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SEPTEMBER 1992
ORIGINAL: ENGLISH

ALUMINIUM ELECTROLYSIS PROCESS DEVELOPMENT AND ENGINEERING

TECHNICAL REPORT[x]

ON THE EXPERT MISSION CARRIED OUT IN INDIA MARCH 30 TO AUGUST 1992

DP/IND/88/015/11-10

INDIA

PREPARED BY: DR. J. HORVATH

BACKSTOPRING OFFICER: VASIL ILIEV, DIO/T/MET

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

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ABSTRACT

The present report on aluminium electrolysis process development and engineering is the result of the expert mission DF/IND/088/015/11-10 carried out in India from 27th March to 10 th Augustus 1992 (with briefing, debriefing)

The therms of reference to the expert mission were the following:

1. To installe the equipments needed for the measurements in aluminium electrolysis
2. To provide a training course for the counterpart staff/scientists of the Centre, in evaluation of measured data.
3. To ellaborate proposal for modernization of BALCO aluminium smelter, in coorperation with BALCO experts
4. To prepare the measuring program and to carry out the measurements and evaluate the data.

The mission was e.tended to review on the future of Hall--Heroult process and the special laboratory measuring methods.

In addition to these, a three day workshop on aluminium electrolysis was organized in NALCO plant Angul.

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

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INTRODUCTION

This report has been written by J. HORVATH as a result of expert mission carried out in India under the UNDP/UNIDO Project DP/IND/89/015 - Jawaharlal Nehru Aluminium Research Development and Design Centre.

According to the job description DP/IND/88/015/ 11-10 with post title: "Expert in aluminium electrolysis process development and engineering", as per Annex-I, the expert was required to provide - the installation of equipments and, preparing of and carriing out of preparing measuring process, evaluation of measured data, ellaboration of proposal for modernization of existing aluminium smelter.

In addition to the job description constructive suggestions have been given to the expert at debriefing in UNIDO Vienna by Mr. V. Iliev, BSO, and UNDP Delhi by Mr. L. Bredal and at JNARDDC in NAGPUR by Dr. J. Zambo, CTA and Dr. T. R. Ramachandran NPD. Both job description and suggestions formed the basis for the schedule programme prepared at beginning of the mission as given in Annex-II.

Ir can be seen from the schedule programme that the activities and duties as per the job description were extended by proposal for BHARAT ALUMINIUM COMPANY modernization. This was done due to the fact that presently the main activities in smelter technology are to decrease the energy consumption and increase the curcent efficiency.

In addition to performing duties mentioned in the job description a three day workshop on aluminium electrolysis, together with other experts (E.A. Yanko, and V. Krjuokovski).

Sections C of report deal the evaluation of measured data and summary of knowledge needed to evaluate the energy and voltage balance of existing aluminium electrolysis cell.

On the base of these komplex evaluation methods the proposal was ellaborated for modernization of BALCO smelter at Korba, as in Section D can be found.

ACTIVITIES

Itinerary and list of main activities following the job description, as per Annes-I and the programme on mission as per Annex-II are given.
The main activities, conclusions and proposals are described as follows.

A. Installation of the equipments needed for the measurements in aluminium electrolysis cells

To determine the complex energy - voltage and heat losses of the existing aluminium electrolysis cell the following equipments were used:

- 16 Channel data acquisition and Processing system
- Heat flow meter
- Thermovision
- X-Y recorder
- Infrared tele thermometer
- Magnetometer-I
- Power supply unit
- Magnetometer-II
- Temperature measuring unit
- Non contract thermometer

All equipment were cheking and some preliminary measurements were carried out in the research center in Nagpur.
Transported to Bharat Aluminium Company Aluminium smelter at Korba.

8. Preparation of measuring process

In close cooperation of the Balco expert the measuring conditions were established.
As our discussion and proposals a measuring room was built. In this measuring room the equipment were located. More detailed information can be founded in annexure-III.

The Balco experts have arrived in JNARDDC at Nagpur. All measuring procedures were explained in detail to BALCO team.

It was founded no difficulty in carrying out the as per the schedule agreed earlier at Korba. In this period proposal for modernization of BALCO smelter was dicussed. On the base of previsouly calculations the team members agreed that the projected operational parameters (current efficiency 88,0 % energy cousumption 15.5 kWh/kg) could be achieved by the proper modification. (Annecure - IV)

In JUNE of 1992 the measurements were carryed out with close cooperation in BALCO and JNARDDC experts.

