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Aluminium Electrolysis Process Evaluation and Control

Technical Report

on the expert mission carried out in India from
7th Nov.,1994. to 16th Jan. 1995

DP / IND/ 88/ O15 / 11-05

Prepared by : Dr. J. Horváth

Backstopping officer : Dr. T. Gróf DIO/ T/ MET/

United Nations Industrial Development Organisation

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Executive Summary

The present report on " Aluminium Electrolysis Process Evaluation and Control" is a result of the expert mission DP/IND/ 88 /O15 / 11-O5 carried out in India from 7th Nov., 1994. to 16th Jan. 1995. (with briefing and debriefing). Duration of this expert mission was 2 months, and it was extended by Aluterv-FKI Ltd. for installation of radiometric density gauge. According to the terms of reference during the expert mission the following activities were undertaken:

1. Elaboration of measuring and evaluation for guaranteed performance test of Balco modernisation
2. Assisting in preparation and evaluation of the plant measurements at Indian Aluminium Company (Smelter Plant, Hirakud).
3. Assisting in preparation and evaluation of the plant measurements at the National Aluminium Company (Smelter Plant, Angul)
4. Offering assistance in installation of the Electrolysis Laboratory

All these activities have been carried out and details are provided in the report, followed by conclusions, proposals and recommendations.

During this expert mission the above mentioned tasks were fulfilled:

- measuring programme was elaborated and handed over to Bharat Aluminium Company (Smelter Plant, Korba) and the Kaiser Technical Service in order to carry out measurements for justification of the test cell parameters.
- the liquid temperature measurements, alumina dissolution and the density measuring equipment were installed and the acceptance reports have been prepared.

- the measurements for evaluation of Cell Operation and the supplementary measurements were carried out at INDAL Plant and a preliminary evaluation was handed over to INDAL.
- offering assistance in preparation of R&D program relating to the mathematical modelling of Electrolysis process
- review on the analytical facilities relating to Electrolysis laboratory
- the heat flux measurements on the cathode and magnetic field measurements in pot-room air were carried out, as per earlier agreement, and the preparation of process study measurements was made by the electrical measurements at NALCO plant.
- the measuring programme was finalised at National Aluminium Company (Angul) for the process study with the using of mobile measuring van. Unfortunately the heat flux measurements and the finalisation of process study was not fulfilled because of industrial relations problem in the Smelter Plant at Angul during the scheduled measuring period.

INTRODUCTION

This report has been prepared by Dr. J. Horváth based on this expert mission carried out in India under UNDP/UNIDO Project DP/IND/88/O15- Jawaharlal Nehru Aluminium Research Development and Design Centre (JNARDDC). This 2 months mission was extended by Hungalu R& D Centre for installation of radiometric density gauge. Duration of extended period was two weeks.

According to the job description DP/ IND / 88 / O15 / 11- O5 with post title "Expert in Aluminium Electrolysis Process Evaluation and Control", as per Annex-I, the expert was required :

- to prepare a measuring program for justification of test performance after the first phase of Kaiser modernisation
- to prepare a measuring program and assist in the plant measurements at INDAL Smelter Plant (Hirakud)
- to prepare a measuring program and assist in the plant measurements at NALCO Smelter, (Angul)
- to assist in installation of Electrolysis Laboratory
- to prepare the plant measurements for process study at NALCO

In addition to the job description some constructive suggestions have been given at debriefing in UNIDO Vienna by Dr. T. Gróf, BSO and at JNARDDC, Nagpur by Dr. J. Zámbo, Chief Technical Adviser and Dr. T.R. Ramachandran, National Project Director and Mr. N. G. Sharma, Deputy Director of JNARDDC. This expert mission program has taken into account the work-plan, which was made by JNARDDC/CTA.

Job description and suggestions formed the basis for the schedule programme, prepared at the beginning of this mission (Annex- II)

It can be noticed in the scheduled programme, that the activities and duties as per the job description were extended by preparation of program for

mathematical modelling and the revising of the analytical methods, relating to the Aluminium Electrolysis .

ACTIVITIES

1. Elaboration of Measuring and Evaluation for Guaranteed Performance Test of BALCO Modernisation.

The modernisation of BALCO Smelter has been started by introducing of pot controllers (Tradename of pot controllers is Celtrol). The installation of pot controllers was finished in middle of Nov. 94 by Kaiser Aluminium Technical Service (KATSI).After this period the stabilisation period has been started. The test performance started on 26th Dec., 94, and its total duration is two months. In connection with this modernisation, the tasks were the followings:

- preparation of Report on status of modernisation in this phase
- elaboration of a measuring programme and evaluation method for justification of cell operation parameters, which were given by KATSI.

During the visit at Balco a list of questionnaire was handed over to Balco and KATSI in order to prepare the measuring programme. A minute of meeting was prepared (Annex-III) and later on a report was made on the present situation of modernisation programme.(Annex- IV)

The standard operation practice was handed over to JNARDDC, as a basic information of cell operation, which will be followed during the test period. On the basis of the Standard Operation Practice, a measuring programme was presented to BALCO and KATSI for approval. After some modifications, this measuring programme was approved by Balco and KATSI. The KATSI cell operation will be evaluated. on the basis of this measuring programme (Annex- V)

As per as this measuring programme, the measurements of cell parameters are being continued.

