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20 January 1995  
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**REPORT ON THE RETURN MISSION**

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**DP/IND/88/015/11-0813  
INDIA**

**of Dr. K. Solymar, Expert in alumina process engineering to India between  
7th November, 1994 and 21st January, 1995**

**for the  
Jawaharlal Nehru Aluminium Research  
Development and Design Centre, Nagpur**

**about**

- **Guidance in the preparation and fulfilment of the follow-up activities concerning the preinvestment studies prepared for BALCO, HINDALCO and NALCO in 1993-94,**
- **Guidance in laboratory simulation of digestion, red mud settling, precipitation and production of speciality alumina hydrates,**
- **Guidance / preparation of training material on the main tendencies in the development of the world aluminium industries with special reference to alumina production**

**Backstopping officer : Dr. T. Grof, Substantive officer, UNIDO, Vienna**

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## ABSTRACT

The return 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 return mission is a continuation of the first one of the expert during the period September and 24th November, 1993 when preinvestment studies for the modernization / expansion of alumina plants of BALCO, HINDALCO and NALCO were prepared by the staff of JNARDDC with the guidance of the consultant.

During the period the activity of the consultant covered the following fields :

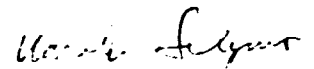
- Guidance in the preparation and fulfilment of the follow-up activities concerning the above studies
- Guidance in laboratory simulation of digestion, red mud settling, precipitation and production of special alumina hydrate
- Guidance and preparation of training material on the main tendencies in the world aluminium industries with special emphasis on alumina production

He has prepared and delivered four papers in the workshop on "Improvement on Alumina Production Technology" held at JNARDDC on 12-13 January, 1995, dealing with digestion lime charge, use of crystal growth modifier, vanadium-salt removal and new digestion options : tube digestion and counter-current double digestion.

Training material and two further studies were also prepared by the consultant on "guideline for formulation by R&D Project Proposals with special reference to alumina production" and "Main development trends, laboratory simulation and modelling of precipitation"

In order to achieve smooth implementation of the work plan of JNARDDC for the year 1995 urgent procurement of a series of well stirred (rotated) digestion bombs, small size settling tubes in water bath and larger size (5-10 l) laboratory precipitator are required. Furthermore extended and faster analytical services and acceleration of recruitment of the scheduled professional staff are suggested. UNIDO / UNDP support to the proposal (for TSS-1 financing) elaborated by JNARDDC on "utilization of India's natural resources and R&D

facilities for the development of bauxite - alumina industry in the Asian region and CIS countries", is highly recommended. Laboratory simulation of the counter-current double digestion. To evaluate the viability of this non-technology, counter-current double digestion for processing gibbsitic-boehmitic diasporic high titanium Indian bauxites, it is necessary to carry out laboratory simulation studies. Urgent plant trials with pressure decanter are also advised.



**Dr. K. Solymar**  
**UNIDO Consultant**

Nagpur 20 January, 1995

## INTRODUCTION

The return mission was also organised by UNIDO, Vienna and by the Jawaharlal Nehru Aluminium Research Development and Design Centre, (JNARDDC) Nagpur in the framework of UNIDO Project "Assistance to the Government of India in setting up a Functioning Aluminium Research Development and Design Centre" (Project No. DP/IND/88/95/11-08). The return mission was the continuation of the first mission of the expert accomplished between 13th September and 24th November, 1993. The main objective of the first mission was providing guidance in the preparation of preinvestment studies (case) studies for the modernization / 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 from the International Subcontractor (ISC), ALUTERV-FKI Ltd. The preinvestment studies were elaborated in draft versions during the first mission of the consultant and have been finalized early 1994 by the staff of JNARDDC.

The discussions of these pre-investment studies with the representatives of companies resulted in follow-up activities which need detailed laboratory simulation of the digestion process for BALCO and that of the precipitation process for all the three alumina refineries, thereafter based on these laboratory tests the techno-economic evaluation of the options is required.

This report has been written by Dr. K. Solymer, expert in alumina process engineering as a result of his return mission. The related job description is enclosed as Annexure-I. The activity was started on 7th November, 1994 and terminated on 21st January, 1995.

## ACTIVITIES

The actualized tasks of the consultant have been determined by Dr. T.R. Ramachandran, Director and Dr. J. Zambo, Chief Technical Adviser in agreement with the above job description, requests of the companies and the expected Work Plan of JNARDDC for 1995. The detailed Work Programme of the consultant is enclosed as Annexure-II.

According to this Work Programme the activity of the consultant covers three main fields :

- Follow-up actions concerning preinvestment studies prepared for BALCO, NALCO and HINDALCO in 1993-94,
- Co-operation / Guidance in laboratory simulation of digestion, red mud settling and precipitation, including the production of special alumina hydrates,
- Guidance / preparation of training material for the expected continuing education of the experts of the companies.

The main activity of the consultant was covered by the preparation of technical reports by the guidance / assistance of the follow-up laboratory work and offered in preparation of related project proposals for the companies.

Technical reports / studies have been prepared by the consultant dealing with the following topics :

- Improvement of the digestion efficiency and liquor productivity by digestion lime charge,
- Determination of the expected level of  $V_2O_5$ ,  $P_2O_5$  and F content in process liquors of alumina plants and removal of vanadium-rich salt at the application of digestion lime charge,
- Laboratory tests and plant results with crystal growth modifier

- Some aspects of high temperature digestion, tube digestion and double digestion and their perspectives in India.

The expert of the Centre, who have participated in the preparation of preinvestment studies in 1993-94, were mostly involved in the follow-up actions, discussions, consultations and laboratory test work, too. The list of the co-operating experts (senior counterpart staff) is enclosed as Annexure-III. The close co-operation with Dr. V. Berkh, UNIDO consultant, expert in instrumentation, process control and automation, especially relating to the slurry adjustment and process control of red mud settling and washing is also to be mentioned.

These topics have been elaborated for the Workshop on Improvement of Alumina Technology held at JNARDDC Nagpur on 12-13 January, 1995, were presented by the consultant as papers and can be found in the Workshop Material. The detailed programme of the Workshop and the list of participants are enclosed as Annexure-IV.

Furthermore, the consultant has prepared an in-house working paper for JNARDDC scientists on.

"Guideline for formulation of R&D Project proposals. (With special reference to alumina production)".

In order to promote the expected extended activity in the field of the physical simulation and mathematical modelling of the precipitation process a study was also prepared on

"Main Development Trends, Laboratory Simulation and Modelling of Precipitation".

The significant part of the draft of the training material on "The Main Tendencies in the Development of the World Aluminium Industries" has also been prepared by the consultant dealing with the status of the world aluminium industry and the main trends of the technical development in alumina production.



The schedule of the return mission is given below :

	1994
Departure from Budapest to Delhi	Nov. 7
Arrival Delhi from Budapest	Nov. 8
Visit UNDP office (meeting with Mr. Sat Pal and Mr. R.K. Jaiswar)	
Arrival Nagpur (from Delhi)	Nov. 9
Evaluation and discussion of the documents and reports prepared in 1994 by JNARDDC Scientists	Nov. 10 - Nov. 24
Preparation of different technical reports and studies	Nov. 21 - Dec. 31
	1995
Preparation / finalisation of workshop material	Jan. 1 - Jan. 11
Workshop on Improvement on Alumina Production Technology	Jan. 12 - Jan. 13
Finalization of the technical reports and preparation of Report on Return Mission	Jan. 14 - Jan. 20
Departure from Nagpur	Jan. 20
Departure from Delhi to Budapest	Jan. 21

A. Follow-up actions concerning the preinvestment studies prepared for BALCO, NALCO, HINDALCO in 1993-94.

Following the reflections of the companies, JNARDDC Scientists have prepared different working materials, carried out and evaluated some laboratory tests and studied the possibilities of the capacity increase, the improvement of the productivity and alumina quality at reduced, minimum investment costs. These reports / studies show the adequate level and capability of scientists dealing with alumina production in the Centre. All reports / studies have been discussed with the related scientists. As far as the low pressure digestion of Panchpatmali bauxite is concerned, the predesilication seems to be very effective to control the silica level in the liquor (and in the alumina), however, spent liquor addition is required to the predesilicated slurry in order to reach the target A/C ratio (RP, MR).

