina refineries.

His main duties will be:

1. To assist in starting up activities in alumina process engineering, provide training to scientists of the centre in the techno-economic justification of R & D projects, calculation of benefits of recommendations of changes in technology, modification of processes, development of equipment, process control etc.

2. To deliver a series of lectures on preparation of feasibility reports, conceptual design and basic engineering packages for modernization of existing alumina plant and establishment of new ones.

3. To guide in the preparation of a case study for the modernization of one of the existing alumina plants and another on the expansion of an alumina plant with new production line.

4. Provide the centre with information related to the economics and international competitiveness of alumina production.

Qualification:

University degree (preferably Ph.D.) in chemical or metallurgical engineering. Well conversant and experienced with the operation of all alumina production units/phases and process parameters as well as with mathematical modelling and basic engineering of alumina production plants.

Language: English

Background Information:

The Indian aluminium industry looks back to a history of 44 years. The first aluminium smelter (in Alumpars, Kerala) was put into operation in 1943. At present there are five alumina plants about 587,000 and 580,000 tonnes per year, respectively. These facilities belong to five aluminium companies, namely Bharat Aluminium Company Ltd. (Balco), Hindustan Aluminium Corporation Ltd. (HINDALCO), the Indian Aluminium Company Ltd. (INDAL), the Madras Aluminium Company Ltd. (MALCO) and the National Aluminium Company Ltd. (NALCO).

With the commissioning of NALCO the share of the public sector in aluminium smelting is more than half of the total installed capacity of India. This indicates the decisive influence of the public sector on the future of the industry. The sustained growth and development of the aluminium industry in India, apart from requiring the adoption of suitable long term policies in relation to production management, output, pricing, and fiscal levies, is also in need for technology and market development, which will gradually be handled by the proposed Centre.

During the past years, India became one of the leading countries in the world having substantial bauxite resources, after the discovery of large deposits in the Eastern Coast in the nearly 1970s. The total bauxite reserves of India are estimated to be of the order of 2,650 million tonnes, which places India on the fifth place in the world list.

With the vast reserves of bauxite and coal in India, the aluminium industry has ambitious plans for a faster growth rate keeping in view the future demand in the foundry and export potentials.

The existing alumina/aluminium plants in India are based almost entirely on technology imported from various sources. Both in the areas of production of alumina and aluminium, a number of technological improvements have taken place in advanced aluminium producing countries. Import of improved technology is not always possible, also its introduction is not feasible in the existing plants. Import of technology necessitates proper assessments to determine its suitability under Indian conditions, the available raw materials, product demands, state of engineering developments, etc. Though research and development work is being carried out by the major aluminium producers in the country, these are mainly directed towards solving their day to day process problems in the plants. No work is done for the development of process know-how and basic engineering. The technologies followed in the existing plants are from various countries/suppliers - KAISER, ALUTERV-FKI, VAMI, ALCAN, MONTECATINI and ALUMINIUM PECHINEY. Apart from the strategic importance of having an indigenous Research, Development and Design Centre for Aluminium, the Centre is expected to save substantial hard currency payments to the foreign partners.

For meeting the estimated demand of aluminium by the turn of the century, substantial additional capacities for alumina and aluminium will have to be set up in the 1990s. Additional demand for aluminium by the turn of the century, which is in excess of the currently available capacity would be of the order of 440,000 tonnes per annum. Considering the payment for know-how, basic engineering and royalties for this additional follow-up stage this would mean an expenditure of at least US$ 95 million.

It is to be pointed out that the cost for Establishment of the Aluminium Centre in Nagpur (both Indian Government and UNDP contribution) is of the order of US$ 12.5 million. The financing of operations and further development of the Centre is envisaged by the Government to be secured through a collection of Rs. 100 per ton of aluminium for aluminium research and development, added to the price of aluminium (established now by the State in India). The funds so generated would serve as financial basis for operation and further extension of the Centre.

When the new aluminium capacity will be established the Centre will be fully functioning and if it contributes to savings of only ten per cent of the expected expenditure for project engineering and royalties, apart from rendering other useful services, its establishment would be fully justified.

It is to be noted that all the leading aluminium producing countries have their own R and D centres. Close interactions among these Centres' Research and educational institutions and industry has enabled numerous technological advances - this example is needed to be followed in India.

In the light of the above, a coordinated effort in R and D will be essential for the development of know-how and basic engineering to self-reliance in alumina and aluminium technology needed for the establishment of future plants without need to go for foreign consultancy. Future development of aluminium industry in the country based on indigenous expertise demands the immediate establishment of a self-reliance full-fledged and independent research, development and design centre for aluminium at the national level.

The development objective of the project is to aim at self-reliance in alumina and aluminium production technology and to achieve faster growth of the Indian aluminium industry to meet the domestic demand for aluminium products. This goal will be achieved by setting up of an Aluminium Research, Development and Design Centre at the national level which will be in a position to carry out research and development in the field of bauxite processing, alumina and aluminium production leading to improvement in the existing plants and creating new production facilities. Thus, the output of the project will be physical facilities of an Aluminium Research Development and Design Centre, adequately equipped with specialized research and testing equipment and trained professional staff to render research and development technology in the existing plants and for setting up of new alumina/aluminium production facilities based on indigenous raw materials and natural resources.