2. Assisting in Preparation and Evaluation of Plant Measurements at INDAL Smelter Plant (HIRAKUD)

The last expert mission was decided, that the measurements will be carried out INDAL Smelter Plant at Alupuram. During this expert mission this has been changed due to industrial relations problem in the Plant, so the measuring program has been carried out in the INDAL Smelter Plant at HIRAKUD. A preliminary measuring programme was handed over to INDAL for study. A meeting was organised to determine the final measuring programme. The approved measuring program can be found in Annex-VI. After finishing the measuring program a preliminary report has been prepared and handed over to INDAL. The preliminary report is shown in Annex-VI. The all fulfilled activities were summarised in the Minute of Meetings, as is shown in Annex-VII.

3. Assisting in Preparation and Evaluation of Plant Measurements at NALCO Smelter Plant (ANGUL)

During the visit at NALCO Smelter Plant at Angul the following tasks were fulfilled, the measuring programme was finalised (Annex-VIII) and the approved measuring programme and scheduled programme was submitted to NALCO. (Annex-IX) The process study measurements were prepared. It is requested, that the anode gas analyser has to put into operation in order to evaluate the current efficiency value.

4. Offering assistance in installation of Electrolysis Laboratory

The following measuring methods and equipment were put into operation and the acceptance report was made: (Annexe-X)

- determination of the liquids temperature for molten salts at high temperature
- determination of the alumina solubility in cryolite melts
- determination of density for molten metal and molten salts

5. The other activities

During the expert mission two topics were discussed more details. One topic was the analytical and material test relating to the Aluminium Electrolysis Department (Annex-XI) and the second one was the R&D program of the mathematical modelling of the aluminium electrolysis.(Annex-XII)

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- Annex- II Scheduled programme and main activities
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Determination of Liquids Temperature in Cryolite- Alumina Melts
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- Annex- XI Discussion to Centre's Capability for Providing Analytical Support to Aluminium Electrolysis Department
- Annex- XII Recommendations on Activities of Mathematical Modelling



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

REQUEST FROM THE GOVERNMENT OF INDIAJOB DESCRIPTION

DP/IND/88/015/11-66

POST TITLE: Expert in aluminium electrolysis process evaluation and control

DATE REQUIRED: end of September 1994

DURATION: 2 man/months.

DUTY STATION: Nagpur, India, with travel within the country

PURPOSE OF
THE 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

...../..

Applications and communications regarding this Job Description should be sent to:
Project Personnel Recruitment Branch, Department of Industrial Operations

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 1970ies. 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 producer 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 1990ies. 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 which at the current selling price of aluminium amounts to Rs. 1180 crores. Considering the payment for know-how, basic engineering and royalties for this additional follow-up stage this would mean an expenditure of at least another Rs. 1.2 billion equivalent to US\$ 95 million.

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 are expected to start in 1991-1992. Training of the staff will be carried out in India and abroad.

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

Schedule Program and the Main Activities

1. Installation and putting into operation of measuring procedures in the Electrolysis Laboratory.

Determination of the Liquids Temperature in Cryolite-based Melts

Determination of the Alumina Solubility in Cryolite Melts

Deadline : 19th Nov., 1994.

2. Visit to Bharat Aluminium Company, Smelter Plant at Korba in order to prepare the measurements during the first phase of modernisation.

Deadline: 23-26th Nov. 94.

3. Preparation of the Report on Status of Modernisation and Measuring Program for KATSI Cell Operation

Deadline: 8th Dec. 94.

4. Installation, Putting into Operation and Training of Radiometric Density Gauge by the Hungalu R&D Centre (Aluterv-FKI Kft.)

Deadline : 9th-21st Dec. 94.

5. Visit to Bharat Aluminium Company, Smelter Plant at Korba for the Approval of the Measuring Program. Discussion about the Following Co-operation Program.

Deadline : 21st-23th Dec. 94.

6. Visit to Indian Aluminium Company, Smelter Plant at Hirakud for Preparation of Measuring Program by Mobile Van.

Deadline : 23th Dec. 94.

7. Visit to National Aluminium Company, Smelter Plant at Angul for Preparation of Measuring Program by Mobile Van.

Deadline: 24th Dec. 94.

8. The Carrying out of the Measuring Program in INDAL Smelter Plant at Hirakud and Preparation of the Preliminary Evaluation.

Deadline: 25th Dec.- 4th Jan. 95.

9. **The Carrying out of the Measuring Program in NALCO Smelter Plant at Angul and Preparation of the Process Study Measurements.**

Deadline: 5th- 10th Jan. 95.

10. **Preparation of the Expert Mission Report**

Deadline : 14th Jan. 95.

on 25/11/94

Record Notes of discussion held between BALCO and
BALCO for assessment of Modernisation Project Phase-I

P r e s e n t

B A L C O

- 1 Mr. AK Ray, GM(Sp)
- 2 Mr. GD Upadhyay, DGM(Sm)
- 3 Mr. IP Singh, AGM(Sm)

J N A R D D C

- 1 Dr. Horvath, UNIDO Expert
- 2 Mr. NG Sharma,
Dy. Director, JNARDDC

1 According to the wishes of Chairman-Managing Director, Balco a team of expert comprising of Dr. Horvath, UNIDO expert and Mr. NG Sharma, Dy. Director, JNARDDC visited Balco on 24th November 1994 for the independent evaluation of the Impact on the Increase in Productivity Reduction in Power Consumption etc. upon the completion of the First Phase of the Modernisation.