The project proposal on evaluation of Mainpat bauxite for alumina production one of the best and carefully prepared documents at JNARDDC and has great importance relating to the future development strategy and competitiveness of BALCO and HINDALCO. (Mainpat and Surguja bauxite occurrences are very similar).

Modified project proposals have been prepared (with the contribution of the consultant) and presented to the Chairman-Managing Director of BALCO, Mr. S.H. Azad on 28th November in the occasion of his visit to the Centre.

In connection with the further details of the expected projects the consultant have prepared the following technical reports, which have been included in the Workshop Material, too.

1. Improvement of the digestion efficiency and liquor productivity by digestion lime charge

Based on the international experiences and the plant trials carried out at Korba Alumina Plant in 1987 and at Renukoot Alumina Plant in 1984 and 1987 it seems to be very realistic to achieve a molar ratio at least 1.50 ( $A/C = 0.64$ ) at both plants under the given digestion conditions (caustic soda concentration and retention time) combined with a significantly improved digestion efficiency. The digestion lime charge is even more required for processing the expected future bauxite supply containing increasing amount of boehmite and especially diaspore.

The adequate saturation of the blow-off liquor by alumina (to achieve the target A/C or molar ratio) is an indispensable precondition of the improvement of the liquor productivity.

It is to be stressed, however, that careful and detailed investigations are required to determine the effect of the peculiarities of the future bauxite supply and to adjust the conditions to the bauxite to be processed, therefore laboratory tests and plant trials are necessary.

In order to avoid the optional difficulties can be caused by the digestion lime charge the following main technical development measures are to be implemented :

- Sophisticated molar ratio control at digestion,
- Instrumentation and process control at red mud settling and washing and use of synthetic flocculant,
- Modified vanadium and soda salt crystallization and control of the sodium carbonate level in the process cycle by means of side-stream or complex causticization.

2. **Determination of the expected level of  $V_2O_5$ ,  $P_2O_5$  and F content in process liquors of alumina plants and removal of vanadium-rich salt on the application of digestion lime charge**

Considering the similarities among BALCO, HINDALCO and Hungarian alumina plants relating to the vanadium-salt removal, the experiences gained at Almasfuzito Alumina Plant are discussed in this report. It is expected that the equilibrium concentrations of  $P_2O_5$  and  $V_2O_5$  in a caustic liquor of about 200 gpl  $Na_2O$  caustic will be 0.2 gpl and 0.8 - 1.0 gpl, respectively, when digestion lime charge has been applied. Effective vanadium salt recovery can be achieved only by means of the cooling of spent or strong liquor to about 35-45°C under the changed conditions caused by lime additive.

### **3. Laboratory tests and plant results with crystal growth modifier**

The available published data are discussed in this technical report. The increasing use of speciality chemicals in the Bayer process is a worldwide trend because significant benefits, higher production capacity, reduced specific consumption of raw materials and energy and alumina quality improvement can be achieved without or at a minimum investment cost. The regular use of synthetic flocculants, dewatering aids (at hydrate filtration) and CGM is highly recommended in all Indian alumina plants. The report contains the description of the procedure of the laboratory tests, too, which can be applied at JNARDDC at the simulation of precipitation. It is also recommended to adapt the method of the determination for critical oxalate concentration developed by Billiton Research. The use of CGM can significantly coarsen the hydrate granulometry and increase liquor productivity (at lower starting molar ratio in precipitation) at BALCO and can improve liquor productivity through increased caustic soda concentration, and seed charge and reduced temperature while maintaining granulometry (sandy type), strength and purity at HINDALCO and (less significantly) at NALCO.

### **4. Some aspects of high temperature digestion, tube digestion and double digestion and their perspectives in India**

This technical report is dealing with the future trends in digestion and red mud separation. The increasing alumina quality requirements are also emphasized relating to both purity ( $\text{Fe}_2\text{O}_3$  0.012 %,  $\text{SiO}_2$  0.012 %,  $\text{Na}_2\text{O}$  0.30  $\rightarrow$  0.25 %) and physical parameters (-45 microns 6%, -20 microns < 1%, +150 microns 1%, attrition index 15%, gibbsite 0.10 %).

The tube digestion process can also produce highly supersaturated pregnant liquor as well as the low-pressure digestion of the gibbsitic bauxites. The Aluminium Oxide Stade Refinery running at 270°C digestion temperature consumes the less heat energy on the world, (8.18 GJ/t) due to the same caustic concentration in digestion and precipitation. (Minimal capacity of evaporation is required for sodium oxalate removal only). VAW and Aluminium Oxide Stade have developed a successful wet oxidation process in tube digestion unit to control organics, especially humates. This study deals with the laboratory and pilot plant simulation of the digestion including tube digestion), as well.

As the latest development the counter current double digestion process for processing gibbsitic-boehmitic bauxite developed by ALCAN is discussed.

The key unit operation of this double digestion is the pressure decantation (at around 6 bars) which itself is a revolutionary novelty in the Bayer Process. The full scale plant trials confirmed that only a very short residence time was required in the pressure decanter and only  $0.07 \text{ m}^2/\text{t}$  red mud solids settling surface area was necessary, more than 50 times less than in the traditional thickeners.

The double digestion enables to achieve very high liquor productivity for mixed bauxite : the 1st digestion takes care of the productivity (dissolution of gibbsite) while the 2nd one that of the completeness of extraction (dissolution of boehmite).

Although the next development stage in the red mud separation is the pressure decanter to settle the slurry before the final flashing, the actual trends are that deep thickener or similar technology is replacing conventional thickeners in new Bayer plants and the deep thickener technology is expanding to other industries. According to the techno-economic calculations made by ALCAN the counter-current double digestion can be implemented at a reduced investment costs and can be operated at a reduced level of production costs relating to both retrofitted plant and greenfield installation in comparison with the conventional high temperature digestion circuit.

It can be predicted that typically liquor productivity of  $> 90 \text{ kg/m}^3 \text{ Al}_2\text{O}_3$  will be achievable of any type of bauxite, for a boehmitic bauxite the digestion constraint will be eliminated and the productivity gain will be very significant at 40-50%.

In order to elaborate the medium-and long-term strategy of the implementation of an optimum technology for processing monohydrate type (containing increasing amount of boehmite and diaspore), high titanium Indian bauxite the autoclave digestion with lime charge, the tube digestion and the counter-current double digestion seem to be most feasible and are to be compared based on detailed laboratory simulation tests, (pilot plant tests and plant trials), and techno-economic studies are also to be prepared. JNARDDC should play determining role in this issue.

**B. Guidance for formulation of R&D project proposals with special reference to alumina production**

The main duties marked under points 1 to 3 in the job description of the consultant have been fulfilled by the direct jointly daily work with the staff members of JNARDDC. Special discussions have been organized by the Director and Chief Technical Advisor to determine and finalize the activity and work plan for 1995 of the Alumina Production Research Department and that of the Process Engineering and Study Group Instrumentation and Process Control. (Mathematical Modelling, Energy Auditing).

It should be mentioned that very successful and attractive activity has been carried out during the last years in the aluminium smelters by means of the mobile van. This instrumentation as a universal tools can be used in alumina plants and in any other industry in order to achieve significant energy saving.

The consultant has also taken part in the detailed discussion of the alumina related activities work plan for 1995, organized by Dr. T.R. Ramachandran, Director and Mr. P. Vidyasagar, Dy. Director with each scientist working for the alumina production field.

A "Guidance for formulation of R&D Project Proposals, with special reference to alumina production" has been prepared by the consultant based on his own experiences and available data in order to use this as a working material at JNARDDC. This Guideline is enclosed as Annexure-V.

A very significant proposal for TSS-1 financing elaborated by the scientists of JNARDDC (considering the results of the in-house discussions with the Director, Chief Technical Adviser, Scientists and Consultant) should be mentioned : "Utilization of India's natural resources and R&D facilities for the development of bauxite-alumina industry in the Asian region and CIS countries"

This document (enclosed as Annexure-VI) has an extremely great importance. The comparative evaluation of the East-Coast bauxite occurrence in India and the actual competitiveness of the Damanjodi Alumina Plant, combined with the already justified high capability at JNARDDC perfectly confirm the viability and necessity of this inter-regional project. The consultant recommends to support this project by all available resources on behalf of UMLDA.

C. Guidance in laboratory simulation of digestion, red mud settling and precipitation and production of speciality alumina hydrates.