In addition, the Centre will handle related projects such as dealing with the use of by-products, design improvements for saving of energy and materials, development of new products and alloys. Another particular problem that the Centre is expected to address is emanating from the lack of adequate and uninterrupted power supplies which has led to poor utilization of capacities in the recent past. Investigations into energy saving technologies of alumina and aluminium production will be one of the important tasks that the Centre will have to tackle.

It is expected that once the Centre is established it will meet the fast growing technological service needs of the aluminium industry in India. The Centre will consist of the following departments:

- Alumina production research department with four laboratories and one pilot plant;

- Aluminium electrolysis research department with four laboratories;

- Analytical research department with three laboratories;

- General services, instrumentations and control department with four sections;

- General administration and finance department with three units.

The civil construction works for the Centre started in Nagpur in 1990 and will be finished by 1992-1993. The centre is planned to fully operate/function by 1994-1995.

The assignment of the national staff and procurement of equipment started in 1989-1990. The first R/D works have started in 1991-1992. Training of the staff is being carried out in India and abroad.

For a more detailed information reference could be made to the Project Document and the Detailed Centre Design.

PROGRAMME FOR PREPARATION PREINVESTMENT STUDIES FOR ALUMINA PLANTS

ACTIVITIES	Deadlines for		
	BALCO	HINDALCO	NALCO
FIRST STAGE			
Description of present status	Aug-Sep	Aug-Sep	Aug-Sep
Preparation of detailed mass and heat balance for present status	Aug-Sep	Aug-Sep	Aug-Sep
Collection of technological flowsheets for units to be changed	Aug-Sep	Aug-Sep	Aug-Sep
Analysis of present status and basic idea for intensification/expansion			
Defining the proposed options			
Preparation technological flowsheets			
Mass and heat balances			
First draft of proposed technological options	Sep 27	Sep 29	Oct 7
Finalisation of technology with representatives of the companies	Sep 27-29	Sep 29- Oct 1	
SECOND STAGE			
Final mass and heat balance			
Preparation of process layouts			
Specification of equipment requirement			
Estimation of investment cost			
Process engineering / second draft	Oct 16	Oct 23	Oct 30
Finalisation process engineering with representatives of companies	Oct 18-20	Oct 30	
THIRD PHASE			
Elaboration production cost	Oct 27	Oct 23	Nov 3
Elaboration investment cost	Oct 27	Oct 23	Nov 3
Techno-economical evaluation of proposed options	Nov 3	Nov 7	Nov 10
Finalisation of the draft reports	Nov 6	Nov 13	Nov 20
Presetation of the proposals to the Companies	December	December	December

List of Experts participation in the preparation of Pre-investment studies

Name of Participants	Designation	Field
JNARDDC		
Dr. T.R.Ramachandran	Director	Overall Supervision
Dr. J.Zambo	Chief Technical Advisor (UNIDO)	Co-ordination & Guidance
Mr. P.Vidyasagar	Deputy Director	Alumina Technology
Mr. R.N.Goyal	HOD (Alumina)	Alumina Technology
Mr. H.Mahadevan	Scientist	Alumina Technology
Mr. H.K.Chandwani	Scientist	Alumina Technology
Dr. A.K.Nandi	Scientist	Bauxite Evaluation
Mr. U.B.Agrawal	Scientist	Techno-economy
Mr. K.V.Krishnan	Scientist	XRD Analysis
Mr. V.Vishwanathan	Scientist	Mass & Heat Balance
Mr. M.J.Chaddha	Scientist	Mass & Heat Balance
Mr. R.J.Sharm	Scientist	Auto-Cad
Mr. M.T.Nimje	Scientist	Auto-Cad
Ms. S.Dharwal	Fellow	Techno-economy
ALUTERV-FKI/UNIDO		
Mrs. E. Molnar	UNIDO Expert	Mass & Heat balance & Process Engg.
Mr. L.Varga	UNIDO Expert	Process Engg. & Equipment design
Mr. A.Molnar	UNIDO Expert	Techno-economy
Dr. K.Solymar	UNIDO Consultant	Co-ordination & Guidance

INTENSIFICATION OF THE PRODUCTION PROCESS AND IMPROVEMENT OF ALUMINA QUALITY AT KORBA ALUMINA PLANT OF BALCO

EXECUTIVE SUMMARY

The rated capacity of the Korba Alumina Plant belonging to M/s Bharat Aluminium Company Limited is 200,000 tpy and its present operating capacity is 194,000 tpy alumina.

The Scientists of JNARDDC together with the International UNIDO experts in agreement and active co-operation of the experts team of BALCO evaluated the existing technology of Korba Alumina Plant and elaborated the present preinvestment study in order to meet the common requirements of intensification of the production process together with the improvement in the quality of smelter grade alumina so as to meet the international standard quality.

The Korba Alumina Plant is using traditional European high temperature digestion at 240°C with 20 minutes retention time to achieve a target molar ratio of 1.55 .The continuous precipitation system produces floury type alumina with high levels of Fe_2O_3 (0.040%) and SiO_2 (0.026%). The alumina is extremely fine (43.6% below 325 mesh)causing significant losses at calcination and dustiness in the smelter. The low purity of alumina results in low grade (99.5%) aluminium ingot and semi-products. So the present alumina quality is quite far from the actual standard and is not suitable for modern smelter operation or for sale.

The modernisation of the aluminium smelter and the quality improvement of aluminium ingot and semis requires standard purity and consistent sandy type alumina. The smelter capacity can be increased by means of intensification up to about 115 Kt/yr which can be reached only by feeding alumina of improved quality.