2 The Expert from JNARDDC wished to have certain data relating to Modernisation Project - information questionnaire .

Various datas asked for were made available by Balco, wherever applicable and whatever available.

3 The experts from JNARDDC suggested that the Operating parameters of the cells should be well defined before the performance guarantee test starts for which efforts will be made by BALCO in consultation with KATSI.

4 Balco handedover the standard Operating practice and other documents. The copy of Project Implementation Report submitted by KATSI was requested by JNARDDC experts which could not be made available immediately.

D. Upadhyay
B A L C O

P. Gokarn
J N A R D D C

Report and Follow-up Action Relating to BALCO Modernisation.

To approach the normal cell operation the following action were made on the test cells (414-440) by Kaiser:

1. The set point (cell voltage) has been increased
2. Metal height has been decreased
3. The broken bath has been removed from the deck-plate
4. The deck plate has removed
5. The anode stud horizons has been changed on 14.
6. The schedule of stud pulling and tapping have been changed
7. The heat isolation on the short side has been increased

Due to the set point value raising and metal height decreasing the cell operation has been improved:

- the significant part of soft sludge has been removed, so the total liquids level (metal and bath) were decreased
- the electrolyte temperature has been decreased , frozen ledge has been generated
- anode effect value has been increased
- bath motion has been improved

Conclusion is, that these modification has been indicated in a more stable cell operation.

Due to the removal of sludge, the liquid level has been reduced, so the broken bath layer on the deck plate could be removed. After this procedure the deck plate has been cleaned, too.

The anode operation also has been changed, the stud horizons have been increased on 14 level, to maintain the better anode current distribution and in this case the modification of set point is not needed after stud pulling.

The Celtrol was installed in the full operation and it is operated successfully.

Evaluation of the first phase of modernisation the following conclusions can be done:

- the earlier proposals for improvement of cell operation were correct (Expert mission Report 1992)
- the voltage and energy balance for the test cells are not proper, therefore the cell operation will not reach the expected values,
- the uniform cell parameters for all test cells could not be achieved till middle of February '95 ; more time is needed.
- the main target in the present situation is to adjust and stabilise the parameters of the existing test cell operation. The problems in this regard are the followings :
 - the carbon skimming generation is very high
 - the used alumina is too fine, the risk of sludge formation is very high
 - fluctuation in thermal state is very high , so the weight of tapped metal indicates significant differences.
 - fluctuation in thermal state causes large fluctuation in the bath volume and the bath height
 - number of anode effect / day is very high and non regular

The heat balance of the test cell are different, different the metal bath height, bath volume, so the uniform operating procedure cause different effects, so the cell voltage is not constant and these changing are compensated by the anode movement. At the normal case, daily 1-2 anode movement is occurred, against the presently 30-50 anode movement/day.

Expected Parameters:

1. Energy Consumption DC : 16.5 kWh/kg
2. Current Efficiency : 87%
3. Cryolite : 15 kg/t
4. Aluminium fluoride; 25 kg/t
5. Anode consumption: 540 kg/t
6. The amperage, production and purity are not forming part of the Kaiser guarantee.

Because of significant hard deposits on the bottom, the prescribed 30 cm metal height and min 16 cm electrolyte level can't be maintained by BALCO, so Kaiser guarantee will not valid.

Presently the alumina used is not suitable, the fine part is very high (below -45μ is 50-60%) (Kaiser opinion).

V.

**Measuring Program for Evaluation of Optimum Control Parameters
Based on Standard Operation Procedure Suggested by KATSI-
Parameters after the First Phase of Kaiser Modernisation.**

The measuring program can be divided two parts:

1. Traditional measurements in the pot room relating to cell operation:

Sl no.	Parameter	Frequency	Actual value	Prescribed
1	Metal height	Every alternate day half way between the taps		30-33 cm.
2	Bath height	Every day		16-20 cm.
3	Anode immersion depth	Twice a week (by JNARDDC)		15 cm.
4	AC distance	Once a week (by JNARDDC)		5.0 cm
5	Anode skirt position	Twice a week (by Room In Charge)		4.0 cm above the bath level
6	Anode voltage drop	After every stud pulling		0.450V
7	Cathode voltage drop	Once a week		0.400V
8	Busbar voltage drop	Not proposed by KATSI		0.300 V

9	Alumina layer thickness on the crust	Once a week in selected cells		10.0 cm
10	Anode current distribution	Twice in cycles of stud pulling		Standard deviation- 0.25
11	Cathode current distribution	Once a month		Standard deviation - 0.15
12	Weight of tapped metal	Every second day		1380 kg
13	Line current	Continuously		98.5 kA
14	Volt hr value	Continuously from the control system		
15	Electrolyte temperature	Once a day		<985 ° C
16	Sampling Electrolyte	Twice a week		2.74 Molar ratio CaF ₂ - 4.0-5.0%
17	Sampling Metal	Twice a week		Fe- 0.12% Si- 0.08%
18	Liquid level	Every second day between taps		47-49 cm.
19	Beam raising			Target- 14 days

20	Anode consumption	in 14 days		Target-540 kg/t 372.6 kg/cell day at 98.5 kA
21	Aluminium fluoride consumption	Accounting period every 10 days		25 kg/t
22	Cryolite consumption	Accounting period every 10 days		15 kg/t

2 Non-traditional measurements :

Sl no	Parameter	Frequency
1	Noise analysis	Periodically
2	Anode effect value	Periodically
3	Cell resistance in function of cell routine	Periodically
4	EMF measurement	Periodically
5	Ohmic voltage drop	Twice during the measuring period
6	Heat flux measurement on constructional elements	Periodically
7	Magnetic field induction measurement for cell stability determination	Periodically

The Energy and Voltage Balance after the First Phase of Balco Modernisation.

