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RESTRICTED

24 September 1993.
ORIGINAL: ENGLISH

WORKSHOP ON COMPUTER-BASED MATHEMATICAL MODELLING OF ALUMINIUM PRODUCTION PROCESSES

DP/IND/88/015/11-60 TO 11-64.

INDIA

Technical report: mission to the JNARDDC (Jawaharlal Nehru Aluminium Research, Development and Design Centre

Prepared for the Government of India by the United Nations Industrial Development Organization, acting as executing agency for the United Nations Development Programme

Based on the work of
A. Charette, S. Peter, V. Potocnik and L. Tikasz.

Substantive officer: Dr. T. Grof.
Metallurgical Industries Branch

United Nations Industrial Development Organization
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DEFINITION OF ACRONYMS

GRIPS	:	Groupe de Recherche en Ingenierie des Procedes et Systemes
UQAC	:	Universite du Quebec a Chicoutimi
JNARDDC	:	Jawaharlal Nehru Aluminium Research Development and Design Centre

ABSTRACT

WORKSHOP ON COMPUTER-BASED MATHEMATICAL MODELLING OF ALUMINIUM PRODUCTION PROCESSES

Posts: DP/IND/88/015/11-60 to 11-64 /J13207

Global Objective:
The immediate objective of the workshop was to assist the Government of India in setting up a functioning Aluminium Research, Development and Design Centre.

Specific Objectives:
- to present the state-of-the-art in the field of mathematical modelling as applied to the aluminium industry,
- to indicate ways as to apply these techniques to the aluminium industry in India.

Duration:
August 23 - September 24, 1993. This includes:
August 23 - September 13 : preparation for the workshop
September 14-18 : workshop
September 20-24 : discussion with JNARDDC personnel and report.

Conclusions and recommendations:
A review is given of the presentations of the four lecturers. The subjects debated at the workshop included mathematical modelling of casting and anode baking furnaces, modelling and simulation of aluminium electrolytic cells and general principles of radiation and magnetohydrodynamics. In view of the possibilities offered by the work presented and considering the present status of the aluminium industry in India with respect to mathematical modelling, it was concluded that serious efforts in this area would be very beneficial. It is recommended that the Centre should concentrate first on simple models that could help the plants in short term. Moreover, efforts should not be made for the moment on developing the software; a more effective way would be to purchase some ready-made specific purpose codes available. These are listed in the Recommendations. JNARDDC should seek collaboration with academic institutions in the framework of joint University/Industry programs. In medium term, some basic thermal and stress analysis package should be bought. In the long term, an extrapolation of the needs leads to the conclusion that a more sophisticated fluid dynamics software package will be necessary; it is indeed expected that design and development problems will be addressed at that time.

CONTENT

INTRODUCTION

This report was prepared jointly by the four experts who conducted the Workshop on Computer-Based Mathematical Modelling of Aluminium Production Processes: A. Charette, S. Peter, V. Potocnik, L. Tikasz (positions DP/IND/88/015/11-60 to 11-63). This workshop was held in Nagpur, India and was hosted by the Jawaharlal Nehru Aluminium Research Development and Design Centre (JNARDDC). The workshop itself lasted five days (14-18 September 1993; see Appendices V. and VI.) and was followed by discussions with the JNARDDC and the writing of the report (20-24 September 1993). Prior to the workshop, the experts devoted three weeks for the preparation of the written and visual material. The written material was distributed to every participant.

An evaluation of the workshop was made with the participants at the end of the workshop. They seemed to be very satisfied and indeed they participated very actively during the technical sessions.

The original and global objective of the project was to assist the Government of India in setting up a functioning centre. This activity was part of several others that were initiated by the JNARDDC in order to promote the Centre.

The specific objectives of the workshop were:
- to present the state-of-the-art in the field of mathematical modelling as applied to the primary aluminium industry,
- to indicate ways how to apply these techniques to the aluminium industry in India.

All these objectives were met. No modification was made to the original program.

The workshop was attended by 41 participants of which 14 were from industry and the rest from various research and academic institutions (see Appendix III). Their technical level was very high and they were able to follow the course closely. The workshop was very well organised by JNARDDC.

The second week of the assignment (20-24 September), was devoted to discussions with senior staff of the JNARDDC (Appendix II) in connection with the initiation of mathematical modelling activities at the Centre. A consensus was reached and the details are given in the Recommendations section. We were also shown the present research facilities and equipment as well as the new research centre, still under construction.

I. INDIVIDUAL ACTIVITIES

A. Modelling of casting furnaces

This part of the workshop was fulfilled by the team leader Andre Charette according to the UNIDO Job Description DP/IND/88/015/11-63, Appendix I.

Four ninety-minute presentations were made on September 17 relative to the themes of radiative heat transfer and mathematical modelling of the casting furnaces. The emphasis was put on the physical interpretation of the otherwise complicated mathematical formulation. Examples of applications to the industrial furnaces were given. Numerous questions arose from the audience during the presentations, the greatest interest being shown for the methods used in radiative heat transfer and in the one-dimensional model of the melting/holding furnace. The latter model is meant to be used for the analysis of the operation of the existing furnaces and has been proved successful in improving industrial furnace performance.

The next day (September 18), a presentation was given on the research activities of GRIPS at UQAC. This included a description of the mathematical model of the calcining kiln and an overview of the experimental facilities available (experimental furnace, infrared camera, laser Doppler anemometer, etc.). This was followed by a rapid presentation on the aluminium industry of Canada.

B. Mathematical modelling of anode baking furnaces

This part of the workshop was fulfilled by the team member Selvin Peter according to the UNIDO Job Description DP/IND/88/015/11-62, Appendix I.

Four ninety-minute presentations were given on the mathematical modelling of anode baking furnaces. Two different models of the vertical baking furnace were introduced in detail:
- two-dimensional model (2D+), which addresses the whole furnace operation, and
- three-dimensional model (3D), which focuses on one particular section of the furnace.

The two dimensional model which analyses the horizontal anode baking furnace operation was passed in quick review. This model would be particularly useful for the Indian aluminium industry that has this kind of furnaces only (at NALCO and HINDALCO). Indeed, the questions of the participants concerned with this aspect and private conversations of the workshop staff members with the participants from one of the plants showed that they would be interested in using such a model for the improvement of the furnace performance, productivity and safety.

The capabilities of the models were demonstrated by presenting the model results and the plant measurements. In addition, two cases were simulated to show one of the many capabilities of the 2D+ model. The results were analyzed in detail. Other capabilities of the model were examined and our experience with the model and its applications to industrial practice were discussed.

Comments were made on similarities and differences between horizontal ring furnaces and the Riedhammer vertical furnace. It was emphasized that the basic principles involved in both furnaces were the same.