The JNARDDC investigated the intensification and alumina quality improvement of Korba Alumina Plant already before. A study has been prepared for sweetening by Orissa bauxite which process was found uneconomic due to the high landing cost of bauxite. An other study was focussed on the production of intermediate type of alumina, however, this process modification has also been postponed due to the actual low alumina quality requirement accepted by Kaiser Aluminium Co. too.

The objective of the present study is the elaboration of the alumina quality improvement required for modern smelter operation along with a moderate increase in production capacity to meet the increased demand of the intensified (modernised) smelter. The basic conception of this study is to join the intensification and quality improvement. The level of elaboration corresponds to a prefeasibility study, which is less detailed than a feasibility study. The later is based on updated offers of equipment and has much higher level of elaboration and cost calculations (accuracy). Nevertheless the present study is based on justified design parameters and suitable to draw decisions on the further course of action.

At present, BALCO's Korba Plant receives bauxite from various mines of Madhya Pradesh and Bihar e.g. Amarkantak, Phutkapahar, Lohardaga, Katni, Satna and from newly opened mine of Mainpat. It is planned by BALCO to increase bauxite mining from its new captive mine at Mainpat so as to reach 400,000 tonnes/year in 1996-97.

The following blended bauxite and Mainpat bauxite compositions have been considered for calculations and elaboration of the options for intensification :

	Blended bauxite	Mainpat bauxite
Al_2O_3%		
in gibbsite	36.65	39.0
in boehmite + diaspore + alumo goethite	7.62	6.6
in kaolinite	2.85	2.4
TOTAL..	47.12	48.0
SiO_2%		
in kaolinite	3.35	2.79
in quartz	—	0.21
TOTAL..	3.35	3.00
Fe_2O_3 % total	17.9	16.0
TiO_2 % total	7.0	9.0

It can be supposed that higher gibbsite and total alumina contents of the Mainpat bauxite will be confirmed by the detailed prospecting than considered and possibility of selective mining would also be considered.

The availability of the relatively low-boehmite, high gibbsitic Mainpat bauxite is the basis for the intensification of the production process (plant expansion) combined with alumina quality improvement.

The following two variants have been elaborated:

1. Parallel stream operation : Processing of Mainpat bauxite and blended bauxite in two parallel streams operating at 150°C and 240°C digestion temperature respectively.

2. Sweetening : Processing of blended bauxite at 240°C in both digestion lines and sweetening by Mainpat bauxite in flashing lines.

At the parallel stream operation the target molar ratios of blow-off liquors are 1.30 and 1.55. At sweetening variant 1.55 before the sweetening and 1.41 thereafter. As a result the starting molar ratio at precipitation can be decreased to 1.48 at both variants (from the actual 1.67) and the liquor productivity at precipitation would be raised from 67.9 Kg/m3 to 82 Kg/m3. In order to reach this high liquor productivity and the improved alumina quality (standard purity and sandy type) the adaptation of the up-to-date precipitation technology developed by Alusuisse is required and has been considered.The improved alumina quality can be characterised as follows :

SiO_2	-	0.015%
Fe_2O_3	-	0.025%
-325 mesh	-	10 ± 2%

Preliminary laboratory tests have been carried out to simulate some key parameters of both options. It was found that the gibbsite mineral in Mainpat bauxite has an adequate reactivity and the target molar ratio of 1.30 at 150°C digestion temperature can be achieved. The sweetening test has been performed by NALCO bauxite which seems to be more adequate for this purpose if it was available at an acceptable price in the future. Although the sweetening can also be considered as a future option, the parallel stream operation seems to be technically-technologically more feasible.

Both technological variants suppose the processing of blended bauxite and Mainpat bauxite simultaneously, therefore, separate storage and handling of Mainpat bauxite is required. The Mainpat bauxite as gibbsitic ore will be digested either in one of the digestion lines at 150°C or will be used for sweetening (NALCO bauxite can be considered for sweetening in the future).

An improved control filtration by means of calcium-aluminate precoat in Kelly filters is necessary to achieve the required alumina purity.

The modified precipitation process corresponds to the up-to-date precipitation technology to produce sandy alumina at high liquor productivity. (Agglomeration, interstage cooling, seed classification, three stage seeding, oxalate control by fine seed washing). The use of crystal growth modifier is also considered at least in the transition period. A computer-aided slurry adjustment is essential to control the unextracted alumina losses and to realize the recommended option.

The considered process technology has good references all over the world relating to both medium pressure digestion (150°C) and uptodate precipitation. The laboratory tests confirmed the adequate digestibility of the bauxite and the reality of the considered low molar ratio of blow-off liquor

The recommeneded process can be implemented, however , more sensitive and more difficult to operate and control it than the existing one. It should be paid special attention to the danger of hydrolysis (autoprecipitation), scale formation and strict operating conditions.More frequent and careful maintenance and more sophisticated process control are required.

The additional manpower requirement has been estimated to be 208 employees comprising :

Foreman	26
Skilled worker	96
Assistant worker	92

The following production level can be achieved after the intensification :

Existing production	187,950 tpy
After intensification	
At option I	234,246 tpy
At option II	233,790 tpy

It should be considered that the smelter capacity will be increased upto about 115 kt/year on step-by-step intensification, which would require 230 kt/year alumina. The improved alumina quality is a precondition to reach this smelter capacity. After the intensification of the smelter only 4,246 tpy or 3,798 tpy surplus alumina will be available for domestic sale at an average price of Rs. 7,000/t.