The applied measuring methods were the followings:

- Magnetic field induction measurements in molten aluminium to determine the stability of cell operation
- Anodic and cathodic current distribution
- Electrolyte temperature and composition (molar ratio by XRD diffraction, alumina by wet chemical method)
- Heat losses on construction elements of aluminium electrolysis cell

- all electrical parameters coming to cell
  = monitoring of pots (Resistance v.s time)
  = noise of pots (instability of cells)
  = anode effect parameters (voltage, duration and development of anode effect)
  = EMF (Electromotive force) by current sinking method
  = metal touching to detemine the anode - cathode distance and anode voltage drop.

With close cooperation of BALCO experts have carried out measurements on 13 experimental pots. Based on the experiment carried out from 5 th June to 26 June preliminary report, conclusions and proposals were made. (Annexure-V)

After discussion with BALCO experts it was proposed by JNARDDC:

- raising the cell voltage from 4,4 to 4,7 volts
- removing of sludge, skiping the alumina feeding and waiting anode effect
- adding of broken bath
- decreasing of metal level
- alumina feeding modification

The BALCO managment have founded these measurements very useful and requested JNARDDC to carry out these measurements after modification of cell operation. (Annexure-VI) our presentation and evaluation were very usefull to improve the technological parameters of existing aluminium electrolysis at BALCO.

C. EVALUATION OF THE MEASURED DATA

The results of the measurements was given in Annexure VII. Some important conclusions arising from these studies are: relating to existing technology

- the set cell voltage is 0,3 V lower than what it should be according to voltage balance of cells this indicates low ACD
- the cell operation indicates unstable
- alumina layer on the crust is non-uniform
- cathode and current ditribution are non uniform
- sludge formation is high
- magnetic field induction components are not stable and non-symmetric
- heat losses are high on side walls

The scheduled programme of proposed modifications consist of two part.
The first step is immediate action without investment by removal of sludge, removal of solid particles from the deck plate, adjustent of metal and bath height.
The second step is the modification of crust breaking and alumina feeding technology.
It is necessary to modify the alumina quality.

The basic requirement is to decrease alumina particles to max 20 % below 45 μm.

It was made a separate report (Annexure-VIII) which is shown the evaluation and analysis of measured data.
The - all measurements data for the noise analysis can be found in FILE No. 1. (with JNARDDC).
- all the measurements data for EMF (electromotive force) can be found in FILE No. 2

- anode effect valve and its duration and increasing period can be found in FILE No. 3 (with JNARDDC)
- Data of the cell resistance as a function of crust breaking monitoring mode can be found in FILE No. 4
- Data of magnetic field induction and anode-cathode current distribution can be found in FILE No. 5. 6.

For the evaluation was used the following software programmes:

- "Magnetic bas" (with JNARDDC) for calculation of the different components of measured magnetic field induction data
- "Anode and cathod current distribution" (with JNARDDC)
- "UNIDO 1 and UNIDO 2" (with JNARDDC) for calculation of voltage and energy balance from data of "metal tovching"

In this report the evaluation and calculation method, equations were summarized, which are needed to determine the energy and voltage balance of cell. The evaluations and calculations use general theoretical relationships, so the complete measuring methods and evaluation are suitable for both Söderberg and prebaked cells.

For the evaluation and calculation the following documents were handed over to JNARDD'S experts, and were ured in this report.

- All measuring procedures, evaluation and calculation methods needed to determine the optimum cell parameters of the BALCO cell operation

- Instruction for technical documentation and completion of magnetic field measurements
- user's quide to data acquisition system
- Determination of cell stability on the basis of magnetic conditions
- Heat-energy balance and current efficiency of aluminium electrolysis cells
- Detection of irregularly operating cells by data acquisition system
- Measuring methods and tools for plant measurements
- Methods for test of magnetohydrodynamic parameters of aluminium reduction cells

The measuring methods and evaluation were used in BALCO smelter to determine status and operation of existing cell. During these measurements and evaluation process the JNARDDC experts were trained to be able to use the measuring methods and evaluate the data. This report was made in close cooperation with JNARDDC experts and BALCO experts. The JNARDDC experts are able to carrying out measurements and evaluate data to determine the optimum parameters of existing cell operation.