C. Mathematical modelling methodology
Overview of primary aluminium production processes
Three-dimensional thermo-electric modelling of the cell
Magnetohydrodynamics

This part of the workshop was fulfilled by the team member Vinko Potocnik according to the UNIDO Job Description DP/IND/88/015/11-61, Appendix I.

At the beginning of the workshop on September 14, a one-hour overview of the aluminium production processes and mathematical modelling methodology was given. In the process overview, areas in which mathematical modelling is being done were brought to light and some examples from the alumina production process, not covered in the workshop, were also shown.

In the methodology session, emphasis was given on the importance of process knowledge and of plant experience in support of modelling. Indeed, nowadays industrial applications of mathematical modelling most often use commercial, ready-made software packages in order to allow the user to concentrate on the process rather than on software development.

On September 15, a one-hour presentation entitled "Three Dimensional Analysis of Thermo-Electric and Mechanical Behavior of Aluminium Reduction Cells" was given. Applications made at Alcan Aluminium Limited in the analysis, design and start-up of the reduction cells were shown and discussed.

On the same day, a four-hour presentation on magneto-hydrodynamics(MHD) of aluminium electrolysis cells was given. The aim was to give a good understanding of the MHD phenomena, rather than elaborate on mathematical details. Examples of practical applications and plant measurements were illustrated. It was explained how the cell operation can affect the MHD and thus decrease the cell performance. A videotape animation of the calculated metal-bath interface waves was shown and was much appreciated by the attendees.

In private conversations, some participants from industry indicated that they were interested in looking into the busbar design of their potlines. They, however, did not indicate in what way they wanted to address this issue. It is believed that they would need some sort of mathematical model with the minimum capability of electrical current calculations in the busbars to analyze the situation.

D. Simulation of an aluminium electrolytic cell

This part of the workshop was fulfilled by the team member Laszlo Tikasz according to the UNIDO Job Description DP-IND-88-015-11-60, Appendix I.

A six-hour presentation including live computer demonstration was given on September 14 and 15.

The topics discussed were arranged in the following order:
- Basic mass and energy balance calculations,
- Approximating selected operation modes,
- Developing a control emulator,
- How to use the dynamic cell model.

Theoretical approach, steps of model construction and of model adaptation were introduced and explained in detail. The capabilities of the model were demonstrated on examples chosen from plant practice. In addition, live computer demonstration completed the presentation, simulating typical operation modes of the cell. The participants had access to the simulator to familiarize themselves with this kind of research or training tools.

During the workshop, an educational version of the Dynamic Cell Simulator was transferred to JNARDDC for fur[illegible]ing and educational purposes. The software package was accompanied by thr[illegible]: User Guide, Setup Guide and Tutorial. However, it should be emphasized that an extended version of the cell simulator would be needed for serious plant applications. This extended software package is recommended for purchase by the JNARDDC (see Recommendations).

Open discussions were arranged in the evenings and on the last day. Further operation examples were given based on individual demand. Some additional software demonstration was done for specific requested areas (data acquisition devices and softwares, steady-state simulation tools, discrete event simulation package, etc.).

II. CONCLUSIONS

Our contacts with the participants, a review of some written information and conversations with JNARDDC personnel lead us to the following conclusions:

1. Primary aluminium plants in India, more specifically in the area of reduction and casting, do not perform at the best of their specific technology. Particular concerns are related to poor energy efficiency and productivity. However, a considerable effort and determination are present to improve the situation. A core of highly skilled personnel is present in most plants, but it is not sufficiently strong to solve the existing problems. The JNARDDC may be able to fill in the gaps. A combination of experimental and modelling approach will be necessary to solve the plant problems.

As it stands now, poor performance of the smelters is acknowledged only by some plants, mostly by BALCO, partly by NALCO (anode baking, current efficiency) and INDAL (energy consumption) and hardly by HINDALCO (they think they are doing fine).

JNARDDC is well suited to help the plants, analyse the situation and recognize their problems.

2. A significant part of cell operation problems arise from improper organization of manpower and machinery. Thorough analysis of potroom activities are needed to determine the resource allocation bottlenecks. JNARDDC may be a partner in such analysis probably jointly with an academic institution. Discrete event simulation approach applied to plant operation is a proven way to increase plant productivity. A typical commercial software package that is suited for such an analysis is SIMAN from Systems Modelling Corporation (USA).

3. Mathematical modelling applications in the reduction/casting area have been virtually absent from Indian aluminium industry and to a very large extent from academic institutions and research centres. The workshop succeeded in giving a clear awareness to the participants of what can be done in this area to solve their problems. However, the development teams in industrial organizations are not strong enough to undertake sufficient mathematical modelling activities individually except on smaller problems. A concrete effort between industry, R&D centres and academic institutions, including government support, is needed.

4. In short term, simple models that address the process or process equipment operation are the most appropriate starting points in Indian aluminium industry. These models will assist solving the problems of immediate concern in relation to the plant performance.

5. The contacts between industry and universities have been very scarce, but have a lot of potential for improvement.

6. The growth towards the application and development of more sophisticated three-dimensional mathematical models can be a fertile ground for university - research centre - industry cooperation and can be adopted as a long term goal.

7. We examined the computer equipment that has been installed or is on order at JNARDDC. In our opinion, this equipment is adequate for short-term mathematical modelling activities at the Centre. Some basic supporting software has been installed, but additional software has to be purchased, particularly for the PC-based environment (see the list in Appendix IV).

8. All aluminium smelters in India use purchased electrolysis cell technology with very different cell designs, electrical busbar arrangements, control systems and cell operation practice. This will require specific model adaptation to each individual technology, accompanied by experimental evaluation in each individual plant.

9. We were shown the experimental equipment for the analysis of electrolysis cell operating conditions. We believe that the equipment and the data analysis software accompanying it are sufficient at least in short term, but the software should be updated regularly.

10. The staff that will take care of the mathematical modelling at the centre (2 persons for electrolysis, 2 for alumina) appears to be sufficient at the beginning for the implementation of the purchased codes. However, the work load depends on the request from the plants. These four people should be headed by a senior person, experienced in mathematical modelling.

11. Cell magnetohydrodynamics (MHD) can be improved by acting on the busbar arrangement and by a good control of the cell. The former is locked into the original design and can be changed to a limited extent (but sometimes quite beneficial!) by busbar retrofitting. Whether this is worth to be done or not depends on economics and on projected gains. Busbar retrofitting is a one time undertaking. The study related to cell control indicates how to avoid trouble related to poor freeze profile, sludge, anode changing, etc. This again is a one time study for a given technology.