The specific consumptions of some raw materials and steam are the following:

		Existing	Option-I
Bauxite t/t		2.726	2.777
NaOH Kg/t		89.92	84.61
Steam t/t	HP	2.4	1.6
	LP	1.1	1.59

The slight increase in bauxite consumption is over - compensated by saving of NaOH and steam.

The total investment costs (in million Rs.) for intensification and quality improvement to reach the expanded full production capacity (3 years after the start of investment) is

	Option-I Parallel Stream	Option-II Sweetening
At 100% loan	814.336	834.462
At 50% loan	730.420	748.614

For these calculations a 10 years amortisation period, 15% interest rate for local investment costs and 8% interest rate for foreign investment costs have been considered.

The economic evaluation was prepared with the consideration of the inevitable need of the alumina quality improvement from point of view of the survival (future) of alumina plant and smelter and to obtain adequate metal quality. Some equipments have been considered for the normal plant operation only. Under these conditions the classical economic evaluation based on the surplus production can not be calculated (unrealistic).

Consequently, the economic analysis has been prepared with the sole purpose to determine the increased production costs of alumina with the requirement that the Internal Rate of Return (IRR) of the investment costs of intensification should be at least 10%. This requirement would however mean a such level of intern alumina price (based on the above mentioned increased production costs) between the alumina plant and aluminium smelter which is high enough to pay off the return of investment costs, too. The sale of about 2% of the total produced alumina at a price of Rs. 7,000/- has also been considered. The rate of income tax at a level of 50% and 15 years production period were calculated.

The total production costs for the 230,000 tpy alumina was found as follows :

Option-I	at 100% loan	Rs. 5,770/ton
	at 50% loan	Rs. 5,735/ton
Option-II	at 100% loan	Rs. 5,830/ton
	at 50% loan	Rs. 5,750/ton

Consequently, an increase of 7-8% is required in relation to the budget cost of Rs. 5,368/ton for 1993.

It was also found that the parallel stream operation (Option-I) is a more feasible variant economically, compared to that of option-II .

The sensitivity of the IRR has been investigated as a function of intern price(s), operating cost(s) and initial investment for the most feasible variant only (Option-I, 100% loan , at Rs. 5,770/ton basic intern price at 100% IRR).

In order to increase the value of IRR by 5% (to reach 15%) the investigated variables should be changed by the following values separately :

Intern price +11%

or operating cost -18%

or Initial investment -25%

In consequence, efforts should be made to reduce the operation costs, especially that of raw materials, auxiliary materials and energy.

There are some opportunities to decrease the production and investment costs, e.g. reconsideration of usage of CGM, retrofitting of calcining kiln in view of its expected very short operating period which along with some other possibilities should be considered in the frame of conceptual and/or detailed design.

CONCLUSIONS

The most important development objective for BALCO has been considered in the present study.

The economic effect of improved alumina quality for smelter operation could not be calculated now. This evaluation is expected in 1994. Nevertheless, it can be stated that the objective can be achieved economically. In details :

1. The availability of the relatively low boehmite and high gibbistic Mainpat bauxite (39% Al2O3 in gibbisite from the total 48.0% Al2O3) enables the intensification of Korba Alumina Plant combined with the significant improvement of the alumina quality to meet international standard requirements.

2. The parallel stream operation (digestion of blended bauxite at 240°C and Mainpat bauxite at 150°C) was found as more feasible variant both from technological and economical points of view, along with the adaptation of the up-to-date precipitation process developed by Alusuisse.

3. The expected expansion of alumina production capacity (46 ktpy) is sufficient to feed the aluminium smelter after the intensification to reach a capacity of about 115 ktpy and a small amount of alumina will be available for domestic sale

4. The total investment costs at 100% loan is estimated to be as high as Rs. 814 million ie. Rs. 17,590/ton of surplus alumina (about US$ 560/ton including all expenses for quality improvement) which is a very attractive value with special regard to the fact that the inevitable necessary alumina quality improvement can be reached only by the recommended way.

5. The total production costs of alumina related to 230,000 tpy capacity (when intensification and quality improvement will be financed at 100% loan) will be Rs. 5,770/ton in comparison with the budget cost of Rs. 5,368/ton for 1993.

   This increase of the intern alumina price (Rs. 400/ton) fully or mostly can be repaid by the improved operation (at lower production cost) and increased capacity of the aluminium smelter.

RECOMMENDATIONS

1. Based on the results of the present preinvestment study the parallel stream operation (option-I) is recommended for further detailed elaboration and realization.

2. The start with the preparatory work of the feasibility study is recommended. The following main activities should be considered.

a. Detailed investigation of the availability of bauxite. Justification of bauxite quality and quantity for future demand of Korba Alumina Plant. Collection of characteristic individual bauxite samples and representative bauxite sample (s).

b. Simulation of the selected variant under lab and optionally pilot plant conditions to justify/finalise the design parameters for feasibility study.

c. Selection of international sub-contractor(s) and/or experts to supply the transfer of technology, especially the up-to-date precipitation process.

d. Finalization of data base and technical details with experts team of BALCO for preparation of the feasibility study.

e. Selection of an Indian counterpart (preferably Engineers India Ltd.) to elaborate the related parts of the feasibility study, in cooperation with JNARDDC. (The elaboration of the feasibility study requires about one year and the implementation 2.0 to 2.5 years)

3. The recommendations and options of the present study relating to the alumina quality improvement (control filtration, use of crystal growth modifier, reintroduction of hydroseparator, etc.) and more sophisticated process control (eg. improved slurry adjustment) can be realized as soon as possible independently on the preparation of the feasibility study.