The implementation and start up of all technological testing equipment and methods have been performed in the new technical complex very successfully and they are operated regularly. The only limitation is the shortage in personnel. The precipitation unit have been taken in operation by the end of December and actions are going on to supply the Centre with proper amounts of samples required for conducting digestion and precipitation simulation studies, according to the advise of the consultant (Annexure-VI). It has been agreed that the HOD will keep an adequate amount of the samples continuously in order to the scheduled laboratory work.

Some digestion tests have also been carried out with BALCO bauxite supply in the well stirred autoclave without and with lime additive to the bauxite slurry to study the digestion kinetics. The first results are encouraging relating to the more completed boehmite and diaspore dissolution and achievable lower molar ratio.

The consultant has recommended to acquire traditional small size settling tubes with temperature controlled water bath for red mud settling tests in series to select the optimum type of flocculant and to determine the optimum dosage.

Urgent actions are recommended to procure well agitated (or intensively rotated) autoclave bombs with temperature control for digestion tests in series to determine the digestion characteristic curves (alumina yield in function of molar ratio), digestion kinetics, effect of lime dosage, etc. (6 parallel samples are preferred).

The test procedures, evaluation of results and programme of the investigation have been regularly discussed with the scientists. The analytical requirements have also been agreed. The analytical (material testing) capacity seems to be as a bottle-neck, especially the chemical analysis of the samples. Fast data supply is requested on behalf of the Analytical Research Department for good and in time planning of the technological tests.

The performance of laboratory simulation of the sweetening and the programme of some informative laboratory tests in order to evaluate the viability of the ALCAN's counter-current double digestion has been discussed and agreed with the head and scientists of the Alumina Research Department. The more effective activity in the field of red mud settling with special regard to the use of synthetic flocculants in settler and washers need lot of investigations in series which are to be performed in traditional, small size temperature controlled settling tubes. Soft gamma-ray Absorption Model Settling tests are recommended only under the preliminary determined optimum conditions.

The procurement of larger size (5-10 l), temperature controlled precipitator(s) to the research activity focused on the production of speciality alumina hydrate is also necessary.

The consultant has taken part in the discussions held between the Alumina Project Team of L&T Bombay and JNARDDC on 28/12/94 at Nagpur to determine the programme of the laboratory tests covering the simulation of the bauxite processing technology relating to the physical testing of the bauxite, predesilication, digestion and red mud settling. The laboratory tests are going on successfully.

A significant part of the activity of the Alumina Production Research Department is focused on the simulation of precipitation including the application of crystal growth modifier and manufacturing of special (high purity and white) alumina hydrate.

In order to promote this activity a study was prepared by the consultant on Main Development trends, laboratory simulation and modelling of precipitation



The study consists of the following main sections :

- Main development trends in the precipitation process (Development of the process technology, equipment improvement, mathematical modelling).
- Simulation and modeling of the precipitation process of alumina plants (Damangjohi, Kolar and Renukoot),
- Laboratory precipitation tests for manufacturing speciality aluminium hydroxides.

The results of the laboratory simulation should be compared with the plant data and the mathematical modelling. When these three series of data are in good agreement each to others, the laboratory simulation and mathematical model calculations can be started relating to the recommended improved precipitation process technology.

Based on this study the detailed work programme of the scientists is being elaborated.

**D. Guidance / preparation of training material on the main tendencies in the development of the world alumina industries with special reference to alumina production**

The Output-6 in the work plan of JNARDDC for the year 1995 contains the Training programme for the aluminium industry. In connection with this activity, preparation of training material on the main tendencies in the development of the world aluminium industries is expected. The consultant has prepared a draft study as a working material which can be up dated, finalized and completed and by the staff of JNARDDC with the assistance /guidance of all international experts visiting the Centre.

This draft study is dealing with the following main topics :

- Up-dated forecasts of the world aluminium industry,
- Geographical restructuring of the world aluminium industry (bauxite, alumina and aluminium),

- Overall competitiveness of aluminium (Trends in production of aluminium, steel, copper, zinc, magnesium and titanium; Energy consumption by production processes; Resource depletion; Pollutant emissions; Summarized overall competitiveness of aluminium).
- Competitiveness of the Indian alumina production (Comparison of the alumina production costs and selected technical data of some alumina refineries; The role of plant size; Liquor productivity and alumina capacity; Energy consumption; Competitiveness of the Indian alumina refineries; Potential improvements at NALCO and BALCO alumina plants,
- Future alumina quality requirements ,
- Main technical development trends in digestion (Tube digestion; Counter-current double digestion with pressure decanter,
- Main technical development trends in precipitation (Process technology; Equipment improvement; Mathematical modelling),
- Main technical development trends in other process stages and fields of alumina production,

The most important conclusion of the study is that the sharing of the Indian primary aluminium industry in the world production amounts to 4% and it is continuously increasing (Now-a-days it is the 5th big power), and the Damanjodi Alumina Plant produces the less expensive alumina on the world (the total production cost is US \$ 141/t, the variable cost US \$ 94/t. Consequently, the further potential of the fast development is justified and JNARDIC can and should play a determining role in it.

#### **E. Providing the Centre with copies of relevant literature**

Copies of following relevant literature were submitted to the Centre:

- a) World Gallium, 1985, Annual Review, Five Year Forecast (Prepared by Advantage Quest, May, 1986.
- b) Initial Report on CGM Plant Test at Energoinvest Plant RO Birac for the Period 1990-01-29 to 1990-03-20 (Prepared by NALCO Chemical GmbH, Vienna, by Mr. A. Frauneder)

- c) Second International Alumina Quality Workshop "Alumina Quality in a Highly Dynamic Market Environment", Proceedings, Perth, Western Australia, October 14-19, 1990.
- d) Conference on Ecologically Sustainable Industrial Development, Copenhagen, Denmark, 14-18 October, 1991. Alumina Industry, Case Study No. 2 (Prepared by P. Siklosi, J. Zoldi and E. Singhoffer).
- e) Light Metals 1993. Proceedings of the 122nd TMS Annual Meeting held in Denver. All papers of the "Bauxite and Alumina" sessions.
- f) Light Metals 1994. Proceedings of the 123rd TMS Annual Meeting, San Francisco, February 27 - March 3, 1994. All papers of the "Bauxite and Alumina" sessions.
- g) Aluminium Analysis, No. 61 - April 1994. Anthon Bird Associates 1994.
- h) Electronic Catalog, ACHEMA 94.
- i) Papers considered for the preparation of technical reports and training material on the status and development trends of the world aluminium industry with special regard to the alumina production. (Mostly papers published in ION, Light Metal Age and ICSOBA conferences.

## CONCLUSIONS

1. Draft versions of the three preinvestment studies for BALCO, HINDALCO and NALCO have been completed successfully with the active participation and co-operation of the staff members of JNARDDC under the guidance of Dr. J. Zambo, CTA.
2. Although the preinvestment studies were appreciated for their technical content, by the companies, very little progress is made in the realization of the recommended options (low pressure digestion of gibbsitic bauxite (low boehmite bauxite) around 145°C, sweetening and adaptation of the up-to-date precipitation technology developed by Alusuisse) due to the shortage of capital for investment at NALCO and the increasing boehmite and diaspore content in the future bauxite supply at BALCO and HINDALCO.
3. The companies have expressed their interest relating to the development of precipitation process in order to increase liquor productivity and improve alumina quality. Modified studies and project proposals were prepared by the Centre to meet these requirements (See Annexure-II, point 1.1), and related activities were built in the work plan for 1995 :  
Development of methods for physical and mathematical modelling of precipitation processes for reliable simulation of production technology including grain size distribution of the products.
  - Study on optimisation of technological parameters for precipitation processes in HINDALCO's and NALCO's Alumina Plant.
  - Follow up of preinvestment study on intensification of production processes and improvement of alumina quality at Korba Plant of BALCO.
  - Follow up on the preinvestment study for intensification of production processes and expansion of Damanjodi Alumina Plant of NALCO.
  - Development of mathematical simulation models for the main production processes of the Bayer technology.