Parameters	Value
Molar ratio	2.74
Average alumina content	Not specified
Calcium fluoride content	4-5%
Line current	98.5 kA
Anode cathode distance	5.0 cm (nominal)
Cell voltage	4.3-4.5 V
Current efficiency	87.0%
Anode voltage drop	0.450 V (to be reached)

Cathode voltage drop	0.400 V (to be reached)
Busbar voltage drop	0.300 V (not proposed for measurement by KATSI)

Voltage components:(these value will be calculated after the experiments)

- Voltage components on construction elements
- Voltage demand for aluminium production
- Voltage drop in AC-gap
- EMF (Electromotive Force)
- Voltage drop in electrolyte

Energy components:

- Superheat
- Energy for aluminium production
- Heat losses
- Energy efficiency
- Energy consumption
- Daily production

FOLLOW-UP ACTION RELATING TO BALCO MODERNISATION.

Traditional measurements for KATSI Cells. (Cell House No. 8)

These measuring program consist of the following main activities:

- Description of the copper dilution technique for determination of metal inventory content before test period.

Description was handed over to BALCO.

- Preparation of Measuring program for KATSI Cells.

The program was handed over to KATSI and BALCO on 21st Dec. 1994.

- Measuring program was approved by KATSI and BALCO.

Letter was submitted to JNARDDC by KATSI.

- Supervising and Measuring Activities by JNARDDC for collection of operating data as per as approved measuring program.

This program is going on.

- Evaluation of the KATSI test cells after two months period.

Non Traditional Measurements.

BALCO requested to carry out a depth study measurements by mobile van after finishing of the first phase of modernisation.(refer Annex II)

KATSI promised his assistance in the manner that may be needed.

Naturally the JNARDDC will request the assistance by KATSI.

**PRELIMINARY REPORT ON MEASUREMENT CARRIED OUT
AT INDAL, HIRAKUD**

(22nd DECEMBER, 94 to 2nd JANUARY, 95)

JAWAHARLAL NEHRU ALUMINIUM RESEARCH DEVELOPMENT AND DESIGN CENTRE has been established with the assistance of UNDP in Nagpur by the Government of India under Ministry of Mines. As a part of UNDP assistance JNARDDC has been provided with most sophisticated equipment for ascertaining Electric, Thermal & Magnetic state of electrolytic cells.

Based on discussion held between representatives of JNARDDC and INDAL at Alwaye and subsequent communication thereafter, JNARDDC team arrived at INDAL, HIRAKUD on 21-12-95 in order to carry out measurement.

JNARDDC experts made a presentation on the various kinds of measurement and their significance before INDAL officers. JNARDDC, team in consultation with INDAL decided to carry out:

- Electric, Thermal and Magnetic measurement in smelter
 - Thermal measurement in cast house and Rectifier station.
1. Analysis of cell stability by NOISE ANALYSIS (120 Measurement carried out. Data handed over to INDAL in File- I)
 2. ANODE EFFECT Intensity, Duration and its behaviour has been analysed
(56 Anode effect analysis done during 5 days. Data handed over to INDAL in File II)

3. Counter Electromotive force of all the 12 cell was measured and analysed by Current Sinking method (C.E.M.F. measured for 12 cells, Data handed over to INDAL in File III)
4. Cell operation work routine were monitored during this period
5. Alumina Feeding (Monitored for 9 days. Data handed over to INDAL in File IV)
6. Rod Raising (Monitored for one day. Data handed over to INDAL in file V)
7. Tapping (Monitored for one day. Data handed over to INDAL In file VI)
8. In addition to these measurements electrolyte temperature of all the 12 cells was measured. (Data handed over to INDAL in file VII)
9. Heat Flux through cathode side above the collector bar and Heat Flux through superstructure door has been measured for three cells (Data handed over to INDAL in file VIII)
10. Magnetic field components in pot room air at ground level, 1 m levels & 2 m levels has been measured for four pots. Data handed over to INDAL in file IX
11. Heat losses through two furnaces from all the sides in Cast house was determined (Data handed over to INDAL in file X)
12. Rate of cooling of metal in Cast house ladle was measured
13. Thermovision was used to determine the temperature distribution around various electrical equipment in rectifier station. INDAL was informed about various hot spots which could lead to failure

PRELIMINARY EVALUATION OF POT ROOM MEASUREMENT

NOISE ANALYSIS Noise measurement indicates that smelter operation in general is stable barring few exceptions. In few pots sludge, extended side freeze and broken anode pieces, projection etc., were indicated. Typical Noise of these pots is as follows

- (1) Normal Noise Fig- 1
- (2) Spikes / Broken carbon pieces Fig 2
- (3) Sludge / Extended side freeze Fig 3

In general because of power outage four times during this measurement period, cells were generally found cold so Noise amplitude was found to be high

ANODE EFFECT : Study of Anode effect data also shows stable operation, However, in some cases irregular behaviour has been noticed. In some cases anode bottom surface is not perfectly even. Some carbon dust is expected to stick to anode bottom. Anode effect duration is normally higher than 7 minutes. Typical normal Anode effect and Anode effect showing uneven anode bottom are given in Fig (4) and (5) respectively.