INTENSIFICATION OF THE PRODUCTION PROCESS AND MODERNISATION OF PRECIPITATION AT RENUKOOT ALUMINA PLANT OF HINDALCO

EXECUTIVE SUMMARY

The Renukoot Alumina Plant's production capacity is 315 kt/y at present and 350 kt/y capacity will be reached by the end of 1993 by means of modification, improvement in process parameters and installing balancing equipments. This 350 kt/y capacity is considered as a basis in the present study. Based on the previous discussion between management and experts of HINDALCO and JNARDDC involving UNIDO experts. Two feasible options of the intensification of the production processes and modernisation of the precipitation of Renukoot Alumina Plant will be discussed here in order to reach 450 kt/y capacity because HINDALCO aims to achieve 450 kt/y production capacity with minimum investment by the end of 1996.

HINDALCO has considered the option of the erection of a new tube digestion unit to reach the target production capacity 450 ktpy. Recently Lurgi (with VAW) has prepared feasibility study on request of HINDALCO for this purpose.

The experts team of JNARDDC, however, could find further possibilities for the intensification of the Renukoot Alumina Plant at limited investment costs. The new idea is based on the availability of low-boehmite, gibbsitic bauxite.

The Renukoot Alumina Plant at present can be characterised by a low caustic liquor circuit with low liquor productivity. Both traditional digestion lines and the batch -wise precipitation with complicated seeding and feeding systems and small precipitator tanks represent the technological level of sixties. The caustic soda concentration of the pregnant liquor will reach 190.7 gpl as Na_2CO_3 caustic and the liquor productivity a value of 55.9 kg/m3 by the end of this year. The alumina losses are very high in the order of 294.5 kg Al_2O_3/t alumina.

The main concept of the intensification is based on the introduction of medium temperature digestion (145-150°C) in both (or only in one) digestion unit, increase in caustic soda concentration of process liquor and modernisation of existing precipitation technology. The new idea presented by JNARDDC is based on the fact that low boehimite, high gibbsitic bauxite would be available for HINDALCO. The adequate processing of this bauxite at medium pressure digestion along with the adaptation of the upto date precipitation technology can increase the plant production capacity to the target 450 kt/y, mostly by intensification instead of plant expansion by the erection of new digestion line and capacity increase of other plant sections on the basis of present technology.

Renukoot Alumina Refinery of HINDALCO receives bauxite from various sources of Madhya Pradesh, Bihar and Uttar Pradesh (Central Indian Bauxite districts). HINDALCO is planning to open new mines at Jamirapat (Surguja district) adjoining to Mainpat for long term bauxite supply to the Renukoot Plant. It is expected that the main characteristic of the bauxite originated from the new bauxite mines will be more or less similar to Mainpat bauxite as both belong to the same ore belt. The average bauxite quality (as per the GSI report) agrees very well with the quality of the future expected bauxite from the above source.

The quality of the presently supplied and future expected bauxite is the following :

	PRESENTLY SUPPLIED	FUTURE EXPECTED
Al_2O_3 %		
in gibbsite	37.8	41.1
in boehmite + diaspore + alumingoethite	7.7	8.1
in kaolinite	2.3	1.9
TOTAL	47.8	51.1
SiO_2 %		
in kaolinite	2.7	2.3
in quartz	0.6	0.6
TOTAL	3.3	2.9
Fe_2O_3 %	16.5	11.6
TiO_2 %	8.0	9.0

The future bauxite quality seems to be somewhat better than the presently supplied one, however, at the elaboration of the preinvestment study the presently supplied bauxite quality has been considered.

Unfortunately, the collection of the representative or individual characteristic bauxite sample from the future expected source was not possible in due time, therefore the present study is based on the similarity of Mainpat bauxite and Jamirapat bauxite (and that of the presently supplied bauxite). Although the availability of low-boehmite/high gibbsite bauxite should be justified and its quality and quantity should be determined in the future, however, the elaboration of the present study could not be postponed.

The decision on further development of Renukoot Alumina Plant is scheduled by the end of this year therefore the availability of the discussed options is required as soon as possible for comparison. Furthermore, the programme of the JNARDDC and the availability of international UNIDO experts also confirmed the urgent preparation of this study in agreement with the above mentioned request of HINDALCO.

The determination of bauxite quality and quantity and the performance of the most important lab simulation tests with selected characteristic samples can be realised before final decision is be made.

The intensification (alumina production capacity expansion) is based on the conversion of the high temperature digestion process (240°C) into medium pressure (150°C) digestion to achieve a much higher supersaturation of the blow-off liquor by Al_2O_3 (higher A/C) so that a higher liquor productivity at precipitation can be achieved due to the high starting A/C ratio at precipitation. (A/C around 0.7). This requires the adaptation of a modified precipitation process (adequate temperature profile, interstage cooling, hydrate classification, two stage seeding).