12. Mathematical modelling combined with plant experiments is preferable to the physical modelling of the electrolysis process. The former is well suited for plant analysis, the latter would at best give some rather fundamental results.

13. Coke calcination in India is not done within the aluminium plants, even though the quality of the product (calcined coke) has a large bearing on the anode quality and performance. It would be quite natural that the coke calcination be part of JNARDDC activity.

RECOMMENDATIONS

Short term (1-2 years)

1. JNARDDC should help the plants to analyse their performance and to recognize in which areas they have problems. This includes coke calcination plants. It should then engage in assisting the plants to solve these problems.

2. JNARDDC should not engage in the development of mathematical modelling software, but should rather purchase a basic set of mathematical models that would address immediate problems and concerns in Indian primary aluminium production plants. The Centre should then use these models to assist the plants in solving their problems according to the priorities established with industrial partners. This, of course, would be accompanied by plant measurements carried out with the Research Centre equipment. This approach will assure the right direction and save many years of development, which would be otherwise required before JNARDDC would be able to serve industry effectively.

3. The models that would be most useful to start with are:
a) Electrolysis cell simulator,
b) Two-dimensional model of the horizontal anode baking furnace,
c) One-dimensional model of the melting/casting furnace,
d) One-dimensional model of the coke calcining kiln.

All these models are specifically designed to address plant operation and to analyze relationships between the process parameters. These models were presented at the workshop in a greater or smaller detail, and a lot of interest was shown for them by the attendees from the plants. The conditions of the acquisition of these models by JNARDDC will be specified in the near future. Contacts with the owners of the models - Alcan International Limited and UQAC - have already been made. The transfer of these models to JNARDDC should include at least three-month user training per model. This would assure appropriate transfer of modelling know-how from model designers to model users. The model users should also spend at least one month/model in an operating plant, in order to get familiar with the practical aspects of the process.

4. The computer working environment should be enhanced by additional commercial software packages which will allow the usage of the cell simulator. A list of these is given in Appendix IV.

5. A magnetohydrodynamics (MHD) study or busbar retrofitting is a one time undertaking for a given technology. If such a study is requested by a plant, it is probably more economical to ask for it as a service from a company that has MHD

models, rather than to purchase the MHD programs. This is so even for mid and long term. However, a basic resistance network computer program would be required for answering some questions about cell busbars that have already been asked by the plants. This program should be purchased in short term or built by JNARDDC.

6. Attempts should be made to create partnerships industry / R&D centres / academic institutions. One sided effort may not succeed. A significant amount of goverment support may be necessary at this stage.

7. A similar workshop in mathematical modelling for alumina production should be organized by JNARDDC as soon as possible, since the situation in those plants seems to be similar to what we have found out about the electrolysis plants.

Mid term (3-5 years)

1. The basic models acquired in the short-term could be improved and extended in the mid-term as industrial needs require. New projects in this area could also be started This could be very well done by the cooperation between JNARDDC, universities and industry. Government sponsorship of such programs has proven to be very stimulating for all partners involved. We can give the example of Canada, and specifically the programs that led to the creation of the models quoted under the heading "Short term" above. Some sophisticated three-dimensional models presented in the workshop were also developed in such collaborative projects. These mathematical models were built in partnership between Alcan Aluminium Limited, UQAC and NSERC (Natural Sciences and Engineering Research Council of Canada).

2. A basic three-dimensional finite element software package for thermal and stress analysis would be useful (e.g. ANSYS, NASTRAN, etc.). The need for such a package would again be driven by industrial requirements, e.g. for the analysis and design of the cathodes of aluminium reduction cells. The development of specific applications could be done in cooperation with academic institutions.

3. It may be desirable to transfer some models directly to the plants after they will have been set up and tested by JNARDDC for the specific plants. This will depend on the objectives of their usage selected by JNARDDC and the plants. The two models, identified as [illegible]a and [illegible]c under "Short term" above, seem to be the most susceptible for this transfer.

Long term (5-10 years)

In this period, JNARDDC should be able to work on more complex models which include three-dimensional heat and mass transfer in fluids and solids. These are applicable to high-temperature furnaces such as remelt/casting furnaces, calcining kilns and carbon baking furnaces. At this stage, a general-purpose fluid dynamics software package (e.g. PHOENICS, FLOW-3D, FLUENT etc.). should be acquired for the analysis and design purposes. Specific applications could be again developed in cooperation with academic institutions and industry.

APPENDICES

I. Job descriptions

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

JOB DESCRIPTION*)

DP/IND/88/015/11-60

Post Title: Expert in Aluminium Electrolysis Process

Duration: 2 weeks homebase, 2 weeks on site including travel

Date required: September/October 1993

Duty Station: Homebase and travel to Nagpur, India

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 co-operation 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

Five experts (Position 11-60 to 11-64) are required by the Jawaharlal Nehru Aluminium Research Development and Design Centre Nagpur for organising a Workshop on Mathematical Modelling of Aluminium Electrolysis Cells and Processes. The Workshop is

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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

expected to be held in Nagpur in September 1993 (preferably during the period Sept. 20-24). Four of these experts (11-60 to 11-63) would actually visit Nagpur while the fifth one (11-64) is expected to finalise the details with UNIDO Vienna and take care of organisational work preceding the Workshop.

The experts are required for conducting a five day workshop in Nagpur India for participants from the aluminium industries, universities and R & D institutions. The following features form the common requirements for all the positions:

- present theoretical developments involved, and the methodology applied in the construction of the models for the processes;

- present mathematical, algorithmic and numerical developments involved and the methodology applied in the construction of the models for the processes;

- demonstrate the capabilities of the models on the [illegible] or more typical industrial units. [illegible] the study of operational or design

- present the various possibilities for adaptation (tuning) of the models to specific applications or units;

- prepare written notes for circulation to the participants in the Workshop (this may form a part of the pre-workshop activity to be carried out in the home country of the experts).

The Workshop is expected to be of one week duration. A set of 10 lectures, each of 90 minutes duration are to be presented in the mornings covering the four major areas and the afternoons could be devoted to practical sessions/discussions. In addition the experts are requested to spend two or three more days for intensive discussion with the industrial participants and the scientists from the laboratories and academic institutions for the formulation of a programme for initiation of work on mathematical modelling of interest to the Indian aluminium industries.

Duties: / Details of topics to be covered are:

- indication of alumina balance and cell voltage alteration for the examined period of time;
- approximation of the process by sample calculations for cell voltage components, alumina balance, thermal balance and current efficiency;
- fundamentals of programme for process development for checking the results in work routine, evaluating the planned algorithm;
- construction of 3-D design models

Qualifications:

University degree (preferably Ph.D.) in Metallurgical or Chemical Engineering with extensive experience in the field of aluminium production.