4. The implementation and successful start up of all technological testing equipment (by the end of 1994 precipitation simulation tests have also been started) and the follow-up actions made by the staff members concerning the preinvestment studies have confirmed the high capability of the technical expert teams of JNARDDC.
5. The workshop on Improvement on Alumina Production Technology concentrated on the most actual tasks and measures of technical development in close connection with the above preinvestment studies. The following topics were covered in the workshop :
  - Role of lime in Bayer Process
  - Improvement of digestion efficiency and liquor productivity by digestion lime charge.
  - Use of crystal growth modified.
  - Synthetic flocculant application in Bayer Process.
  - Vanadium-salt removal on the application of digestion lime charge.
  - Process control in alumina production at bauxite grinding, slurry adjustment (molar ratio control), instrumentation and process control of red mud settling and washing.
  - Perspectives of tube digestion and counter-current double digestion in India. (Medium-term development strategy)

The significant contribution of the JNARDDC scientists (especially on behalf of Mr. P. Vidyasagar, Mr. H. Mahadevan, Mr. R.N. Goyal Mr. H.K. Chandwani and Mr. V. Vishwanathan) to the great success of the Workshop justified the significant progress achieved during the last year.

6. The Centre has well trained key personnel in bauxite geology and evaluation, furthermore in laboratory simulation, material testing and mathematical modelling of the Bayer process who are able to tackle the above detailed tasks of the Work plan for 1995. The consideration of some special aspects of the laboratory simulation of digestion and precipitation discussed in the technical reports prepared by the consultant is recommended.

## RECOMMENDATIONS.

1. Strict adherence to the work plans formulated for the year 1995 is crucial for the realisation of the recommended follow-up actions in connection with the preinvestment studies, too. In order to improve the efficiency of the technological testing activity in the Alumina Production Research Laboratory urgent implementation and start up of the following equipment are recommended :
  - Digestion autoclave bombs with intensive agitation in series (The simultaneous use of 6 autoclave bombs is necessary) equipped with stirrers or rotated in a temperature controlled oil or Molten salt bath.
  - Traditional small size settling tubes in temperature controlled water bath (at least 6 tube simultaneously) for settling tests in series. (floculant selection, optimisation of dosage, effect of digestion conditions, e.g. lime charge on sedimentation, etc.)
  - Larger size precipitators (5-10 l) for the tests to produce speciality alumina hydrates.
2. The simultaneous laboratory simulation of precipitation, digestion and red mud settling along with the production of speciality alumina hydrates require high capacity, high level and fast analytical service (material testing). Adequate measures are requested to meet the requirements of the physical modelling.
3. In connection with the above acceleration of recruitment of the scheduled professional staff is highly recommended, although the difficulties are well known.
4. The evaluation of new bauxite resources according to the work plan for 1995 and the building up of a bauxite data bank (along with collection of representative bauxite samples) are of first priority in the development strategy of the Indian alumina industry.
5. UNIDO / UNDP support to the proposal (for TSS-1 financing elaborated by JNARDDC on "Utilization" of India's natural resources and R&D facilities for the development of bauxite-alumina industry in the Asian region and CIS countries" is highly recommended because the Eastern Ghats bauxite resources have world-wide importance (only high grade

gibbsitic bauxite in the region) and can be processed with extremely good competitiveness (NALCO's Damanjodi Alumina Plant produces the less expensive alumina on the world total production cost : US \$ 141/t alumina variable cost US \$ 94/t alumina), and JNARDDC is capable of organising and co-ordinating the activity with full success.

6. Further efforts are needed on behalf of JNARDDC and companies to introduce the following technical development measures at the alumina plants :

- Digestion line charge at BALCO and HINDALCO
- Use of crystal growth modifier at BALCO and NALCO (HINDALCO uses it)
- Synthetic flocculant application at each plant
- Alumina quality improvement at BALCO
- Improvement of the liquor productivity by means of the adaptation of the "Alusuisse precipitation process"
- Improved instrumentation and process control, first of all at slurry adjustment (molar ratio or A/C control) at BALCO and HINDALCO, - instrumentation and process control at red mud settling and washing

In order to accelerate the implementation, the related supplementary laboratory simulation tests should be carried out at JNARDDC and techno-economic justification is also required, as soon as possible.

7. Informative laboratory tests are recommended to determine the feasibility (viability) of the counter-current double digestion. (developed by ALCAN) for processing gibbsitic-boehmitic-diasporic, high titanium bauxites (Mainpat and Samripat) according to the tentative programme handed over by the consultant.
8. Plant trials with pressure decanters are recommended as soon as possible, as the process offers high potential for the development of the alumina industry.

## UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

## JOB DESCRIPTION

DP/IND/88/015/11-08

**Post Title:** Expert in alumina process engineering

**Duration:** 2.5 m/m

**Date required:** end of September 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



- (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 economic and international competitiveness of alumina production.

**Qualification:**

University degree (preferably Ph.D.) in chemical 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 years. The first aluminium smelter (in Alumpars, Kerala) was 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.

WORK PROGRAMME

For Dr. K. Solyman, UNIDO Expert

14th November, 1994 - 20 Jan., 1995 at JNARDDC

The following main fields of activity are planned in connection with the related job description.

1. Follow-up actions concerning the preinvestment studies prepared for BALCO, DALCO, BENDALCO in 1993-94.
  - 1.1 Evaluation and discussion of the following documents and reports prepared in 1994 by JNARDDC scientists.
    - Low pressure digestion studies on Panchpatmali bauxite,
    - Review of the methods of oxalate / organic control in Bayer's process of alumina extraction.
    - Analysis of red mud pond problems at Damanjodi and possible solutions.
    - Improvement of alumina quality at DALCO
    - Revised techno-economical evaluation for production of 46,000 ton per annum extra alumina.
    - Enhancement of production at BALCO Alumina Plant with addition of crystal growth modifier.
    - Project proposal on evaluation of Mainpat bauxite for alumina production at Korba Plant.

1.2 Cooperation/ guidance in the preparation of further studies / project proposals for BALCO, NALCO and HINDALCO.

- Alumina quality improvement at BALCO.
  - Lab. trials and plant results with CGM, review of the available data.
  - Enhancement of production at BALCO by means of computer aided slurry adjustment.
  - Improvement of the digestion efficiency and liquor productivity by digestion lime charge at BALCO.
  - The expected level of V<sub>2</sub>O<sub>5</sub>, P<sub>2</sub>O<sub>5</sub> and F contents in the process liquors of alumina plants and removal of vanadium salt at the application of lime chemistry. (Digestion lime charge)
  - Low pressure digestion at NALCO without significant changes in precipitation.
  - Evaluation of the Surguja (Samripat) bauxite for production of alumina for HINDALCO.
  - Some aspect of the high temperature digestion (tube digestion) without and with lime additive and the perspectives of double - stage (ALCAN) digestion for processing high titanium gibbsitic - boehmitic bauxite (at BALCO and HINDALCO)
2. Cooperation / guidance in laboratory simulation of digestion,, red mud settling and precipitation and also relating to the production of speciality alumina hydrates.
- Lab tests in connection with the expected further studies :
- Digestion of BALCO bauxite at 240°C without and with lime addition, studying of the digestion kinetics; low pressure digestion tests with Panchpatmali bauxite.
  - Simulation of the precipitation process of the alumina plant including the expected modified parameters and use of CGM.

- Laboratory test in order to produce white and high purity alumina-hydrates.
- 3. Cooperation in programming / preparation / performance of Pilot plant tests expected at BAI CO with Panchpatmali bauxite (low pressure digestion)
- 4. Guidance / preparation of training material on the main tendencies in the development of the world aluminium industries with special regard to the alumina production.