The digestion unit of the Renukoot Plant is the main bottleneck for the whole production process and the plant should run at a relatively high A/C ratio in blow-off liquor (A/C = 0.662) under the given conditions resulting in high unextracted alumina losses (7-8 % unextracted Al_2O_3 in the red mud, mostly in form of boehmite)

Two options have been selected and elaborated in this Preinvestment Study :

1. Both digestion lines are in operation at 150°C, Blow-off liquor Na_2CO_3 = 272.6 gpl, A/C = 0.697, pregnant liquor Na_2CO_3 = 213.7 gpl, A/C = 0.679.

2. Only the larger digestion unit is in operation at 150°C; Blow-off liquor Na_2CO_3 = 278.0 gpl, A/C = 0.740, pregnant liquor Na_2CO_3 = 213.7 gpl, A/C = 0.714.

In order to reach high liquor productivity at precipitation by keeping unchanged the standard high grade sandy alumina quality not only a much higher starting A/C ratio is required but an essential modification of the whole precipitation process including agglomeration, modified temperature profile (by interstage cooling), hydrate classification, two stage seeding, increase of seed ratio from 0.92 to 1.60 and the retention time from 31.9 hours to 42.7 & 46.3 hours, respectively as well.

The liquor productivity at digestion will be increased by 53.7% and at precipitation by 30.6% at option I. (from 55.9 kg/m3 to 73.0 kg/m3) while the related figures at option II are 72.2 and 44.0% (from 55.9 kg/m3 to 80.5 kg/m3).

The considered process technology has good reference all over the world relating to both medium pressure digestion (150°C) and upto- date precipitation. The preliminary lab test confirmed with a great probability the adequate digestibility of Jamirapat (Surguja) bauxite (based on its similarity to Mainpat and blended supplied bauxite) and the reality of the design parameters considered. The recommended process can be implemented, however, more sensitive and more difficult to operate and control than the existing one. Special attention should be paid to the danger of hydrolysis (autoprecipitation), scale formation and strict operating conditions. More frequent and careful maintenance with more sophisticated process control are required.

Limited volume of lab simulation tests have been carried out to justify the main technological preconditions of the recommended variants. Unfortunately, Sarguja (Samirapat) bauxite was not available, therefore the tests have been performed by means of Mainpat and blended HINDALCO bauxite samples. The fast dissolution (adequate reactivity) of gibbsite mineral has been confirmed and the target A/C ratio of 0.74 could be achieved at the digestion of blended HINDALCO bauxite. Nevertheless option I seems to be technologically-technically more feasible and the process parameters may be controlled better and easier. It is to be mentioned that an Na_2O/SiO_2 ratio of 0.7 was found in red mud formed at 150°C indicating that the TiO_2 minerals did not react with caustic liquor yet. (Designed Na_2O/SiO_2 ratio 0.844). The Al_2O_3/SiO_2 ratio in red mud did not exceed the value of 4.0 (Designed ratio was 4.41).

The extra manpower requirement for both options would be as follows : 12 foreman, 92 skilled worker and 76 semi-skilled worker, altogether 180 employees.

The total investment costs were calculated considering 10 years amortisation period, 15% interest rate for local and 8% interest rate for foreign investment costs and 3 years grace period.

The total investment costs is estimated as follows (in million Rs.)

	OPTION I	OPTION II
at 100% loan	1810.380	1782.902
at 50% loan	1628.111	1602.318

Consequently, the total investment cost at 100% loan is equivalent with about USD 600/t of surplus alumina produced.

The economic analysis has been elaborated supplying 15 years production period and 50% rate of income tax.

Two approaches were used for economic analysis. In the first approach the increased production costs of alumina has been determined with the requirement that the Internal Rate of Return (IRR) of the investment costs for intensification should be at least 10%. This means at such level of intern alumina price between the alumina plant and aluminium smelter which is sufficient high to pay off return of investment costs, too.

The following results were obtained :

ITERN ALUMINA PRICES	OPTION I	OPTION II
at 100% loan	Rs.4970/t (+452/t)	Rs.4960/t (+ 442/t)
at 50% loan	Rs.4925/t (+407/t)	Rs.4960/t (+392/t)

It can be stated that an increase of 9-10% is required related to the base cost of Rs.4518/t for 1993 considering the whole alumina production.

In the second approach only the surplus production (100 kt/y) has been considered with the same preconditions (At least 10% IRR). The following results were obtained :

INTERN ALUMINA PRICES	OPTION I	OPTION II
at 100% loan	Rs.6700/t	Rs.6640/t
at 50% loan	Rs.6500/t	Rs.6430/t

The sensitivity of the IRR has been investigated for both of the above approaches. It was found that the effect of the intern price of alumina is the most significant and the initial investment has a relatively less effect on the IRR.

In order to increase the value of IRR by 5% (to reach 15%) the investigated variables should be changed by the following values separately :

	OPTION I	OPTION II
Intern price	+ 12.7%	+ 12.16%
or Operating costs	- 23%	- 21%
or Initial investment	- 25%	- 25%

Very similar (about the same) results were obtained for the second approach,too.

The intern price is determined by the company and the initial investment can not be reduced sufficiently to increase significantly the IRR. Consequently, the efforts should be focussed on the reduction of the operating costs.

CONCLUSIONS

The most important and very actual development objective for HINDALCO Alumina Plant has been considered in the present study. The results confirm the feasibility of the option(s) both from technical and economic points of view. The proposed intensification is considered to be competitive with other alternatives. The detailed conclusions are the following :

1. The availability of the relatively low boehmite, gibbsitic blended and Jamirapat (Surguja district) bauxite enables the intensification (expansion) of Renukoot Alumina Plant at a reasonable low level of investment costs to reach the target 450 kt/y capacity. (from 350 kt/y).