WORK ROUTINE MONITORING Monitoring of cell operation in alumina feeding mode indicate that average alumina content is normally higher around 4-6 %. In few cases it was found to be near 2-3 % as well. Typical graphs showing low alumina content and high alumina content are given in Fig 6 and Fig 7

Monitoring of rod raising indicates that cell voltage should be raised by 300 mV in order to compensate for increase in cell resistance. Typical graph showing increase of cell resistance due to rod raising is given in fig.

Study of tapping mode shows operators generally raise cell voltage at fairly higher level before starting tapping but it is brought back to normal after completion of tapping.

E. M. F. Measurement Study of Electromotive force indicates that all the cells are operating in stable zone of Magneto - hydrodynamic curve. Value of E.M.F.. in all the cells was more than 1.65 V

The conclusion of electrical measurements are as follows:

- Noise is normal but amplitude of noise is high which indicates cold cell condition.
- Anode effect value shows stable cell operation which is justified by the fact that E.M.F.. values of all cells is more than 1.65 V. It must be noticed that there is a very good possibility of decreasing anode effect duration.
- Alumina concentration is very close to saturation value.

In summary INDAL cell operation can be considered stable under controlled cell operation.

The voltage and energy balance calculation are summarised for the following cases. The details of results were handed over.

1. PRESENT CELL OPERATION
2. INCREASING LINE CURRENT TO 60 kA WITHOUT ANY CHANGE
3. USING POINT FEEDER WITH RAISING SET POINT VOLTAGE BY 100 mV
4. USING POINT FEEDER WITHOUT ANY CHANGE
5. PRESCRIBED PARAMETERS FOR USING POINT FEEDERS IN PRESENT SITUATION AND EXPECTED RESULTS

On the basis of measured data the minimum operation ACD will be 3.75 cm at unchanged cell resistance with increased line current. Decreasing of set point is also not proposed. In this case operation will become unstable. By comparing different variation in table - I It can be seen that increased line current (Case-II) increases production but lowers current efficiency which results in higher energy consumption. Use of point feeders ensures low alumina concentration in the bath (Case-III & IV) but in these cases super heat is not enough for dissolution of alumina (Case III). Minimum 10 -12 °C super heat is needed for proper dissolution of sandy alumina. In (Case-V) 10 °C super heat is obtained which is ideal for ensuring proper alumina dissolution.

MAGNETIC MEASUREMENT: On the basis of preliminary evaluation of magnetic field components, it is found that B_z is symmetric around X-Y plane. Its absolute value is well within the norms. Its average absolute value varies from 27 Gauss to 40 Gauss for all the pots at all levels. There is no major change in average absolute value of B_z in all the pots at all the points.

HEAT FLUX MEASUREMENT IN POT ROOM: In table - I total heat loss in INDAL cells can be seen. Target of heat flux measurement was to find out how much of this total heat is escaping from cathode sides. In order to determine this value heat flux has been measured at various points of cathode side. Cathode side has been divided in four zones, Barrier, Block, Metal, & Bath zone. Average heat flux has been multiplied by respective area. It was found that heat losses from upper part of cathode side (Above collector bar) varied from 15.0 - 16.9 kW which means 13-14 % of total heat loss. Heat losses from superstructure - Doors varied from 6 - 11.5 kW which amounts to 6.5% - 10 %

HEAT FLUX MEASUREMENT AT CAST HOUSE : Heat flux through various surface of both furnaces A & B was found. Total heat flow through both the furnace was about 50 kW but heat losses from Railway side from furnace A was much lower than heat losses from Railway side of furnace B where as heat losses from pot room side of furnace A was much higher than heat losses from pot room side of furnace B.

Measurement of Temperature Distribution of Various Equipment at Rectifier: Thermal profile in and around various electrical joints was monitored. Abnormal temperature around 126 °C was observed around R phase of out going power transformer No. 3 which was duly informed to INDAL.

All measuring data and Figures were handed over, the original data can be found the in the archive of JNARDDC.

FINAL PROPOSAL AND CONCLUSIONS

1. Electric, Thermal and Magnetic status of INDAL cells indicate that INDAL pots are operating in a stable condition.
2. After analysing voltage and energy balance, it was found that existing cell operation is very near to optimum AC distance. The optimum ACD is 4.0 cm in present situation.
3. Decreasing set point at this stage is not proposed because it would cause significant decrease in current efficiency.

4. Increasing line current is not proposed at this stage.
5. It is proposed to analyse voltage components of anode voltage drop since it appears higher than normal. Voltage and energy balance calculation shows significant advantage of introducing low alumina content in the bath. This results in higher current efficiency and lower energy consumption.
6. JNARDDC is ready to prepare feasibility study for above mentioned project.