#### Time schedule

- 1.1 10 Nov 94. - 24 Nov. 94
- 1.2 21 Nov. 94 - 31 Dec. 94
- 2 28 Nov 94 - 31 Dec. 94
- 3. 5 Dec. 94 - 20 Jan 95
- 4. 2 Jan. 95 - 20 Jan 95

**Annexure-III****List of the co-operating experts (Senior counterpart staff)**

<b>Name of Participants</b>	<b>Designation</b>	<b>Field</b>
Dr. T.R. Ramachandran	Director	Overall Supervision
Dr. J. Zambo	Chief Technical Advisor (UNIDO)	Co-ordination & Guidance
Dr. V. Berkh	Consultant (UNIDO)	Process control & automation
Mr. P. Vidyasagar	Dy. Director	Alumina Technology
Mr. R.N. Goyal	HOD (Alumina)	Alumina Technology
Mr. H. Mahadevan	Scientist	Alumina Technology & Lab. Simulation
Dr. A.K. Nandi	Scientist	Bauxite Evaluation
Mr. U.B. Agrawal	Scientist	Techno-economy
Mr. H.K. Chandwani	Scientist	Alumina Technology & Lab. Simulation
Mr. V. Vishwanathan	Scientist	Mass & Heat Balance
Dr. K.V. Krishnan	Scientist	XRD Analysis
Mr. Ramana Murthy	Scientist	Alumina Technology & Lab. Simulation
Mr. M.J. Chaddha	Scientist	Alumina Technology, Mass & Heat Balance
Mr. K.J. Kulkarni	Scientific Assistant	Lab. Simulation
Mr. R.K. Meshram	Steno-cum-Assistant	Preparation of reports



**JAWAHARLAL NEHRU ALUMINIUM RESEARCH  
DEVELOPMENT AND DESIGN CENTRE, NAGPUR**

**WORKSHOP ON IMPROVEMENT OF  
ALUMINA PRODUCTION TECHNOLOGY**

**Thursday, January 12, 1995**

**Session I-Lime Chemistry**

0900 to 0930 hrs	Inauguration
0930 to 1030 hrs	Role of Lime in Bayer Process-II Mahadevan, H.K. Chandwanji and G.N. Sharma
1030 to 1100 hrs	Tea
1100 to 1200 hrs	Improvement of Digestion Efficiency & Liquor Productivity by Digestion Lime Charge-K Solymer
1200 to 1300 hrs	Determination of the expected level of $V_2O_5$ , $P_2O_5$ and F contents in process liquors of alumina plants and removal of vanadium salts on the application of lime charge-K Solymer
1300 to 1400 hrs	Break
1400 hrs	Session II - Process Control and Automation
1400 to 1500 hrs	Process control in alumina production-application of static and dynamic models application in closed control loops-V Berkh
1500 to 1530 hrs	Tea
1530 to 1630 hrs	Control system development in alumina production-problems and approaches of "Red side" automation (Bauxite grinding and digestion, red mud settling and washing) - V. Berkh
1630 to 1800	Visit to Technical Complex

**Friday, January 13, 1995**

**Session III-Special Chemicals, Future trends**

0930 to 1030 hrs	Laboratory tests and plant results with crystal growth modifier (CGM) - K Solymer
1030 to 1100 hrs	Tea
1100 to 1200 hrs	Synthetic flocculant-Applications of Bayer Process - V Vishwanathan
1200 to 1300 hrs	Some aspects of high temperature digestion (including tube digestion) with and without lime additive and the perspectives of ALCAN's double stage digestion in India-K Solymer
1300 to 1400 hrs	Break
1400 to 1500 hrs	General discussion

**JAWAHARLAL NEHRU ALUMINIUM RESEARCH  
DEVELOPMENT AND DESIGN CENTRE, NAGPUR**

**LIST OF THE PARTICIPANTS FOR THE WORKSHOP ON  
IMPROVEMENT OF ALUMINA PRODUCTION TECHNOLOGY  
12-13TH JANUARY**

Sl. No.	Name of the participant	Company
1.	Shri R.S. Singh	BALCO
2.	Dr. B.B. Gupta	BALCO
3.	Shri A.K. Mandal	BALCO
4.	Shri M.G. Agrawal	BALCO
5.	Shri P. Ashwadhama	L&T
6.	Shri M. Kapadia	L&T
7.	Shri G. Panda	INDAL
8.	Shri Shrikant Jayakumar	INDAL
9.	Shri D.C. Agrawal	HINDALCO
10.	Shri V. Sapra	HINDALCO
11.	Shri P. Vidyasagar	JNARDDC
12.	Shri R.N. Goyal	JNARDDC
13.	Shri H. Mahadevan	JNARDDC
14.	Dr. A.K. Nandi	JNARDDC
15.	Shri H.K. Chandwani	JNARDDC
16.	Shri V. Vishwanathan	JNARDDC
17.	Shri Ramana Rao	JNARDDC
18.	Shri M.J. Chaddha	JNARDDC
19.	Shri S.S. Rao	JNARDDC
20.	Shri K.J. Kulkarni	JNARDDC
21.	Dr. K. Solymar	UNIDO Expert
22.	Dr. V. Berkh	UNIDO Expert

## GUIDELINES FOR FORMULATION OF R&D PROJECT PROPOSALS

(with special reference to alumina production)

Every research and development proposal has its own requirements; however there are certain common models for the classification and elaboration of such types of projects. The most sensitive questions are the justification of the expected benefits (economized results of plant operations if any) and the finance of research projects. The short term and specific interest of the manufacturers (alumina plants and companies) is to increase the profitability by means of optimum (minimum) investment cost. In many cases the research activity aims at long term benefits for which scientific results of high order are required. This also helps to develop a well trained and good scientific staff which is a pre-condition for any successful activity.

### 1. MAIN CLASSIFICATION OF RESEARCH PROJECTS

The research projects can be divided into three main groups:

1. Development of process technology and new products.
2. Applied and fundamental research connected with the development of process technology.
3. Development of methods for chemical, physical and structural investigations (material science), to carry out, control and evaluate the technological tests more adequately.

#### 1.1 Development of process technology and new products :

These research projects are production and / or product related, with the following main aim :

- to improve the production process technology including both the technological solutions and equipment development,
- to manufacture new products (e.g. special alumina hydrates and aluminas) or improve the quality of the existing products, (e.g. production of higher purity and coarser metal grade alumina)

These types of projects in the field of alumina production can deal with the development of all stages of the Bayer process (digestion, red mud separation, washing, causticization, precipitation, etc.) with the primary aim to improve the production capacity and / or reduce the specific consumption of raw and auxiliary materials, energy, manpower, etc., so that the reduction in specific production costs can be achieved.

In as much as these research projects are focused on the improvement of the economy, they need at least preliminary calculations concerning the expected benefits with special regard to the optional investment costs. Based on the laboratory test results sometimes pilot plant tests, techno-economic studies (Opportunity study, Prefeasibility study) can be prepared. Feasibility Studies need elaborate authentic data base, as far as possible by means of plant trials or by using operating experiences of other plants as references.

Examples for these type of projects are quality improvement (CGM, synthetic flocculant applications etc.) and plant capacity expansion (by means of improved MR control, application of digestion lime charge) at BALCO, the use of low-pressure digestion at NALCO and improvement of precipitation technology at HINDALCO.

## 2. Applied research activity

Significant number of projects can be clubbed into this group. They are in close connection with the development of the process technology and often the given measurements or knowledge to be acquired are inevitable preconditions of the process development aimed. Some examples in the field of alumina production are the following :

- Determination of organics dissolution at the digestion of different kinds of bauxite to be processed,
- Determination of organic balance of the given alumina plant,
- Studying the effects of impurities of the process liquor on digestion, precipitation, vanadium-salt recovery.
- Determination of the equilibrium solubility diagram of process liquors at different levels of impurities,

- Technological evaluation of characteristic (representative) bauxite samples to be processed in order to optimise the processing conditions or to realize selective mining and proper blending (e.g. Evaluation of Mainpat bauxite of BALCO or Mainpat bauxite of HINDALCO).

Although the technical and such research projects are very useful for all or at least for the directly related alumina plants, the long-term, systematic and sophisticated research work without quick and direct results is not always well understood, accepted and supported by the companies. Consequently, the techno-economic justification of the medium or long term benefits, estimation (although sometimes without exact figures) of the expected advantages, should be discussed in these project proposals, too.

### **1.3 Development of the methods applied**

The technological tests can be evaluated only by means of a high capacity, and well organized analytical service. So, the related procedures of the chemical, physical and textural investigations should be available and continuously further developed. This field has an even more significance at JNARDDC where most up-to-date, sophisticated, very valuable instruments are in operation. Some of them can also be used for extra studies in the field of material science, preferably in connection with alumina and aluminium production and with particular regard to the special alumina hydrates and aluminas. Special methods, as determination of the organics in the Bayer cycle need attention. Further role of JNARDDC may be in the field of regular & periodic plant auditing to develop better management system for the company. Another important field of activity for research Centre like JNARDDC is to develop expertise to accredit laboratories and industries for ISO-9000, 90001 & 9002.

The economic justification of these projects is extremely difficult, sometimes it is impossible, although the cost of some kinds of services on the request of the plants should be borne directly by the companies.