This report was considered as a basic material for the finalisation of main action during BALCO modernization.

D. PROPOSAL OF MODERNIZATION OF THE EXISTING ALUMINIUM SMELTER

With Using of this basic material proposal was made for the modernization of BALCO smelter at Korba. (Annexure-IX).

The detailed energy and voltage balance was discussed with BALCO experts at site and a joint proposal was prepared for the modernization of the whole plant.

The measuring data and evalvation methods were used to determine the main direction of modernization. The Bharat Aluminium Company plans to modernize its aluminium smelter (Korba), commissioned in 1975.

The main stress of this modernization is to improve the operational parameters and to achieve the predicted industrial average data and to meet the more strict enviromental requirements.

The main elements of modernization Concept are:

- installation of pot controller
- introducing of automatic crust breaking system with bar breaker
- training programme,
- investment cost

The salient features of the proposal are the following:

- modification of technology and operational routine without introducing changes in cell operation
- installation of controllers and bar breakers for improvement of existing operational parameters.

E. THE OTHER ACTIVITIES

The cooperation between National Aluminium Company and JNARDDC were discussod by representatives. To clarify the technical details a meeting was organized in Angul between JNARDDC and NALCO experts.
During of this meeting the following topics were discussed.

- characterisation of Electric/thermal state of existing cells with amorphous cathode blocks and modified cells with graphitised cathode blocks
- heat balance of existing cells and cells built with indigineous bricks
- heat balance of anode baking furnace.

The tentative work programme was proposed to carry out the above mentioned project. (Annexure-X).

A 3 day international workshop on "Aluminium ELECTROLYSIS" was organized by JNARDDC and NALCO in Angul on July 13. As many as 40 delegates from various aluminium industries/consultancy organizations have participated in the workshop. (BALCO, NALCO, INDAL, HINDALCO, MECON, NORTON).
The program can be found in Annexure-XI. The course material was handed over to participiants.

In addition, the following technical information was provided to the Centre/Companies:

- The future of Hall-Heroult process and supplementary information to development of Indian Aluminium Smelter technology (review).
- Training material for technical assistants

- Proposal for determination of heat transfer coefficient between frozen and liquid bath
- Training programm for BALCO and JNARDDC experts
- Transparencies (30 pieces) for demonstration purposes

A N N E X U R E - I.

UNIDO

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

REQUEST FROM THE GOVERNMENT OF INDIA

JOB DESCRIPTION

DP/IND/88/015/11-10

POST TITLE: Expert in aluminium electrolysis process development and engineering

DATE REQUIRED: November 1991

DURATION: 4 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

..../..

DUTIES: The expert will be required to advise on evaluation and application of laboratory/pilot plant and industrial plant level investigation/research results from aluminium electrolysis cells as well as on preparation of techno-economic feasibility studies and basic engineering for improvement of the electrolysis cells.

His main duties will be to:

a) Provide advisory services and assist in feasibility techno-economic justification for improvement of the aluminium electrolysis cells based on process data and recommendations available from the special mobile van measurement unit.

b) Provide a training course for the counterpart staff/scientists of the Centre in evaluation of research/investigation process data and in preparation of techno-economic pre-and feasiblity study reports in the field of aluminium electrolysis.

The expert is expected to submit a final technical report upon completion of his mission.

QUALIFICATION: University degree (preferably Ph.D.) in Chemical or Metallurgical Engineering experienced and well versed in evaluation/application of research results from aluminium electrolysis cells and in preparation of techno-economic feasibility studies.

LANGUAGE: English

BACKGROUND INFORMATION: The Indian aluminium industry looks back to a history of 44 years. The first aluminium smelter (in Alumpara, 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 installled 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 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 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.

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 tonne 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 co-ordinated 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:

- Aluminina 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.

ANNEXURE-II.

SCHEDULE

1) PREPARATION OF EQUIPMENT AT JNARDDC TO CHECK THE STATUS OF EQUIPMENT NEEDED FOR THE MEASUREMENT AT PLANT SITE AND TO TAKE CORRECTIVE ACTION AS REQUIRED - 10TH APRIL.