MINUTES OF MEETING

- | INDAL | JNARDDC |
|---------------------|------------------------|
| 1. Mr. A.T. Mathew | 1. Dr. J. Horvath |
| 2. Mr. J.R. Panda | 2. Mr. G.S. Sengar |
| 3. Mr. Amit Pradhan | 3. Mr. Anupam Anihotri |
| 4. Mr. J.P. Naval | 4. Mr. Ranraj Sid |
1. Mr. G.S. Sengar apprised INDAL regarding various kinds of measurement which are possible by Mobile van equipments and their significance on 22/12/94
 2. JNARDDC carried out all the Electric, Thermal and Magnetic measurements as per the mutual agreement from 22/12/94 to 2-1-95. INDAL requested to measure Heat Flux at two furnaces of Cast House and measurement of Thermal profile of various equipments at Rectifier Station. JNARDDC carried out the necessary measurement.
 3. All the Measured Data of Electric, Thermal and Magnetic measurements are handed over to INDAL as mentioned in the preliminary report.
 4. A Preliminary report on evaluation of this measurement programme, was submitted to INDAL on 3/1/95
 5. Mr. G.S. Sengar made a short presentation regarding evaluation of measured data and preliminary conclusions & recommendation on 3/1/95
 6. JNARDDC agreed to send a detailed report on evaluation of this measurement program **BY MARCH, 1995**
 7. INDAL agrees that JNARDDC fulfilled all measurements which were requested by INDAL during this period.
 8. JNARDDC submitted an invoice of Rs. 65,000 for this measurement programme. INDAL agreed to send this amount by Demand Draft in the name of JNARDDC payable at Nagpur shortly

A.T. Mathew
3/1/95

[Signature]
3/1/95

G.S. Sengar
3/1/95

[Signature]
3/1/95

Record Notes of Discussion between NALCO & JNARDDC, Nagpur at Smelter Plant, NALCO on 26-12-94

NALCO

S/Shri

S.D. Chauhan, DGM(Potlines)

S.P. Mahapatra, DGM(TS)

S.S. Manurkar, CM(C&I)

T.V.S. Rao, Sr. Manager(C&I)

JNARDDC

Dr. J. Horvath, UFIWG Exper:

Mr. H.G. Sharma, Dy. Director

1. As a follow up on discussion between NALCO & JNARDDC, Nagpur at Shubaneswar on 4-3-95 about joint R&D Projects, JNARDDC, Nagpur are deputing a team of scientists for conducting various measurements at Smelter from 4-1-95 to 21-1-95, along with their mobile laboratory. The period of visit may be extended if required.
2. The measurement program will cover the following areas
 - (a) Heat flow and thermal balance of 2 dypsil, 2 Graphite and 3 normal lined pots (Normal lined pots of different pot ages). Heat flux measurement will be carried out for pot cathodes. Preliminary measurement of heat flow through superstructure of 2 - 3 pots will be carried out.
 - (b) Magnetic mapping around normal and shunted pots will be carried out.
 - (c) Continuous monitoring of 15 pots through DAS will be carried out.
 - (d) Counter EMF, ACD, Voltage drop in construction elements for 3 pots will be carried out.
3. JNARDDC will send a detailed program for the study to NALCO before 31-12-94. When the JNARDDC team arrive, the program will be finalised through joint discussion

(Contd..F/...2)

4. HALCO will make preliminary arrangement for measurements like approach and parking of mobile van, voltage tapplings from Pots etc.
5. JHARDCO have requested HALCO to pay Rs. 1,50,000/- (Rupees one lakh fifty thousand only) to cover their expenses for the present study programme which is expected to be completed in the above mentioned period.
6. JHARDCO request HALCO to arrange for Safety equipments for their team on returnable basis.
7. JHARDCO request HALCO to provide hospitality and transport to their team without any charge.
8. Process study for optimization of pot parameters will be carried out on a later date.

(S. P. SHARMA)
DY. GENERAL MANAGER (T.S.)
HALCO, SHELTER

(K. G. SHARMA)
DY. DIRECTOR
JHARDCO, RAIPUR

CC: ED(CP&BE), Corporate Office : for kind information.
GM(S) - for kind information
SGI(Potlines)
DGM(R&D), Corporate Office.

Annex-IX

To: Mr. S.P. Mohapatra, Dy. General Manager (TS)
Company: National Aluminium Company Ltd.
Smelter Plant, NALCO Nagar-759145
Dist. Angul, Orissa
From: Mr. G. S. Sengar/ Dr. Horvath JNARDDC
Fax No. : 06760-20132

Subject: Measuring program

As per our discussion (dated 26-12-1994) please find enclosed measuring program.

The JNARDDC's team will arrive to Angul on 4th of January 1995 along with the mobile van.

The measuring program will be started on 5th of January, as shown in the scheduled program below:

5th January	Safety Instruction to the Team
	Location of Mobile Van
	Unpacking and Checking of Instruments
	Preparation of Heat Flux Measurements on the
Cathode	
	Removal of Slab
6th January	Installation of Mobile Van
	Heat Flux Measurements on 50 points, on side wall in
	three layers and bottom
	Removal of Slab
7th January	Heat Flux Measurements
	Data collection, Noise, Process Monitoring