Language requirements:

English

Background information:

The India. [illegible] industry looks back to a history of 4- [illegible] the first aluminium smelter (in Alumpars, [illegible] put into operation in 1943. At present there are five alumina plants in operation and six aluminium smelters with an overall capacity of 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.

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.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

JOB DESCRIPTION*)

DP/IND/88/015/11-63

Post Title: Expert in Modelling of Casting Furnace

Duration: One month

Date required: September/October 1993

Duty Station: Homebase and travel to Nagpur, India

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
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c) Analytical Research Department
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e) General Administration and Finance Department

The Centre will develop capability of carrying out the following main functions on behalf of and in co-operation 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.
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expected to be held in Nagpur in September 1993 (preferably during the period Sept. 20-24). Four of these experts (11-60 to 11-63) would actually visit Nagpur while the fifth one (11-64) is expected to finalise the details with UNIDO Vienna and take care of organisational work preceding the Workshop.

The experts are required for conducting a five day workshop in Nagpur India for participants from the aluminium industries, universities and R & D institutions. The following features form the common requirements for all the positions:

- present theoretical developments involved, and the methodology applied in the construction of the models for the processes;

- present mathematical, algorithmic and numerical developments involved and the methodology applied in the construction of the models for the processes;

- demonstrate the capabilities of the models on the basis of one or more typical industrial units. [illegible]e are for the study of operational or design [illegible]

- pres[illegible] [illegible]e various possibilities for adaptation (tuning) of the models to specific applications or units;

- prepare written notes for circulation to the participants in the Workshop (this may form a part of the pre-workshop activity to be carried out in the home country of the experts).

The Workshop is expected to be of one week duration. A set of 10 lectures, each of 90 minutes duration are to be presented in the mornings covering the four major areas and the afternoons could be devoted to practical sessions/discussions. In addition the experts are requested to spend two or three more days for intensive discussion with the industrial participants and the scientists from the laboratories and academic institutions for the formulation of a programme for initiation of work on mathematical modelling of interest to the Indian aluminium industries.

Duties: Demonstration of the capabilities of the model by presenting and analysing the results obtained from the simulation of a typical rectangular shaped tilting furnace and offer comments on similarities and differences between the furnaces available in Indian companies and those modelled by the expert.

Qualifications:

University degree (preferably Ph.D.) in Metallurgical or Chemical Engineering with extensive experience in the field of aluminium productions.

Language requirements:

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 in operation and six aluminium smelters with an overall capacity of 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$ [illegible] 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.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

JOB DESCRIPTION*)

DP/IND/88/015/11-62

Post Title: Expert in Modelling of Anode Baking Furnace

Duration: One month

Date required: September/October 1993

Duty Station: Homebase and travel to Nagpur, India

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 co-operation 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

Five experts (Position 11-60 to 11-64) are required by the Jawaharlal Nehru Aluminium Research Development and Design Centre Nagpur for organising a Workshop on Mathematical Modelling of Aluminium Electrolysis Cells and Processes. The Workshop is

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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

expected to be held in Nagpur in September 1993 (preferably during the period Sept. 20-24). Four of these experts (11-60 to 11-63) would actually visit Nagpur while the fifth one (11-64) is expected to finalise the details with UNIDO Vienna and take care of organisational work preceding the Workshop.

The experts are required for conducting a five day workshop in Nagpur India for participants from the aluminium industries, universities and R & D institutions. The following features form the common requirements for all the positions:

- present theoretical developments involved, and the methodology applied in the construction of the models for the processes;

- present mathematical, algorithmic and numerical developments involved and the methodology applied in the construction of the models for the processes;

- demonstrate the capabilities of the models on the basis of one or more typical industrial units. These are for the study of operational or design problems;

- present the various possibilities for adaptation (tuning) of the models to specific applications or units;

- prepare written notes for circulation to the participants in the Workshop (this may form a part of the pre-workshop activity to be carried out in the home country of the experts).

The Workshop is expected to be of one week duration. A set of 10 lectures, each of 90 minutes duration are to be presented in the mornings covering the four major areas and the afternoons could be devoted to practical sessions/discussions. In addition the experts are requested to spend two or three more days for intensive discussion with the industrial participants and the scientists from the laboratories and academic institutions for the formulation of a programme for initiation of work on mathematical modelling of interest to the Indian aluminium industries.

Duties:

The expert is expected to demonstrate the capability of the model by presenting and analysing the results of various simulations made on a typical RIEDHAMMER furnace and also offer comments on similarities and differences between furnaces available in the Indian companies and those on which models have been developed by the expert.

Qualifications:

University degree (preferably Ph.D.) in Metallurgical or Chemical Engineering with extensive experience in the field of aluminium production.

Language requirements:

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 in operation and six aluminium smelters with an overall capacity of about 537,000 and 380,000 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;

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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.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

JOB DESCRIPTION*)

DP/IND/88/015/11-61

Post Title: Expert in Modelling of Aluminium Electrolysis Cell Construction

Duration: One month

Date required: September 1993

Duty Station: Homebase and travel to Nagpur, India

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

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Electrolysis Cells and Processes. The Workshop is expected to be held in Nagpur in September 1993 (preferably during the period Sept. 20-24). Four of these experts (11-60 to 11-63) would actually visit Nagpur while the fifth one (11-64) is expected to finalise the details with UNIDO Vienna and take care of organisational work preceding the Workshop.

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- prepare written notes for circulation to the participants in the Workshop (this may form a part of the pre-workshop activity to be carried out in the home country of the experts).

The Workshop is expected to be of one week duration. A set of 10 lectures, each of 90 minutes duration are to be presented in the mornings covering the four major areas and the afternoons could be devoted to practical sessions/discussions. In addition the experts are requested to spend two or three more days for intensive discussion with the industrial participants and the scientists from the laboratories and academic institutions for the formulation of a programme for initiation of work on mathematical modelling of interest to the Indian aluminium industries.

Duties:

- evaluation of magnetic field components, determination of metal and bath velocities, distortion of metal surface, demonstration of potential distribution; examples of practical model applications to different cells designs and technologies operating with different electric currents should be given. The expert is expected to offer quantitative comments about the MHD of Indian smelters.

Qualifications:

University degree (preferably Ph.D.) in Metallurgical or Chemical Engineering with extensive experience in the field of aluminium production.

Language requirements:

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 in operation and six aluminium smelters with an overall capacity of 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).

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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.