2. The modernization of the precipitation by the adaptation of the up-to-date process assures both the high liquor productivity (alumina production capacity expansion) and the actual high standard sandy alumina quality.

3. The plant expansion and modernisation of precipitation can be carried out by the conversion of the digestion units from high temperature (240°C) digestion into medium temperature (150°C) process, when the A/C ratio of blow-off liquor would be 0.697 and that of the pregnant liquor 0.679.

4. A further development is possible by reducing the blow-off liquor A/C ratio to 0.740. The key design parameters

of both variants have been justified by informative lab simulation tests.

5. The intensification (plant expansion to 450 kt/y) and modernisation of precipitation required about US $ 600/t of surplus alumina.

6. The total increased alumina production will be electrolysed in the HINDALCO smelter. The internal price of alumina should be increased by 9 to 10% i.e. at 100% loan an intern price of Rs.4970/t is expected in comparison with the base cost of Rs.4518/t for 1993 (at option I).

RECOMMENDATIONS

HINDALCO should compare this Option with other alternatives elaborated by the company with other agencies and in case of competitive acceptance further action should be initiated.

1. Preparation work of the feasibility study should be performed by the company, JNARDDC and engineering agency. Also international experts should be involved whenever required. The following main activities should be included :

a) Detailed investigation of the availability of low boehmitic, gibbisitic bauxite. Justification of bauxite quality and quantity for future supply of Renukoot Alumina Plant. Collection of characteristics individual bauxite samples and representative bauxite samples to be carried out.

b) Finalisation of selected variants(s) under laboratory (and optionally pilot plant) conditions to justify/finalise the design parameters for feasibility study.

INTENSIFICATION OF THE PRODUCTION PROCESS AND EXPANSION OF PRODUCTION CAPACITY OF DAMANJODI ALUMINA PLANT AT NALCO

EXECUTIVE SUMMARY

The Damanjodi Alumina Plant of NALCO has a capacity of 800,000 tpy of calcined alumina in two production lines which are in operation since mid 1988. The plant layout has a provision for doubling of the capacity by installing two additional identical production lines 400,000 tpy capacity each.

The plant design is based on the technology and know-how of Aluminium Pechiney applying atmospheric digestion process and crystal growth precipitation technology resulting in standard quality sandy type alumina.

The plant capacity expansion is under consideration at NALCO where intensification (debottlenecking) and erection of new production line can also be considered.

Based on the previous discussions between the executive and experts of NALCO and JNARDDC both options are discussed in the present study.

The preinvestment study has been prepared by the experts team of JNARDDC with the assistance/guidance of some international UNIDO experts.

The main objective of the study is to evaluate the intensification and capacity expansion of the Damanjodi Alumina Plant from both technical/technological and economic points of view.

The analysis is even more actual because projects of erection new, greenfield export-oriented alumina refineries on the basis of the same Orissa bauxite deposit are under consideration/preparation in India.

Although the Damanjodi Alumina Plant can produce standard grade alumina at the lowest production costs in India, the liquor productivity both in digestion and precipitation is limited by the atmospheric digestion process (RP in blow-off liquor 1.058; or MR = 1.555). The liquor productivity in precipitation 64.7 kg/m³. The temperature drop of precipitation is 3°C (from 60°C to 57°C, without interstage cooling), retention time 42 hours and the seed ratio 4.25 (extremely high). Post desilication is required after digestion with a holding time of 8 to 10 hours.

The concept of the intensification is based on international experiences and plant practice and contains the conversion of the digestion from atmospheric into medium pressure (from 105°C to 145°C) and the adaptation of the up-to-date precipitation process with high liquor productivity developed by Alusuisse.

The following bauxite composition has been considered in the study :

Al_2O_3 total	=	42.50%
Al_2O_3 available	=	40.54%
SiO_2 reactive	=	1.65%

The basic principle of intensification is the substitution of the atmospheric digestion unit, by medium pressure facility (tube digester heating elements with holding autoclaves) operated at 145°C when both boehmite conversion and autoprecipitation should be and can be controlled, furthermore the adaptation of the up-to-date precipitation process. As new process stages agglomeration, interstage cooling, hydrate classification, fine seed washing (oxalate control) and two stage seeding should be introduced at this adaptation which means a revision and completion of the whole system.

The following two variants (options) have been elaborated :

1. Intensification of the production process by means of 145°C digestion and improved precipitation

2. Plant capacity expansion based on the improved technology

The new medium pressure (145°C) digestion results in an increase of blow-off liquor R.P. from 1.057 to 1.237 which means more than 25% improvement in the liquor productivity in digestion.

The laboratory tests confirmed that 30 minutes retention time is sufficient to reach the expected RP value of 1.237 (MR=1.363) and adequate desilication of the liquor, however 1 hour retention time has been considered.

Significant changing in process parameters are requested in precipitation as well. The starting temperature will be increased from 60°C to 75°C, two stage interstage cooling facility will be installed (temperature drop 14°C) to reach the same final temperature of 57°C. The hydrate seed ratio will be decreased from 4.25 to 1.7, the initial RP will be increased from 1.032 to 1.210, the retention time from 42 hours to 49.7 hours, furthermore agglomeration, hydrate classification and two stage seeding will be introduced.