The organisation of a project proposal is expected to be on the following lines :

## **2. CONTENT OF THE PROJECT PROPOSAL**

The main structure of the research project proposals shows a lot of similarities, but there are significant differences according to their classification reported in Section-1. The main and common aspects of the research projects will be discussed below:

## 2.1 Title of the project (theme)

The title should cover exactly and precisely the content of the project (study) emphasizing the focus of the work. A subtitle might classify the nature of the topic. Proper selection of the title is extremely important to avoid any potential misunderstanding later.

## 2.2 Level and character of the project

It is necessary to mention whether the research theme belongs to :

- fundamental research
- applied research
- process development
- product development
- physical modelling (process simulation in lab.)
- mathematical modelling
- pilot plant test
- plant trial (measurement)
- method development

Mostly the research projects can be characterized as applied research. It is advisable to use the combination themes wherever required (e.g. applied research, product development).

## 2.3 Aim and objectives

The most significant part of the research project proposals is the aim of the work. It is recommended to quantify the aim as far as possible. (e.g. at alumina quality improvement to give the results to be achieved : max. 20% -45  $\mu$ m particles, SiO<sub>2</sub> in alumina max. 0.020 %, etc. or in plant capacity extension : excess alumina production of 20 kt/y by means of improved liquor productivity, etc.)

The main objectives are the main activities to be performed, however, the detailed tasks should be reported in the work plan. The main objectives should widen and explain the aim only. (e.g. alumina quality improvement at BALCO by means of CGM, synthetic flocculants, reintroduction of hydroseparator and improved control filtration).

#### 2.4 Responsible institution or company (plant)

Mostly this is the JNARDI/C but sometimes can also be jointly with one of the plants or other institutions where the activity is focussed on.

#### 2.5 Co-operating plant(s) (Company) and / or institutions and their responsibilities

All partner institutions and companies (plants) should be mentioned with their exact contributions and responsibilities. These tasks should be detailed in the work programme.

#### 2.6 Project Manager / Director / Supervisor

The project leader (Team leader) is responsible for the whole activity and has to organize the work. All partners should have responsible contact persons.

#### 2.7 Evaluation: (analysis) of the international and domestic situation relating to the R&D project

This activity involves critical review of the related technical literature and analysis of the status of the given field in the country (in India) at different companies / plants with special regard to the particular plant.

For example let us see the development of precipitation at BALCO. In this case the evaluation should be extended to the review of the up-to-date precipitation processes such as Alusuisse, Pechiney, ALCAN options, etc. considering the alumina quality requirements, then to compare the existing precipitation processes in India at different alumina plants along with the analysis of these processes in comparison with the up-to-date one(s). Thus the gap in technological developments must be highlighted in the project proposal.

This evaluation should be formulated as a short and summarized overview in the research project proposals in order to justify the need of the research and development project. In general, the detailed elaboration of the critical review of literature is a significant initial phase of the realisation of the project, however it can also be prepared as a preliminary study to prepare and justify the expected research activity in the selected field, (e.g digestion or precipitation). The available, topic related critical review of literature may be enclosed (as Annexure) to the research project proposal. It is recommended to elaborate such kind of

studies (critical review of literature) by the scientists and research fellows concerning their main field(s) of activity and up-date the same from time to time.

The critical review of the literature should show that the writer has studied existing work in field with insight. The literature search should be planned and the following main points of view should be considered : **All investigations require evidence of reading.** One may get ideas about methods and processes applied and also about methods of data collection and analysis. It is very important that the most relevant items and findings of the published information should be discussed. The critical review of the literature should provide the scientist (research fellow) with a picture of the state of knowledge in the subject. Before the start of literature search it is requested to determine exactly what we need to know, therefore **we have to select the topic (s) and to define the terminology and parameters. They are :**

**Language** : English, French, German, Russian, Spanish, etc.,

**Geography** : Location of publications e.g. Light Metals as Proceedings of the TMS Annual Meetings, Proceedings of the Int. Alumina Quality Workshops (held in Australia), Proc. of Bauxite Tailings Workshops, TRAVAUX de l'ICSOBA, JOM, etc., or UK, US, Australia, India, or any other country.

**Time period** : e.g. from 1980 or 1990 to present ;

**Types of material** : books, journals, proceedings of conferences, reports, etc.,

**Selection of Sources** : Library catalogues, bibliographies, abstracts, indexes, etc,

**List of possible search terms.**

Everything that is read must be noted and the systematic method of record-keeping is to be developed at the earliest.

It is recommended to establish a **card index system** in order to facilitate the processing and use of the sources in any time without wasting energy in locating each technical paper. The cards should have complete references and should indicate all the information required for drawing up the references or bibliography for the project report. Reasonably the cards should include brief notes about the content of book or article and reminders that a certain chapter or page (figure or table) had useful information about some topic. So, this stock-in-trade can be used later on other research projects, too, saving the time of repeated search.



The record keeping can be more efficiently carried-out by using personal computer and suitable software. Name of all the technical papers alongwith short write up, name of author, details of publication, location and important key words can be stored in PC, which can be retrieved any time by search menu. Papers on similar specialized topic can be seen immediately, for example, all the technical literature related to bauxite and beneficiation can be listed out by giving search for bauxite a beneficiation. This kind of computer storage can be quite useful for preparing report/papers and R&D proposals.

The information required regularly are the following :

#### Books, Proceedings

Authors' surname and first name or initials

Date of publication

Title (underlined)

Place of publication

Publisher

(Note the chapter(s), part(s) of special interest indicating the pages)

#### Articles

Authors surname and forename or initials

Date of publication

Title (in inverted commas)

Source of the article, namely :

Title of journal (Proceedings)

Volume

Issue and page numbers

For proceedings, all data relating to the books are also to be recorded.

All data (tables and figures) which will be included in the report should be quoted exactly.

When important publications are collected, studied and analysed, the next stage is the categorisation of evidence, the selection of sources according to their importance and classification of the information selected for the different main topics (e.g. search terms) and then one can start the writing of critical review of the literature. The preliminary selection of the data, tables, figures to be cited is very practical and facilitate report writing. So the explanation of the data, the evaluation of the results and the justification of the conclusions are much easier.

## 2.8 Justification of the R & D project

Based on the aim and objectives of the project and the critical review of literature the technical necessity of the project should be confirmed. Although very often foreign experiences and know-how are available, it seems to be useful to check the adaptability of the given development, finding or method considering the different existing conditions, process parameters and equipment. e.g. the bauxite raw material and the contaminants in the process liquor in general differ significantly from the related data of the alumina plants in abroad. It is worthwhile to study the various offers given by the foreign companies and consultants for development and incorporate the same in the report. Sometimes the development of a tailor-made solution to the given plant conditions is the only technical and economic way to reach the expected goal (e.g. alumina quality improvement at BALCO).

Beside the technical justification, the economic viability of the project is also required to be verified. It has been mentioned already that this criterion does not mean the direct benefits (profit) only. e.g. method of the determination of organic materials is inevitable to determine organic balance, which is required to realize the improvement of the precipitation process. The improved alumina quality (higher purity and limited amount of fines) will improve the smelter operation and metal (alloy) quality. It is a real danger that without significant alumina quality improvement the smelter reconstruction at BALCO can not be fulfilled with the expected success and the aluminium semis products may not be marketable in the future.

Nevertheless the justification of the projects by means of techno-economic calculations (by use of COMFAR programme) is essential as is usually done by JNARDDC.

## 2.9 Methodology of the solution

The aim of the research project can be generally achieved by means of different consecutive stages. For the development of process technology or new products, usually the first step is the laboratory simulation of the selected process or process stage, e.g. digestion or precipitation under varying parameters in a relatively wide range. The varied parameters should cover the full range of the possible i.e. lab. field.

The applied research activity and the development of methods for physical, chemical and structural investigations are mostly limited to the laboratory investigations and measurements, including adaptation of the methods.

Based on the laboratory test, the programme of the pilot plant test can be determined, however, it is reasonable firstly to prepare a techno-economic estimation relating to the viability of realising the project objectives, first of all to determine the most sensitive elements of the process from economic point of view. Further efforts should be focussed on these questions.

The next phase is the pilot plant test if adequate facilities were available and the pilot plant test could be justified. It is to be mentioned that the pilot alumina plant at BALCO has a lot of limitations due to sizing, poor measuring system and process control, batchwise digestion operation, etc. Moreover the simulation of the red mud settling and washing and the precipitation can not be carried out there.