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

II. Senior counterpart staff

Dr. T. R. Ramachandran	Director, JNARDDC
Dr. J. Zambo	Chief Technical Adviser UNIDO/UNDP JNARDDC
N. G. Sharma	Deputy Director, JNARDDC
P. Vidyasagar	Deputy Director, JNARDDC

III.. List of participants

WORKSHOP ON COMPUTER BASED MATHEMATICAL MODELLING OF ALUMINIUM PRODUCTION PROCESSES

14-18 SEPTEMBER 1993 NAGPUR

LIST OF PARTICIPANTS

1.	Prof. S.P. MEHROTRA	IIT KANPUR
2.	Prof. A.K. LAHIRI	IISC BANGALORE
3.	Mr. E. SRIDHAR	IISC BANGALORE
4.	Mr. C.P.S. SODHI	BALCO KORBA
5.	Mr.B.R. JAIN	BALCO KORBA
6.	Mr. R.N. JENA	NALCO, ANGUL
7.	Mr. M.K.B. NAIR	NALCO, ANGUL
8.	Mr. S.N. SINGH	NALCO, ANGUL
9.	Mr. N.K. PAUL	NALCO, ANGUL
10.	Mr. P.K. NATH	NALCO, ANGUL
11.	Dr. J. SINGH	HINDALCO, RENUKOOT
12.	Mr. N. MISHRA	HINDALCO, RENUKOOT
13.	Mr.S. MUKHERJEE	HINDALCO, RENUKOOT
14.	Mr. S. SAXENA	HINDALCO, RENUKOOT
15.	Mr. H. BHATIA	HINDALCO, RENUKOOT
16.	Mr. A. KOSHY	INDAL, ALUPURAM
17.	Mr. A. PATI	INDAL, HIRAKUD
18.	Dr. U. SEN	CECRI, KARAIKUDI
19.	Mr. S. DEVASAHAYAM	CECRI, KARAIKUDI
20.	Dr. V. ANANTH	CECRI, KARAIKUDI
21.	Dr. K.M. GODIWALLA	NML, JAMSHEDPUR
22.	Mr. S.K. DAS	NML, JAMSHEDPUR
23.	Dr. S.K. BANERJEE	MECON, RANCHI
24.	Mr. [illegible] MISHRA	MECON, RANCHI

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25.	Dr. T.R. RAMACHANDRAN	JNARDDC, NAGPUR
26.	Dr.J. ZAMBO	JNARDDC, NAGPUR
27.	Mr.N. G. SHARMA	JNARDDC, NAGPUR
28.	Mr. P. VIDYASAGAR	JNARDDC, NAGPUR
29.	Mr. G.S. SENGAR	JNARDDC, NAGPUR
30.	Mr. S. DASGUPTA	JNARDDC, NAGPUR
31.	Mr. U.B. AGRAWAL	JNARDDC, NAGPUR
32.	Mr. A.K. BASU	JNARDDC, NAGPUR
33.	Mr. K.G. DESHPANDE	JNARDDC, NAGPUR
34.	Mr. A. AGNIHOTRI	JNARDDC, NAGPUR
35.	Mr. R.J. SHARMA	JNARDDC, NAGPUR
36.	Mr. P. DUNGORE	JNARDDC, NAGPUR
37.	Mr. D. RAMAKRISHNA	JNARDDC, NAGPUR
38.	Dr. R. SHEKHAR	IIT, KANPUR
39.	Mr. V. ASOKKUMAR	V.R.C.E. NAGPUR
40.	Mr.S.U. PATHAK	V.R.C.E. NAGPUR
41.	Mr. D.V. MOGHE	V.R.C.E. NAGPUR

WORKSHOP ON COMPUTER BASED MATHEMATICAL MODELLING OF ALUMINIUM PRODUCTION PROCESSES

14-18 SEPTEMBER, 1993

ADDRESSES OF COMPANIES/INSTITUTIONS PARTICIPATED

Sl. No.	Name of the Organization	Address
1.	Indian Institute of Technology (IIT, Kanpur)	P.O. KANPUR-208 016 (U.P.)
2.	Indian Institute of Science (IISC, Bangalore)	BANGALORE-560 012
3.	Bharat Aluminium Co. Ltd. (BALCO, Korba)	P.O. BALCO Township KORBA-495 684 Dist. Bilaspur (M.P.)
4.	National Aluminium Co. Ltd. (NA[illegible] Angul)	NALCO Nagar ANGUL-759 145 (Orissa)
5.	[illegible] um Co[illegible] (HINDALCO, Renukoot)	P.O. RENUKOOT-231 217 Dist. Sonebhadra (U.P.)
6.	Indian Aluminium Co. Ltd. (INDAL, Kalamassery)	ALUPURAM, Post Box 30 KALAMASSERY-683 104 (Kerala)
7.	Indian Aluminium Co. Ltd. (INDAL, Hirakud)	HIRAKUD (Orissa)
8.	Central Electro-Chemical Research Institute (CECRI, Karaikudi)	KARAIKUDI-623 006 (Tamil Nadu)
9.	National Metallurgical Laboratory (NML, Jamshedpur)	JAMSHEDPUR-831 007 (Bihar)
10.	Metallurgical & Engineering Consultants (I) Limited (MECON, Ranchi)	Doranda RANCHI-834 002 (Bihar)
11.	Jawaharlal Nehru Aluminium Research Development and Design Centre (JNARDDC, Nagpur)	Mohta Apartments Katol Road, Chhaoni NAGPUR-440 013
12.	Vishveswaraya Regional College of Engineering (VRCE, Nagpur)	VRCE Campus, NAGPUR

IV. List of additional softwares needed

The proposed Dynamic Cell Simulator of Aluminium Electrolytic Cells can be implemented on both workstations and PC-class computers. These computers provide rather different working environments for the users. In order to provide easy transfer of source code files between these different hardware platforms, a professional program developing environment has to be established on the PC-s.

The following commercial software products are proposed to support the cell simulation project.

f

For a selected workstation:
* F77 Fortran compiler (usually provided by the
 ·upplier)
* HOOPS graphic library ·ftware)

For PC-class computers:
* DOS extender (from Phar Lap Software Inc.)
* NDP Fortran compiler (from Microway Inc.)
* HOOPS graphic library (From Ithaca Software)

Note: A general-purpose mathematical library is needed for both platforms. The NMAS library package which accompanies the book Numerical Methods and Softwares by D. Kahaner et. al. from Prentice Hall, 1989 can be mentioned as an example.