2) VISIT TO KORBA SMELTER :
   - TO ORGANISE AND PREPARE FOR THE PLANNED MEASUREMENTS
   - TO BRIEF THE BALCO MANAGEMENT ON THE PURPOSE OF MEASUREMENTS
   - TO GIVE COMMENTS TO BALCO FOR SITE PREPARATION

   15TH APRIL

3) VISIT TO NALCO (ANGUL)
   - TO COLLECT INFORMATION FOR DEMANDED MEASUREMENTS
   - TO CLARIFY THE NUMBER OF MEASUREMENTS AND THE METHODES OF EVALUATION
   - REPORT ON NALCO VISIT

   8TH MAY

4) FINALISATION OF EQUIPMENT AND TRANSPORT TO BALCO

   16TH MAY

5) CARRYING OUT MEASUREMENTS AT BALCO SMELTER

   15TH JUNE

6) EVALUATION AND ANALYSIS OF MEASURED DATA. STANDARDISATION OF MEASUREMENT AND TRANSFER OF KNOWLEDGE. ON THE BASE OF EVALUATION MAKE RECOMMENDATION FOR IMPROVEMENT OF EXISTING ALUMINIUM ELECTROLYSIS TECHNOLOGY AT KORBA PLANT

   30TH JUNE

7) WORKSHOP, SEMINAR ON ALUMINIUM ELECTROLYSIS TECHNOLOGY

   15TH JULY

MAIN ACTIVITIES

1) CHECKING ALL THE EQUIPMENT NEEDED FOR CARRYING OUT MEASUREMENTS IN THE PLANT (DATA ACQUISITION, HEAT FLUX, MAGNETIC FIELD INDUCTION, CURRENT DISTRIBUTION, GAS ANALYSIS FOR DETERMINATION OF CURRENT EFFICIENCY).

2) BALCO VISIT (DISCUSSION FOR SITE PREPARATION (PLACE, CELL NUMBER, CABLING)

3) TRANSFER OF KNOWLEDGE FOR DETERMINATION OF CELL PARAMETERS AND MONITORING OF ALUMINIUM ELECTROLYSIS PROCESS
   i) MEASURING PROCEDURES
   ii) EVALUATION SYSTEM

4) MEASUREMENTS AT BALCO PLANT (SMELTER)

5) NALCO VISIT, DISCUSSION FOR DETERMINATION OF HEAT BALANCE :
   i) ALUMINIUM SMELTING POT
   ii) ANODE BAKING FURNACE

6) DATA EVALUATION, ANALYSIS OF MEASURED DATA. DEVELOPING PROPOSALS FOR IMPROVEMENT OF EXISTING ALUMINIUM REDUCTION CELL TECHNOLOGY AND MODIFIED CELL OPERATION.
THE FOLLOWING PARAMETERS WILL BE MEASURED AND THE EQUIPMENT WILL BE USED, AS SHOWN BELOW

PARAMETERS	EQUIPMENT	REQUIREMENT OF PREPARATION AT SITE	MEASURING PROCEDURE	EVALUATION
CELL VOLTAGE CELL LINE CURRENT	16 CHANNEL DATA ACQUISITION SYSTEM	CABLING, LOCATION AC	SEE: INSTRUCTIONS AND OPERATING MANUAL ATTACHMENT NO. 1	NOISY PROGRAM ANODE EFFECT MONITORING CURRENT SINKING TAPPING PROGRAM
EMF AC-DISTANCE SHORT CIRCUIT VOLTAGE ELECTROLYTE TEMP AND COMPOSITION (Al_2C_3 MOLAR RATIO ADDITIVES)	-----"-----	-----"-----	SEE: INSTRUCTIONS AND OPERATING MANUAL ATTACHMENT NO. 2	EVALUATION
ANODIC AND CATHODIC CURRENT DISTRIBUTION	VOLTMETER	UNIFORMITY OF LINE CURRENT	SEE ATTACHMENT NO. 3	EVALUATION ATTACHMENT NO. 3
HEAT LOSSES DISTRIBUTION MEASURING	HEAT - FLUX METER	SMALL CHANGES IN IN CELL PARAMETERS	SEE ATTACHMENT NO. 4 (OPERATING DESCRIPTION OF HFM)	HEAT FLUX DISTRIBUTION ON CONSTRUCTION ELEMENTS (ANODE-CATHODE ASSEMBLY ALUMINA-LAYER)
MAGNETIC FIELD INDUCTION	GAUSSMETER	UNIFORMITY OF LINE CURRENT, TO REACH MOLTEN METAL	SEE ATTACHMENT NO. 5	VALUE OF VERTICAL MAGNETIC FIELD COMPONENT AND B_x BY SYMMETRY
CURRENT EFFICIENCY BY ANALYSING GAS	HARTMANN-BRAUN INFRARED GAS ANALYSER	TAKING SAMPLE AND FILTERING OF EXHAUST GASES	SEE ATTACHMENT NO. 6 OPERATING DESCRIPTION	CURRENT EFFICIENCY DETERMINATON