As far as digestion is concerned, simulation of the digestion process under laboratory condition is also quite good and the transfer of the lab results in the plant operation has been made in many cases with considerable success by different companies. (e.g. digestion with lime additive). Nevertheless the BALCO pilot plant can be used properly to study the digestion variant and to develop the process technology for production of few special alumina chemicals. The plant trials can be carried out step by step approach of the modified parameters, thereby minimizing the risk of the potentially disturbed operations.

Finally, this kind of the project can be terminated with the elaboration of a Feasibility Study based on the plant trials, and all experiences gained in India and collected from abroad.

### 2.10 Preconditions of the research project.

It is to be investigated whether the equipment, materials and the manpower available for the project or which type of further actions (purchasing new equipment, completion of the staff ) would be necessary. The position of laboratory activity at JNARDDC is very good.

The realisation of process development at the plants needs some kind of investment. The detailed analysis of these conditions is the subject of the Feasibility Study.

Special estimation should be prepared relating to the optional pilot plant tests.

### 2.11 Work programme

Based on all the earlier knowledge and considerations collected concerning the given research project a detailed work programme should be prepared.

At this point the earlier work carried out relating to the selected research project should also be considered as a basis. (e.g. at the "Evaluation of Mainpat bauxite for alumina production" the earlier work fulfilled by JNARDDC and BALCO).

The work programme can be divided into the following main activities:

- Critical review of literature at JNARDDC
- Collection and evaluation of the related data of the alumina plant(s)
- Collection of raw and auxiliary materials and further data required for the lab tests.
- Joint field work to be carried out (if any) (e.g. at the evaluation of Mainpat bauxite, Surguja, Samripat bauxite or Panchpatmali bauxite.)
- Laboratory tests and studies to be carried out at JNARDDC Detailed programme is requested including the estimated scope (volume) of work, e.g. number of tests, equipment to be used, requirements of analytical work (chemical, mineralogical textural analysis, physico chemical measurements, etc.). The manpower requirement should also be indicated. (The detailed tasks of JNARDDC staff members are not the subject of project proposal, that is an in house working programme which should also be elaborated in detail).

- Techno-economic estimation based on lab test results.
- Pilot plant tests (if any)
- Preparation of prefeasibility study (if any)
- Plant trials (if any)
- Preparation of feasibility study (if any)
- Data compilation, analysis, report preparation and discussions.

#### 2.12 Time schedule (Work Plan)

The work programme should be transformed into a time schedule (Work plan) which can also be plotted. The work plan should contain all the main activities with special regard to the critical stages which can influence the fulfilment of the whole project in time. As a good example the work plan for evaluation of Mainpat bauxite can be mentioned.

#### 2.13 Estimated cost of the project

The cost of the research project should be calculated on the basis of the break-up of costs according to the main activities as : tours and travels (field work, collection of raw and auxiliary materials and plant data, discussions, participation at optional pilot plant tests and plant trials), laboratory simulation of the process technology, analytical activity (chemical and instrumental analysis, including XRD, SEM and physical investigations), costs of pilot plant tests (if any), manpower costs, administrative expenses. (See the Mainpat project proposal).

#### 2.14 Documentation of the fulfilment

In general the Final Report (Study, Prefeasibility Study or Feasibility Study) is the document of the fulfilment. Sometimes it is requested to include in the project proposal the expected content of the Report, too, therefore a general outline is given below :

#### 2.15. Content of the Report

Report writing should not be a frantic activity carried out at the end of the project. It is a continuous process at various stages all of which need to be recorded at the time they are completed. The first drafts are certainly to be revised, therefore report writing needs discipline, self-control and good

scheduling and should start as soon as possible when one chapter (one section of the investigations, critical review of the literature etc.) can be finalized.

In general the report should include the following major sections : -

**Executive Summary, Conclusions and Recommendations.**

Recommendations may also include any suggestions for future work.

1. Outline of the Research,
2. Review of Previous Research,
3. Precise Statement of the Scope and Aims of Investigation,
4. Description of the Procedure, Sample and Tests of Measurement Used,
5. Statement of Results,
6. Analysis and Discussion,
7. Summary and Conclusions.
8. List of References.

All tables and figures should be numbered, given a title and carefully checked.

It is recommended to reserve some time for revision of the draft and final report before its finalization for printing.

**JAWAHARLAL NEHRU ALUMINIUM RESEARCH  
DEVELOPMENT & DESIGN CENTRE  
NACPUR, INDIA**

**PROPOSAL FOR TBS- FINANCING**

**UTILIZATION OF INDIA'S NATURAL RESOURCES  
AND R&D FACILITIES FOR THE DEVELOPMENT OF  
BAUXITE-ALUMINA INDUSTRY IN THE ASIAN  
REGION AND CIS COUNTRIES.**

**DECEMBER 1994**

## PROPOSAL FOR TSS-1 FINANCING

**COUNTRY :** India

**TITLE** Utilization of India's natural resources and R&D facilities for the development of bauxite-alumina industry in the Asian region and CIS countries.

**AGENCY:** Jawaharlal Nehru Aluminium Research Development & Design Centre, Nagpur, India.

### **I. BACKGROUND**

India is endowed with large resources of high grade metallurgical grade bauxite in the Eastern Ghats, which make her one of the most potential country in this region to develop bauxite-alumina industry. There is a vast scope to produce alumina at internationally competitive cost in this part of the world. The existing and planned alumina plants of the other Asian countries such as China and Iran are mainly based on the poor grade diasporic ore, the process economics of which can be appreciably enhanced by partly introducing good metallurgical grade bauxite available in the Indian subcontinent and applying suitable technological changes in the process. Apart from this many Asian countries devoid of good metallurgical grade bauxite but having cheap energy resources (e.g. middle-east countries), may like to participate in production of bauxite-alumina in this region. Some CIS countries, e.g. Russia, are producing alumina at much higher cost due to non-availability of high grade ores in their country and would like to switch-over to production at more competitive cost particularly after introduction of market economy there. On the other hand, some Asian countries such as China have good resources of non-metallurgical grade bauxite, which can be bartered for good alumina grade ore.

An important activity of the Jawaharlal Nehru Aluminium Research Development & Design Centre (JNARDDC), Nagpur (India), established by Government of India with the financial assistance of UNDP, is to analyse and evaluate the status and development of bauxite-alumina industry in the region. JNARDDC have a well equipped laboratory and highly qualified and trained scientists and staff to undertake various R&D activities and in-depth survey in the field of bauxite-alumina. This centre is unique in Asia and well equipped to organise and constitute forum of technocrats and economists of this region for the development of this industry. The discovery of large good metallurgical grade bauxite in the eastern part of India is relatively a recent discovery compared to Australia, south & central America and west Africa. This is an appropriate time to involve all interested Asian and CIS countries to know the potential of this region for bauxite-alumina production and capability for research & development in this field.

### **II. ISSUES TO BE ADDRESSED**

- Techno-economic evaluation of bauxite deposits of Asian and CIS countries and highlight present status of their exploration, mining and beneficiation.



- Bauxite processing values of potential Asian and CIS countries and comparative economics of alumina production.
- Work-out major R&D thrust areas in bauxite-alumina field in this region.
- Find-out techno-economic viability of simultaneous use of local poor quality ore and high grade easily digestible bauxite of India by sweetening technology.
- Analyse technical and commercial points for bauxite and alumina export/import in this region.
- Propose alternatives for improving alumina production and productivity in various plants of this region based on study and laboratory/pilot plant tests.
- Highlight areas of future bilateral and multilateral co-operation in exploration/exploitation of bauxite and production of alumina.
- Prepare pre-feasibility and feasibility analysis for all the alternatives proposed in the report.
- Boost co-operation among Asian and CIS countries for the growth of bauxite-alumina industry.

### III. INTENDED USE OF THE RESULTS

- Some Asian countries for example China and Iran are planning to set-up new alumina production facilities in their country based on locally available poor grade ore or by partly importing bauxite. These countries may derive direct benefits from this project work.
- Many CIS countries such as Russia and Ukraina are planning to modernize or shut-down uneconomical alumina plants of their country, which are also based on fairly low grade ore. They may look for cheaper alternatives to produce alumina in their plants or participate with other prospective countries to produce this raw material for their aluminium smelters. The proposed study may provide them necessary data/information for future planning in this direction.
- Some of the middle-east Asian countries such as Saudi Arabia, Dubai and Bahrain are practically devoid of metallurgical grade bauxite, however, they have cheap sources of energy and thus constructed aluminium smelters based on imported alumina. These countries may come-up for setting-up new alumina production facility in the vicinity and thus get benefit from this proposed study.
- Some of India's neighbouring countries for example Pakistan, Sri-Lanka and Bangladesh have limited reserves of lateritic bauxite. These countries may like to develop their resources or set-up plant based on imported blended ore and thus proposed study may provide them complete details and information for such planning.