V. Course content

JAWAHARLAL NEHRU ALUMINIUM RESEARCH DEVELOPMENT AND DESIGN CENTRE NAGPUR

WORKSHOP ON COMPUTER - BASED MATHEMATICAL MODELLING OF ALUMINIUM PRODUCTION PROCESSES

FACULTY

ANDRE CHARETTE*
SELVIN PETER*
VINKO POTOCNIK**
LASZLO TIKASZ*
* UNIVERSITE DU QUEBEC CHICOUTIMI QUEBEC CANADA
** ALCAN INTERNATIONAL LIMITED JONQUIERE QUEBEC CANADA

SEPTEMBER 14 - 18, 1993

WORKSHOP SCHEDULE

Nagpur, India

September 14-18, 1993

DATE	TIME	TOPIC	LECTURER
14/09/93	9:00 - 9:30	Welcome and introduction.	JNARDDC Director
		Organization of Workshop.	UNIDO team Leader
	9:30 - 10:00	Mathematical modelling methodology.	V. Potočnik
	10:00 - 10:30	Process overview.	V. Potočnik
	10:30 - 11:00	Simulation of an Aluminium electrolytic cell: basic mass and energy balance calculations.	L. Tikasz
	11:00 - 11:30	Break	
	11:30 - 13:00	Basic mass and energy balance calculations: approximating selected operation modes.	L. Tikasz
	13:00 - 14:30	Lunch	
	14:30 - 16:00	Developing a control emulator. Using the dynamic cell model; examples.	L. Tikasz
	16:00 - 16:30	Break	
	16:30 - 18:00	Computer demonstration of the dynamic cell simulator and participants' contributions.	L. Tikasz

15/09/93	9.30 - 10.30	3D thermo-electric modelling of the electrolysis cell.	V.Potocnik
	10.30 - 11.00	Computer demonstration of the dynamic cell simulator	L.Tikasz
	11.00 - 11.30	Break	
	11.30 - 12.00	Modelling of potroom activities for cell operation	L.Tikasz
	12.00 - 13.00	Magnetohydrodynamics (MHD): introduction	V.Potocnik
	13.00 - 14.30	Lunch	
	14.30 - 16.00	Electric current calculations. Busbar design. Magnetic field calculations	V.Potocnik
	16.00 - 16.30	Break	
	16.30 - 18.00	Cell hydrodynamics	V.Potocnik
16/09/93	9.30 - 11.00	The anode-baking Riedhammer furnace: Design and operation. Motivation for modelling.	S.Peter
	11.00 - 11.30	Break	
	11.30 - 13.00	Development of the 2D+ model	S.Peter
	13.00 - 14.30	Lunch	

	14.30 - 16.00	Simulation results and capabilities of the 2D+ model.	S.Peter
	16.00 - 16.30	Break	
	16.00 - 18.00	Development of the 3D model. Simulation results and capabilities of the 3D model.	S.Peter
17/09/93	9.30 - 11.00	Description of some casting furnaces and overview of the ralated studies carried out at UQAC. Numerical methods in radiative heat transfer.	A.Charette
	11.00 - 11.30	Break	
	11.30 - 13.00	Numerical methods in readiative heat transfer (continued). Detail of the mathematical modelling of the casting furnaces : 1D analytical model	A.Charette
	- 14.30	Lunch	
	14.30 - 16.00	Details of the mathematical modelling (continued) (a) 1 D control model (b) fuel optimization calculations (c) 3D model	A.Charette

	16.00 - 16.30	Break	
	16.30 - 18.00	The remelting furnace	A.Charett
18/09/93	9.30 - 11.00	A general presentation on : (a) the various research projects undertaken by the faculty members in Canada, and (b) an overview of Canadian aluminium industry.	A.Charett
	11.00 - 11.30	Break	
	11.30 - 13.00	Further elaboration on aspects identified by participants during the week and/or free discussion	All staf partici-pants
	13.00 - 14.30	Lunch	
	14.30 - 16.00	Same topics, continued	All staff and parti cipants
	16.00 - 18.00	Conclusion - dismissal	JNARDDC Director, UNIDO tea leader

Note: Free discussions may be held in the evening in consultation with the participants. Decision can be made on the spot.

FACULTY LISTING

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Dr. Laszlo Tikasz obtained his masters (M.Sc.) degree in electrical engineering in 1978 and his doctorate degree (Dr. Techn.) in 1986, both from the Technical University of Budapest. From 1978 until 1980, he worked at East Hungarian Electricity Board as development engineer. From 1980 until 1989, he worked at Hungalu Engineering and Development Centre, Division of Aluminium Metallurgy in the area of process measurements and process control. In 1989, he joined the Université du Québec à Chicoutimi as invited research professor. There, he has worked in building a computer simulator of an aluminium electrolytic cell and in supervision of expert system applications. In 1984, he lectured as a member of UNIDO expert group at Zheng-Zhou Light Metals Research Institute in China.

André Charette

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Dr. André Charette obtained a diploma in chemical engineering at Laval University Québec, Canada in 1966 and a doctorate degree in high temperature chemical kinetics in 1972 from the same University. He joined the Université du Québec à Chicoutimi in 1970 where he is now in charge of the courses in thermodynamics and heat transfer as a full professor. His research activities include the computation of radiative heat transfer in industrial furnaces, general modelling of thermal processes and pyrolysis and calcination of carbonaceous products. he participated actively in numerous research projects conducted jointly with industry, namely Alcan, Comalco, ELF-Atochem. He authored or co-authored more than 60 technical papers, presentations and research reports and supervised 17 graduate students.

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Dr. Selvin Peter obtained a B.Sc.E. degree in Chemical Engineering in 1984 and a Ph.D. degree in heat transfer in 1992 at the University of New Brunswick, Fredericton, Canada. Working as a research engineer at the Université du Québec à Chicoutimi since 1989, he has been involved in the electrode baking furnace modelling for Alcan (Canada) and Comalco (Australia). He has been author or co-author of 15 research papers, conferences and industrial reports. He is an active member of the Combustion Institute of Canada and the Order of Engineers of Québec, Canada.

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Dr. Vinko Potočnik obtained a diploma in engineering physics at the University of Ljubljana in 1967, and a Ph.D. in plasma physics at the University of British Columbia, Vancouver, Canada in 1973. Since 1973, he has been working at Alcan International Arvida Research and Development Centre, Jonquiere, Canada. There, he is presently senior scientist and consultant. He has been working in the area of mathematical modelling, simulation, process control and expert systems. He also taught a graduate course (master's level) in mathematical modelling and simulation at the Université du Québec à Chicoutimi, Chicoutimi, Canada, for 6 years. He is also one of the lecturers at the bi-annual one-week Aluminium Electrolysis Course at Carnegie Mellon University, Pittsburgh, USA.