7) WORKSHOP/SEMINAR ALUMINIUM ELECTROLYSIS (PROGRAM WILL BE ELABORATED LATER)

8) REPORT ON STATUS OF INDIAN ALUMINIUM SMELTER TECHNOLOGY AND COMPARISON WITH STATE OF ART SIMILAR SMELTER TECHNOLOGY, CONCLUSIONS AND RECOMMENDATIONS.

ANNEXURE - III.

RECORD NOTES OF THE MEETING HELD BETWEEN JNARDDC, NAGPUR AND BALCO FROM 15TH APRIL TO 18TH APRIL 1992 AT BALCO KORBA

P R E S E N T

JNARDDC, NAGPUR	BALCO, KORBA
1. Dr.J.Horvath	1. Shri P.N.Sharma
2. Shri GS Sengar	2. Shri SC Bhattacharjee
3. Shri Anupam Agnihotri	3. Dr P.K.Moitra
	4. Shri PK Gairola
	5. Shri ON Sharma

JNARDDC representatives informed BALCO that measurement of Magnetic, Thermal and Electric state of cell will commence in the 1st week of June 1992. During discussion a schedule of work plan is prepared(Annexure-I) and following observations were made:

1. Determination of various cell parameters by sophisticated equipments like Data Acquisition System, thermovision, heat flux meter etc. will be done. Thermal State, Heat Balance, Voltage Balance of the Cell can be carried out to determine existing state of cell. However, due to current fluctuation problem (graph attached) cathode current, anode current and magnetic field distribution can be determined only approximately. BALCO agreed to keep the current fluctuation to the minimum possible extent.

2. JNARDDC representatives informed BALCO that Data acquisition system requires line current intensity in the form of 0-5V signal. BALCO informed that normally line current intensity is measured in the form of either 4-20m Amp current signal or 0-10V Voltage signal. BALCO agreed to carry out necessary modifications in their system so that line current intensity in the form of 0-5V signal will be available to Data Acquisition system for measurement.

3. The proposed room in cell house 5 for measurements was found to be small and requires changes/modification as below:

   a) Minimum of $15m^2$ working space should be made available.

   b) Vinyle Flooring and Painting of wall be done.

   c) Two Nos. AC, Fan etc to be provided

   d) Working Platforms on Two sides of Room with cubboard below to be made.

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e) Double Door arrangement with proper locking facilities to be arranged.

f) Isolation transfer and voltage stabilizer of 5 KVA be provided.

g) One wash-basin be provided

h) Table/chairs be arranged

BALCO agreed to make all the above mentioned arrangement by May 15, 1992.

4. JNARDDC representative requested BALCO to make following arrangement:

   a) Cushioned casing with transparent front side for heat flux meter of size 30x30x18 cm

   b) A list of simple measurement tool was given to BALCO. These can be fabricated as per the given sketch with any modification based on BALCO Cells.

   c) A list of parameters which needs to be measured during test period is given to BALCO. It was agreed by BALCO.

   JNARDDC proposed to train few BALCO personnel on the measurement methods prior to commencement of study. BALCO agreed to constitute a working team and shall send the same to Nagpur.

5. JNARDDC requested BALCO to provide working uniform alongwith necessary safety appliances to all personnel of JNARDDC involved in the measurements. It was agreed by BALCO.