- The proposed study may boost exploration, research and developmental activities of bauxite-alumina field in this region and India can certainly play a vital role and as well find potential market for alumina and bauxite.

#### **IV. EVIDENCE OF GOVERNMENT PRIORITIES, COMMITMENT AND PARTICIPATION**

Many countries of Asian region such as China, Iran, India and CIS nations are planning to modernise or set-up new alumina-aluminium plants in their country. In this context, joint efforts and deliberation by experts of technical and economical affairs of this region may provide proper atmosphere for co-operation and further growth of bauxite-alumina industry. This is one of the priority areas for Governments of many countries and thus technical forum may be set-up with the participation of potential Asian nations. Further commitments of respective Governments may be obtained after detailed techno-economic analysis.

At present there are four major bauxite producing regions in the world e.g. Australia, South America, Central America and West Africa (Guinea). However, there are 4 regions e.g. Australia, USA, South America and Central America considered to be major alumina producers of the world. There is a vast scope for the development of bauxite-alumina industry in this part of the world also and promote this to one of the major bauxite-alumina producing region.

#### **V. DESCRIPTION OF WORK AND SCHEDULING OF ACTIVITIES**

Jawaharlal Nehru Aluminium Research Development & Design Centre (JNARDDC), Nagpur (India) may act as nodal agency to organise and conduct complete study for this project. The work plan for the proposed project is divided into 2 phases- 1st phase dealing with in-depth study / laboratory tests and recommendations and 2nd phase for concrete bilateral and multilateral talks/negotiations, pilot testing and preparation of feasibility reports. Detailed work-plan for each phase is as follows:

##### **PHASE I**

- Data/information collection and literature survey on status of bauxite quality, reserves, exploration, mining and alumina production and technologies available in Asian countries including CIS nations.
- Preparation of draft objectives and first report based on above study and discussions/comments of International UNDP/UNIDO experts.
- Circulation of draft report among all interested Asian countries for comments and nominating experts representing their nation.
- Formulation of experts group of representative countries (mainly India, China, Japan, CIS nations, North and South Korea, Japan, south-east and middle east

Asian countries) for undertaking in-depth analysis and study on status of bauxite evaluation, mining and alumina production in the region and bring-out all possible lines of bilateral and multilateral co-operation. Systematic documentation of complete proceeding will be taken-up.

- Organisation of working group meeting (preferably in India) of participating Asian nations to modify and elaborate the report on status of bauxite-alumina and aluminium industry in the region and commitment for full scale co-operation .
- Field study on bauxite deposits, mines and alumina production centres of individual Asian and CIS countries of the region. Collection of representative samples of selected bauxite deposits/mines.
- Laboratory study (chemical, quantitative mineralogical, texture/structure and preliminary technological tests for sweetening and low-pressure) of selected bauxite samples of major Asian deposits/ ore districts for uniform evaluation system.
- Preparation of opportunity/pre-feasibility report by selected experts of Asian region and other International UNDP experts for consideration of respective Governments.
- Final joint report and recommendations for UNDP.

**TOTAL PERIOD FOR PHASE I WORK : 18 MONTHS**

**PHASE II** (Preferably after the gap of 6 months)

- Based on the comments/suggestions of individual countries of Asian and CIS region, work-out areas of bilateral and multilateral co-operation in the field of bauxite evaluation, mining and alumina production.
- Organise bilateral and multilateral meetings/visits to finalise given recommendations.
- In-depth study of selected bauxite deposits/mines and collection of representative samples for total evaluation.
- Laboratory and pilot scale testing for simultaneous use of local poor quality ore with high grade ores of India to improve production and productivity of alumina production.
- Techno-economic analysis and evaluation of various proposed alternatives and concrete recommendations for proposing industrial implementation.
- Preparation of pre-feasibility report(s).

- Submission of final report and recommendations to individual Governments and UNDP.
- 

TOTAL PERIOD FOR PHASE II WORK : 18 MONTHS

## VI. PROPOSED BUDGET

### A] GOVERNMENT OF INDIA INPUT

#### PHASE I

Estimated to be of the order of one million Indian Rupees (equivalent to US\$ 30,000 approx.) mainly for the collection of data/information/correspondence, laboratory testings, preparation of draft and final objectives/report/recommendations and circulate them among interested countries.

#### PHASE II

Estimated to be of the order of two million Indian Rupees, equivalent to US\$ 60,000 (Approx.) for laboratory and pilot scale testing, techno-economic analysis and preparation of pre-feasibility report(s) and recommendations.

### B] UNDP INPUT:

UNIDO/ UNDP assistance will be mainly desired for placing experts and financing technical meetings, study/visits to various bauxite-alumina producing countries of Asia including CIS nations and bilateral/multilateral meetings.

#### PHASE I

- Organisation of working group meeting (preferably in India) of participating Asian nations : Meeting of about 30 representatives of Asian and CIS nations for 2 weeks: US\$ 90,000
- Study and collection of samples, data/information on bauxite exploration, mining and alumina production facilities in the selected Asian and CIS countries of the region by JNARDDC: 2 scientists for 10 weeks each : US\$ 20,000
- Placing of 2 international experts for 4 weeks each : US\$20,000

Total UNDP input for Phase I work is estimated to be US\$ 130,000

#### PHASE II

- Organisation of bilateral and multilateral meetings/visits involving 20 persons of technical and economical streams of interested Asian and CIS countries for 2 weeks : US\$ 60,000
- In-depth study of recommended bauxite deposits/mines, collection of technological samples and alumina plant parameters in selected Asian and CIS countries by JNARDDC : 2 scientists for 10 weeks each : US\$ 20,000

- Placing of 4 international experts for 12 weeks each for guiding specific laboratory / pilot plant test works and suggesting technological modifications in the process and preparation of feasibility report: US\$ 60,000

Total UNDP input for Phase II work is estimated to be US\$ 140,000

#### **VII. LOCAL COSTS AND SOURCES OF FINANCE**

Indian local input can be financed by Government of India through Jawaharlal Nehru Aluminium Research Development & Design Centre (JNARDDC), Nagpur. However, UNDP have to place experts and provide funds for organisation of working group meetings and study of deposits, mines and industries.

#### **VIII. INDICATION OF PRIORITY ASSIGNED**

The results and recommendations of the proposed report would be of immense help in developing bauxite-alumina and aluminium industry in the Asian region and CIS countries. The exploitation of fairly high grade bauxite deposits concentrated in the Eastern Ghats of India (proved reserves more than 2000 million tonnes) may boost the alumina production in the region and can play vital role in economic tie-ups of Asian and CIS countries.

**Jawaharlal Nehru Aluminium Research  
Development and Design Centre, Nagpur**

Date : January 3, 1994

**Sample required for conducting digestion and precipitation  
simulation studies**

Company : HINDALCO, BALCO & NALCO

- 1) Digestion lab simulation tests :
  - a) Process Bauxite or any other bauxite in which respective company is interested to get investigated laboratory tests or both 20 kg each
  - b) Evaporated liquor/test tank liquor digestion liquor/ green liquor 100 litre
  - c) Burnt lime 5 kg.
- 2) Precipitation simulation test :
  - a) Product hydrate 20 kg.
  - b) Seed hydrate
    - i) Fine seed washed
    - ii) Fine seed unwashed 10 kg each 10 kg each.
    - iii) Coarse seed
  - c) CGM 500 ml.
- 3) Red mud settling
 

Natural flocculant	1 kg.
Synthetic flocculant	200 g.
- 4) Special chemicals from NALCO, ALLIED COLLOIDS, CYANAMID  
Samples from all products used or potentially usable in alumina refinery such as :
  - i) Synthetic flocculants for settler & washers
  - ii) CGM
  - iii) Dewatering aid for hydrate filtration
  - iv) Fluidizer for red mud transportation, pumping for dry stacking
  - v) Anti foam
  - vi) Organic (humate) removal
  - vii) Hydrate flocculant