UNDER THE AUSPICES OF
THE UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

WORKSHOP ON COMPUTER-BASED MATHEMATICAL MODELLING OF ALUMINIUM PRODUCTION PROCESSES

Jawaharlal Nehru Aluminium Research
Development and Design Centre
Nagpur, India
September 1993

MATHEMATICAL MODELLING METHODOLOGY

OVERVIEW OF PRIMARY ALUMINIUM PRODUCTION PROCESSES

THREE-DIMENSIONAL THERMO-ELECTRIC MODELLING OF THE CELL

Vinko Potočnik

Alcan International Limited
Jonquiere, Quebec, Canada

1. Mathematical Modelling Methodology

Mathematical modelling has become one of the most important activities in process analysis and design. It consists of a number of staps that have to be combined in the most appropriate way for a given problem. Process understanding and plant measurements link it to reality. Building the equations, choosing the numerical algorythms and programming used to be the most intensive tasks in the past. The advent of good commercial software packages has shifted the emphasis to process related activities, to setting up the scenarios and to the analysis of the computer runs. Relationships among all these activities are the subject of the mathematical modelling methodology presented in this session.

2. Overview of the Primary Aluminium Production Processes

Primary aluminium production processes comprise alumina production, alumina reduction and casting.

Alumina is produced mostly from bauxite using the Bayer process. Some applications of the mathematical modelling in this area will be mentioned but not analysed in depth, since this part of the process is not a subject of the workshop.

Reduction process includes electrolysis and carbon electrode production. In electrolysis perhaps the most important subject is the thermal and electrical balance, which will be overviewed. Mass balance and process dynamics are closely related to cell operation and control. The electrode production process starts with coke calcination and ends with the cathode and anode baking. Both have been extensively studied by mathematical modelling, but only anode baking will be presented at the workshop.

Casting is preceeded by ingot or scrap remelting, impurity elimination and alloying. The remelting as well as casting itself have been the subject of mathematical model development and applications, but only remelting will be prosented at the workshop.

3. Three-Dimensional Thermo-Electric Modelling of the Cell

Complex material composition or complex boundary conditions require three-dimensional (3D) models whenever detailed distribution of the temperature or heat loss is required. This is certainly the case when the cathode or the anode is to be designed or redesigned.

In this lecture the issues in 3D modelling will be discussed. Examples of the simulations, obtained with a commercial finite-element software package will be given.

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SIMULATION OF AN ALUMINIUM ELECTROLYTIC CELL

Laszlo Tikasz

University of Quebec at Chicoutimi
Quebec, Canada

1. Basic Mass and Energy Balance Calculations

This part is intended to guide the reader through the construction of a simplified dynamic cell model of an aluminium electrolytic cell. The proposed Model itself is an integrated sofware package for simulating different operational states of aluminium electrolytic cells. The focus is on the theoretical aspects, whereas programming details as well as necessary preparatory steps (e.g. data acquisition problems are not coverd.

A theoretical approach is outlined showing how to derive basic equations to approximate the dynamic and static operation of a cell. The structure of the computation is demonstrated with special emphasis on the user-adjustable subroutines and functions. These user-adjustable parts can serve as starting points toward a more sophisticated description of the process.

The current state of an electrolytic cell is described by lumped parameters averaged over a selected part (lump) of the cell. For educational purposes, considerable simplifications are proposed regarding the granularity of the Model: the geometry is the simplest possible and the upper and lower side-carbon and freeze blocks are put into generalized side-wall and freeze blocks. The selected control volume contains only the bath, freeze and metal lumps, and the boundary conditions are approximated by generalized anode, cathode and side-wall lumps. The environment outside the cell model is represented by temperatures above, below and beside the cell. The material and energy balances are performed on all the selected lumps and during the simulation, the mass and temperature variations are calculated by solving the relevant ordinary differential equations.

Geometrical, chemical and electrical aspects of the aluminium electrolytic cell are considered. Alumina dissolution sub-model is introduced. Algebraic equations for steady-state simulation are also derived.

2. Approximating Selected Operation Modes

The adjustable model components can be used to approximate special operation modes, also. The most important components are:

- line current,
- current efficiency,
- mass densities,
- eutectic temperature,
- heat transfer coefficients,
- specific heat coefficients,
- equivalent thermal resistances,
- bath resistance and conductivity.

In this part, some examples are given showing how to select, tune, verify and validate equations or develop appropriate sub-models.

3. Developing a Control Emulator

In simulating the dynamic behavior of an electrolytic cell, it is a must to provide a unit which approximates the necessary maintenance routines. In real situations, the maintenance is provided partly manually and by and adequate process controller. Here we concentrate on the representation of the automatic control. The main points discussed are the following:

— selection of control variables,
— data exchange between Model and Control Emulator,
— developing a control date base,
— developing a simple alumina feeding routine,
— developing a simple resistance control routine.

4. Using the Dynamic Cell Model

An advanced Dynamic Cell Model is presented during the Workshop. The Dynamic Cell Model is a computer program, escorted by a
— User Guide and a
— Set-Up Guide

Based on these Guides, the general structure and the use of the Dynamic Cell Model are discussed. Examples are given where the Dynamic Cell Model is used to simulate different operating conditions.

5. Computer Demonstration

In this part, live computer demonstrations are provided on advanced PC-class computers. Both the basic mass and energy calculations and the Dynamic Cell Model will be presented.

With the basic equations, the particpants can carry out static and dynamic computations. This facility helps them understand the process fundamentals as well as the main relations and trends of the process.

Using the Dynamic Cell Model, they will acquire hands-on experience with a complete simulator.

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MAGNETOHYDRODYNAMICS (MHD)

Vinko Potočnik

Alcan International Limited
Jonquiere, Quebec, Canada

1. Introduction

Magnetohydrodynamics (MHD) is the study of fluid behaviour under the influence of the electromagnetic forces. This force is a vector product of the electric current density and the magnetic field, therefore, MHD modelling can be divided into: electric current, magnetic field and hydrodynamics calculations.

In this session, we will also explore the consequences of MHD on the cell performance.

2. Electric Current and Magnetic Field Calculations

The objective of the electric current calculations is to determine the current density in the liquid metal and electrolyte (bath). This current density is determined by the cell and busbar design, its thermal state, and its operation. The methods of calculation, software and the influence of the cell design and operation on the current density will be presented. It will be shown how a well balanced durrent distribution can be obtained.

The magnetic field is generated by the electric current distribution in the cell as well as by cell-to-cell busbar connections. Steel structural elements of the cell redistribute considerably the magnetic field due to currents. This greatly complicates the calculations. Calculation methods and applications to different cell designs will be discussed.

3. Hydrodynamics

Cell hydrodynamics is described by the Navrer-Stokes equation that includes the electromagnetic force. The solution of this equation gives the velocity patterns in the metal and in the bath and the metal-bath interface deformation. Steady state and dynamic models will be examined. Criteria for the MHD design will be discussed.

Applications to different cell designs will be shown, including a video presentation of the metal-bath interface waves.