As a result the liquor productivity at precipitation will be increased from 64.7 kg/m³ to 83.4 kg/m³.

The surplus production of alumina would be 216.5 ktpy reaching a total production of 1016.5 ktpy.

It should be emphasized that both the recommended digestion process at 145°C and precipitation process with high liquor productivity developed by Alusuisse are well experienced and proven e.g. at ALCAN, INDAL, GOVE , ALCOA of Australia on one hand and at GOVE, Interalumina, Euralumina, QAL on the other hand.

The additional manpower requirement at Option I has been estimated to be 80 employees comprising :

Foreman	=	24
Skilled worker	=	24
Assistant worker	=	24

The other variant (Option II) based on the production level and process technology achieved after the realisation of Option I. This is a brown field expansion of the alumina plant.

(At Option II further 680 employees are considered (90 executives and 590 non-executives)

The following production level can be reached after the intensification and plant expansion respectively :

Existing production	800,000 tpy
After intensification (Option I)	1016,500 tpy (+ 216,500)
After plant expansion (Option II)	1512,400 tpy (+495,900)

Option I was selected as the basis for Option II at all calculation and evaluation.

The total investment costs (in million Rs.) for intensification and expansion to reach the expanded full production capacity (3 years after the start of investment) is :

	OPTION I (Intensification)	OPTION II (Expansion)
At 100% loan	3444.557	13013.250
AT 100% equity (local)	2971.199	11347.083

For these calculations a 10% amortization period, 15% interest rate for local investment costs and 8% interest rate for foreign investment costs have been considered.

The specific investment costs per 1 ton of surplus alumina produced is the following :

	OPTION I (Intensification)		OPTION II (Expansion)	
	Rs./t	US $/t	Rs./t	US $/t
At 100% loan	15910	509.9	26242	841.1
At 100% equity	13724	439.9	22882	733.4

(1 US $ = 31.20 Rs.)

It can be seen that the intensification need significantly less specific investment costs than the brownfield expansion. The Rs. 15910/t (equivalent with US $ 510/t) value might be accepted, however, the brownfield expansion is extremely expensive.

The economic analysis has been prepared with the aim to determine the increased production costs of alumina with the requirement that the Internal Rate of Return (IRR) of the investment costs should be at least 10%.

The calculations were prepared at 100% loan and at 100% equity, furthermore two variants were investigated, namely the whole production or only the surplus production was considered.

The total production costs of alumina was found as follows :

	OPTION I (Intensification)	OPTION II (Expansion)
Related to the whole production :		
At 100% loan	Rs. 4600 (+505)	5870 (+1270)
At 100% equity	Rs. 4562 (+467)	5760 (+1198)
Related to the surplus production :[2]		
At 100% loan	Rs. 6408 (+2313)	8540 (+3940)
At 100% equity	Rs. 6210 (+2215)	8240 (+3640)

(Basis for Option I is Rs.4095/t, for Option II Rs.4600/t).

Consequently, an increase of 11 to 13% is required in relation to the budget cost of Rs. 4095/t for 1993 when the whole production after intensification is considered. The related figure for plant expansion (considering Rs. 4600/t basis costs) is 26 to 28%.

The total production costs related to the surplus alumina only is very high, especially at the brownfield expansion.

Consequently only the intensification seems to be feasible at present and in the near future. It should be emphasized that the capital costs of erection of a new greenfield refinery can be estimated at least 50 to 60% higher than the brownfield expansion.

CONCLUSIONS

1. The most important development objective for NALCO has been considered in this study, i.e., the increase of production capacity by means of intensification and thenafter plant expansion.

2. The basic principle of the improved (modified) process technology is the substitution of the atmospheric digestion by medium pressure digestion (at 145°C) and the adaptation of the uptodate precipitation process.

3. The recommended new (modified) process technology is based on well proven plant practice all over the world and can be implemented without any significant risk.

4. The expected increase in alumina production capacity amount to 216.5 ktpy (reaching a level of 1016.5 ktpy) by intensification and further increase of 495.9 ktpy can be achieved by means of brownfield expansion (reaching a level of 1512.4 ktpy)using the modified technology considered at intensification.

5. The total investment costs at 100% loan is estimated to be as high as Rs. 3444.6 million at intensification and Rs. 13103.2 million at expansion, i.e. Rs. 15910/t (US $

509.9/t) and Rs. 26242/t (US $ 841.1/t) related to surplus alumina respectively.

6. The total production costs of alumina related to the whole capacity at 100% loan would be Rs. 4600/t at intensification and Rs. 5870/t at expansion.

The related figures concerning the surplus alumina production only would be Rs. 6408/t at intensification and Rs. 8540/t at plant expansion.

Consequently only the intensification (Option I) seems to be feasible at present and in the near future.

RECOMMENDATION

1. Based on the results of the present preinvestment study the plant capacity increase by intensification (Option I) is recommended for further detailed elaboration and realisation.

2. To start with the prepatory work of the related feasibility study is recommended. The following main activities should be considered :

a) Finalisation of data base and technical details with experts team of NALCO for preparation of feasibility study and performance of lab simulation tests where they are requested

b) Selection of international subcontractor(s) and/or experts, to supply the transfer of the technology, especially relating to the up-to-date precipitation process technology.

c) Selection of an Indian counterpart (preferably Engineers India Limited) to elaborate (the related parts of) the feasibility study with collaboration of JNARDDC and NALCO.