	Preparation of Magnetic Field Induction Measurements in the Pot-Room Air (at Normal Case)
8th January	Magnetic Measurements for Three Pots Anode Effect Monitoring
9th January	Anode Effect Monitoring Preparation and Maintenance
10th January	EMF and Metal Touching Measurements on the Three Pots Preparation of Heat Flux Measurements Removal of Slab,
11th January	Heat Flux Measurements on Cathode Data Collection, (Noise, Tapping, Block Changing) Preparation of Magnetic Measurements
12th January	Magnetic Field Measurements on Shunted Pots
13th January	Magnetic Field Measurements on Shunted Pots Preparation of Heat Flux Measurements Removal of Slab
14th January	Heat Flux Measurements on Cathode Data Collection, (Process Monitoring, Noise)
15th January	Preliminary Evaluation for Hysil and Graphite Heat Flux Data in Consultation with NALCO Data Collection (Anode Effect Monitoring)
16th January	Preliminary Analysis of Magnetic Field Data Data Collection (Anode Effect Monitoring) Removal of Slab
17th January	Heat Flux Measurements Data Collection Removal of Slab
18th January	Heat Flux Measurements on Cathode

Data Collection and Processing
Removal of Stab
19th January Heat Flux measurements on Cathode
Data Collection and Processing
20th January Evaluation of the Measured Data
Packing and Preparation of Transportation to Nagpur
21st January Evaluation of the Measuring Program
22nd January Leaving Angal

I hope to complete this measuring program successfully in close co-operation with you.

Best Regards,

(G. S. Sengar)

Team-leader

Copy: S.D.Chouharia Dy. General Manager(Potlines)

N.G. Sharma Dy. Director of JNARDDC

ACCEPTANCE REPORT

1.) Name of Process : Liquidus temperature measurements
2.) Name & Address of Supplier : The measurement method utilise various equipments. Their names and suppliers addresses are enlisted below:

a.) Vertical Tube Furnace : M/s INDFUR
P.B. No. 645, Kennedy IInd Street,
Mylapore, Madras-600 004 INDIA

b.) Digital thermometer: NORMA MESSTECHNIK GmbH
A-235, Wiener Neudorf
Austria

c.) Digital Voltmeter: Schlumberger Technologies, Instrument
Division,
Victoria Road, Farnborough, Hampshire,
ENGLAND

3.) Purchase order and date:

- a.) Vertical Tube Furnace: P.O. No. 168/JNARDDC/ADM/94
dtd. 17.3.94
- b.) Digital Thermometer: P.O. No. 15-0-1181 K dtd. 14/9/90
- c.) Digital Voltmeter P.O. No. 15-9-1540 K dtd 30/20/89

4.) Date of Delivery and & Installation:

- a.) Vertical tube Furnace: Date of delivery: Aug. 1994
Date of installation: Oct. 1994

b.) Digital Thermometer: Date of Delivery: 6.11.90.

Date of Installation: Apr. 94

c.) Digital Voltmeter: Date of Delivery; 27.12.89.

Date of Installation: Sept. 94

Complete installation of the measuring procedure was completed in Nov. 94.

5.) Any reference problem faced in installation :

The Vertical Tube furnace heating elements damaged during pre-installation checks, which was subsequently replaced by supplier.

6.) General Description of facility:

A mixture of salts is heated up till it is completely molten. Subsequently the temperature of the melt is recorded while switching off or by manually adjusting the rate of cooling of furnace. The resulting temperature data from the digital thermometer is stored in the memory of the digital voltmeter. The stored data is then plotted vs. time to ascertain the phase change from liquid to solid.

From the plot, liquidus temperature of the molten mixture is found out. The calibration of the measurement set-up is done with analytical reagent grade sodium chloride with well known melting point.

7.) Measurement Procedure, operation and Maintenance Manuals for Main Equipments : Available

8.) Safety Precautions:

i) Asbestos hand gloves, safety goggles and long handled crucible tongs are to be used while handling the molten salt mixture.

ii) A thick layer of alumina must always be available at furnace bottom to prevent damage of furnace by accidental toppling of the crucible.

iii) Care must be taken while handling the molten salt and after measurement the molten salt must be poured out into a stainless steel crucible.

iv) Necessary electrical and fire safety precaution must be taken.

9.) Record Note on Installation & Start up:

A copy of calibration and test measurement report is placed in the measuring archive in the Electrolysis laboratory.

10.) List of consumables, Spares, Accessories etc.

a) Consumables : Alumina, Cryolite, Aluminium Fluoride, NaCl, Thermocouple,

b) Accessories: Spot light, Pt- crucible

c) Tools: Crucible tongs, Screwdriver set, Stand,

d) Spares: Heating element for furnace, thermocouples,

e) Standard, Ref. Mat.: Nil

11.) Training provided, List of trained staff: S. Dasgupta, K.G. Deshpande

12.) Report on performance test:

The calibration was done with analytical grade NaCl. The melting point measured was 795 °C against the literature data of 800 °C which is less than 0.65% of measured data.. Subsequently the electrolyte sample from one of the primary smelters also analysed for liquidus temperature. The liquidus temperature of the electrolyte sample was found out to be 948 °C which is an acceptable value for the usual bath composition used by the particular smelter.