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MODELLING OF ANODE BAKING FURNACES

Selvin Peter

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1. The Riedhammer Furnace: Design and Operation, Motivation behind Modelling.

This part is intended to give a description of the construction and operation of the Riedhammer furnace. The work it is supposed to do, the general structure of its construction, the main phenomena taking place in the furnace (fuel combustion, air infiltration, release and combustion of volatile matters, combustion of packing coke, heat losses) are described. The role of various furnace sections (preheat sections, firing sections, cooling section) and the configuration of each section ((head wall and fireshaft zone, underlid zone, pit zone, underpit zone) are explained. Comments are made on the operational parameters of the furnace (composition of fire train, fire cycle time, air flowrate, fuel flowrate, baking temperature, finishing temperature) and the effects of changing these parameters on overall furnace behaviour. Therefrom are drawn the motivations leading to the mathematical modelling work.

2. Development of the 2D+ Model

Comments are first given on the reasons for, and the limitations of, approximating the process by a two-dimensional (2D) model, and the need for extending it to a 2D+ model to account for the critical differences between inner and outer pits, due to heat losses through lateral walls.

The model is next presented in its mathematical concept as well as in the way it is solved.

The model extends from the 1st preheat section to the last covered cooling section. This model considers each of the four zones, links them together with common boundary conditions and determines the energy sources and sinks for each zone. This part of the course describes the conceptual approach used in the model by presenting the equations for the control volume of each zone and explaining how the four zones are treated and linked together. In addition, this part will include how the 2D transient conduction is solved and how the volatile matters release and combustion are taken care of by the model.

The solution procedure involves the calculation of mass flow, temperature and composition of the gas and solid temperature for each time step, until the end of the fire cycle period at which time a new preheat section is added and the last cooling section is dropped. A new fire change starts and the program is executed until the total number of the fire changes or a quasi-steady state (5°C temperature difference of the gas temperature between two fire changes) is achieved.

3. Simulation Results and Capabilities of the 2D+ Model

The geometrical parameters and the initial values required to run the model will be presented for a general-purpose base case. The output from the model including draught profile, gas temperature profile, fuel consumption, oxygen profile, gas mass flow, anode temperature profile, anode finishing temperature will be provided and compared with the measured values.

The capabilities of the model include changing operational parameters such as draught, firing scheme, fire cycle time, flow distribution across the furnace as well as changing geometrical parameters such as number of pits, adding or removing a section from the fire train. The effect of firing change on the performance of the furnace will be presented and compared with the base case.

4. Development of a 3D Model

The 3D model is built on the general-purpose code known as PHOENICS™ marketed by CHAM of London, U.K.. A brief introduction to the structure of PHOENICS and how it solves the transport equations will be given. Emphasis will be placed on the Riedhammer Furnace model conception in 3D and how this CFD code suits the needs of the work.

Next, the overall conception of the 3D model is presented. One section of the fire train is considere[illegible] the control volume for the model. Body-fitted coordinates are used to [illegible] the geometry of a section. How various physical phenomena (a[illegible] turbulence, combustion, radiative heat transfer, conduction through the [illegible] losses) are accounted for in the section of interest will be discussed. [illegible] the initial and boundary conditions along with the solution procedure for the flow and energy simulations will be presented.

5. Simulation Results and Capabilities of the 3D model

A base case considers the simulations for the 4th preheat section. The input parameters for these simulations will be introduced. The resulting flow and energy distribution in this section will be presented and discussed. Wherever general plant observation data are available, a comparison will be made between predicted and observed results on baking temperatures, temperature gradients, baking uniformity or the lack thereof... .

The capabilites of the 3D model include the effect of blocking any fireshafts or any CE5 or AE5 brick holes, non-uniform flow through the fireshafts, changing the geometry of the lid, on flow and energy distribution in the furnace. Examples will be presented to illustrate the flexible use of the model in these parameter studies.

Note: *Ownership by industries will be duly mentioned.*

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MODELLING OF CASTING FURNACES

André Charette

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1. Docription of some melting/holding furnaces and overview of the related studies carried out at UQAC.

Work undertaken on a classical melting-holding furnace and on a top-charged remelting furnace is outlined.

2. Numerical methods in radiative heat transfer

Radiation is the dominant mode of heat transfer in casting furnaces. A number of different numerical techniques are available for its calculation. Some of them are addressed in this presentation. The zone, discrete transfer, imaginary planes, discrete ordinates and Monte Carlo methods are described and compared. Reference cases are used to assess the accuracy of the methods. Ways by which radiation is incorporated into the solution of the conservation equations are discussed. Computation time is also analysed.

3. Details of the mathematical modelling of the furnaces described above.

3.1 The classical melting/holding furnace

3.1.1 1D model (analytical model)

This simplified model is dynamic and it can simulate any sequence of operations such as loading, heating, stirring, skimming, etc... It has been validated on a real furnace. Hottel's real gases formulation has been used for the combustion chamber and the phase change problem has been treated with the enthalpy method. The techniques and the results are explained.

3.1.2 1D reduced model (control model).

A tenth-order non-linear control model has been obtained from the analytical model by least-squares approximation. A detailed description of the methodology is given as well as a comparison of both models.

3.1.3 Fuel optimization calculations.

Such calculations have been performed using the control model in open and closed loop. First the open-loop formulation and results are presented. More emphasis is laid however on the closed-loop schemes with PID control possibilities. The mathematical formulation is built around the minimization of a cost function.

3.1.4 3D model

This complex model is divided in two parts: the combustion chamber and the metal. The general-purpose code PHOENICS™ is used in both parts. Special algorithms are incorporated in the code: radiation heat transfer in the gas phase is treated by the imaginary planès method, the melting process in modelled with the aid of the effective thermal properties concept and an augmented conductivity technique takes care of the convection in the liquid metal. This 3D model can be used to predic for instance the best dimensions of the furnace and the best position of the chimney or of the solid charges. A complete description of the model is presented.

3.2 The remelting furnace

This cylindrical furnace is loaded with pieces of different sizes which form a porous medium. Heat comes from burners imbedded in the walls at specific angles. Predicting the heat transfer in such an arrangement is a very difficult task. Several studies have been undertaken at UQAC to elucidate various aspects of the problem, namely:

— flow visualization studies of the interacting burner jets (in a cold physical model).
— impact convection heat transfer study (also in the cold model).
— experiences on the transmissivity of light through different porous media.
— one - and two-dimensional simplified models of the rate of melting of a typical pile by using an assumed heat penetration depth formulation.

The presentation includes a description of the experimental set-ups and a discussion of the results obtained up to the present time.

VI. Course material

The course material was sent to UNIDO headquarters prior to the workshop.