- | | | |
|-----|---|---|
| 1.) | Name of Process : | Alumina dissolution in cryolite melt |
| 2.) | Name & Address of Supplier | a.) Vertical Tube Furnace M/s
INDFUR, P.B.NO.645,Kennedy
IInd Street, Mylapore, Madras 600
004 India |
| 3.) | Purchase order No. and Date: | a.) Vertical Tube Furnace
P.O.No.168/JNARDDC/ADMN/dt
d17.3.94. |
| 4.) | Date of delivery &
Installation: | a.) Vertical Tube Furnace: Date of
delivery: Aug.,1994 Date of
installation: Oct.1994. |
| 5.) | Any reference problem in
installation: | No |
| 6.) | General Description of
Facility: | alumina dissolution process can be
determined in cryolite melts, by
visual method. |
| 7.) | Measurement Procedure,
Operation and Maintenance
Manuals for Main
Equipment: | Available |

- 8.) Safety Precautions:
- i) Asbestos hand gloves, safety goggles and long handled crucible tongs are to be used while handling the molten salt mixture.
 - ii) A thick layer of alumina must always be available at furnace bottom to prevent damage of furnace by accidental toppling of the crucible.
 - iii) Care must be taken while handling the molten salt and after measurement the molten salt must be poured out into a stainless steel crucible.
 - iv) Necessary electrical and fire safety precaution must be taken.
- 9.) Record Note on Installation & Start up: A copy of calibration and test measurement report is placed in the measuring archive in the Electrolysis laboratory.
- 10.) List of consumables, Spares, Accessories etc.:
- a) Consumables : Alumina, Cryolite, Fluoride, Thermocouple, Accessories: Spot light, Pt-crucible, mirrors, c) Tools:
 - d) Spares: Heating element for furnace, thermocouples, e) Standard, Ref. Mat.: Nil
- 11.) Training provided, List of trained staff: S. Dasgupta, K.G. Deshpande

- 12.) Report on performance test: The dissolution process of alumina was measured at 980 °C temperature without stirring by feeding 1.0% alumina doses. The relationship between the alumina content and dissolution time was determined. On the base of these results the method and equipments are suitable for study of alumina dissolution process.

The installation and training for the radiometric density gauge was made by Hungalu R&D Centre,

**Discussion to Centre's Capability for Providing Analytical Support to
Aluminium Electrolysis Department**

Present : Dr. J. Horvath,
Mr. S Dasgupta,
Mr. K.G. Deshpande,
Dr. K.V. Krishnan,
Dr. G. Balasubramanian,
Dr. K.V. Ramana Rao,
Mr. R.S. Mishra

Dr. Horvath apprised all the participants about the analytical support needed for effective operation of Aluminium Electrolysis Department. A comprehensive list was also prepared (Enclosed).

The following was decided at the meeting :

- a) Alumina analysis will be done by wet chemical methods. However for trace impurities e.g. CaO, CuO, ZnO, MgO and Na₂O content will have to be analysed by AAS and/or XRF. It was informed by Dr. Krishnan that standards for Alumina for XRF analysis is not available with Centre as at present.
- b) For coke & pitch analysis-XRF standards are available with the Centre. XRF may be used for coke and pitch analysis.
- c) Regarding electrolyte analysis, it was informed that molar ratio and additives content can be analysed by pot flux analyser (WRD). But alumina content in bath will be done by wet chemical methods for which standard methods are not available at present. Suitable efforts will be made to adopt possible methods for alumina content

analysis by wet chemical section. Possibilities of alumina content determination by XRF will also be looked into.

- d) Metal analysis facilities are already existing both by XRF and OES.
- e) Dissolved metal content determination will be done by wet chemical methods. Separate detailed discussion needed for adoption of methods available at Centre. The discussion will be held separately by Dr. Horvath with Mr. Mishra.
- f) Mettler differential scanning calorimeter was (DSC) considered for determining phase diagrams. It was informed that the DSC temperature range is only upto 750°C which is not sufficient for the purpose of phase diagram studies of electrolyte.
- g) It was informed that BET surface area of coke and alumina are already being determined by surface area analyser.
- h) FTIR studies for pitch components was also considered for which methods are to be surveyed from related literatures.
- i) It was informed that carbon content in electrolyte can be accurately determined by C&S analyser. But it is learnt that the C&S analyser in Centre is not suitable for powdered samples. The same will be considered after proposed new C&S analyser arrives at the Centre.

Put up for information please.

Enclosed Annexure - XI

Analytical Chemistry and Procedure, Methods Relating to Aluminium Electrolysis

Determination of impurity content in raw materials : Alumina
Coke, pitch

Determination of electrolyte composition : molar ratio
alumina content
additives content

Metal analysing:

Determination of dissolved metal content : gas volumetric method

Applied Methods for Research Purposes :
XRF- alumina content determination in electrolyte
infrared spectrometer- pitch component

Mettler- Phase diagram

BET surface: coke, alumina

LECO : carbon in electrolyte

Annex-XII

Recommendations on Activities of Mathematical Modelling

The major area of research in the field of aluminium electrolysis cell will be:

1. Alumina feeding model:

The simulator obtained from University of Quebec, Chicoutimi should be used to study effect of different alumina feeding technologies on process parameters. As the present simulator is only a demonstration package, effort should be made to adapt it as per the Indian Aluminium Smelters. The supporting software should be purchased to make the required changes as per the need of industries.

2. Heat Balance

Collect the available literature in this area and establish the heat balance equations to estimate heat and temperature profile in the cathode area. A method of solving these equations should be evolved in view of the available software in the Centre. A software should be developed to estimate the freeze profile in cells. data collected by heat flux meter at different plants can be used for validation.

3. Voltage Balance

A software should be developed to calculate the voltage balance of the cells and present it a graphical form. The software should be user friendly and can be used by any level of plant personnel.

4. Laboratory Measurements

Programmes should be developed to evaluate the data collected in the laboratory by various instruments.

5. Joint project should be started based on the offer of Rajiv Shekar's proposal.