(Dr.J.Horvath)

(G.S. Sengar)

(S.C. BHATTACHARJEE)
G.M.(Smelter)

(O.N. SHARMA)
M (R&D)

ACTIVITIES

Sl. No.	ACTIVITY	PERIOD	RESPONSIBILITY
1	Outlining the requirements on Preparation of Site	Aprl 14-18	JNARDDC
2	Preparation of Site	Aprl 18-May 18	BALCO
3	Training of BALCO Personnel at Nagpur	May 10-May 13	JNARDDC
4	Transportation of equipment from Nagpur to Korba	May 15- May 25	JNARDDC
5	Installation and commissioning of Equipment	May 25. May 30	JNARDDC & BALCO
6	Measurement on Korba Cells	June 1-June 21	JNARDDC & BALCO
7	Evaluation of Data at Nagpur	June 21-July 5	JNARDDC & BALCO

ANNEXURE-IV.

JAWAHARLAL NEHRU ALUMINIUM RESEARCH
DEVELOPMENT AND DESIGN CENTRE NAGPUR

RECORD NOTES OF THE MEETING HELD BETWEEN JNARDDC, NAGPUR AND BALCO FROM 11TH MAY TO 13TH MAY 1992 AT NAGPUR

PRESENT

JNARDDC NAGPUR

1) Dr. T.R. Ramachandran
2) Dr. J. Zambo
3) Dr. J. Horvath
4) Dr. A.V. Kryukousky
5) Dr. E.A. Yanko
6) Mr. G.S. Sengar
7) Mr. Anupam Agnihotri

BALCO KORBA

1) Shri P.K. Gairola
2) Shri D.K. Das
3) Shri S. Nag
4) Shri S. Badri Appan

At the outset, Director JNARDDC welcomed the BALCO team which came to Nagpur for undergoing training in measurement procedures for electric, thermal and magnetic state of cell. Following points were discussed :

1. BALCO informed JNARDDC that proposed room in cell house for measurement is being modified in line with various changes/modifications as suggested by JNARDDC in the earlier meeting at BALCO. This room will be ready for carrying out the measurement by 20th May 1992.
2. BALCO informed JNARDDC that all measurement tools and cushioned casing for heat flux meter is ready.
3. All the measuring procedures were explained in detail to BALCO team. BALCO team was satisfied with the training programme and expected no difficulty in carrying out the measurement as per the schedule agreed earlier at Korba.

contd...2...

4. BALCO team inspected the packing of various measuring instruments and expressed the opinion that packing is of good quality and instrument can be transported in existing packing.

5. Proposal for modernisation of BALCO smelter including raw material requirement, training programme and spares for testing equipment was discussed and finalised.

6. All the members present agreed that the projected operational parameters (current efficiency 88%, power consumption 15.5 kWh/Kg) could be achieved by the proper modifications.

JNARDDC

13/5/92

BALCO

13/5/92

ANNEXURE-V.

PRELIMINARY REPORT, CONCLUSIONS AND PROFOSALS BASED ON THE EXPERIMENTS CARRIED OUT FROM 5TH JUNE TO 26 JUNE 1992

INTRODUCTION

The JNARDDC experts with close co-operation of BALCO experts carried out measurements on 13 experimental pots. Following parameters were measured on the same pots:

- Magnetic field induction
- All Electrical parameters coming to cell
- Heat losses on construction elements
- Anode and cathode current distribution
- Electrolyte composition and temperature

In the first phase of measurements following parameters were measured and analysed :

- Monitoring of pots (Resistance Vs time)
- Noise of pots (Instability of cells)
- Anode effect parameters (Voltage , duration and development of anode effect)
- Metal Tapping (Resistance Vs time)
- EMF (Electromotive force) by Current Sinking method
- Metal touching (ACD)

It was concluded that the noise is very low, the value of anode effect is low too (below 20 volts) indicating a warm cell operation. The EMF gives a very useful information about cell operation, its value was also low (1.40 - 1.44 volts). The evaluation of these values show warm cell operation which is caused by low ACD i.e. exothermic back reaction.

JNARDDC after discussion with BALCO experts proposed to raise the cell voltage from 4.4 to 4.7 volts. The effect of raising voltage of the cell no. 514, 515 and 516 is shown in table below.

Table I :Change in measured parameters after raising cell voltage

PARAMETERS	EXPERIMENTAL CELLS (514, 515 & 516)	TRADITIONAL CELLS (517 - 526)
NOISE	NORMAL	LOW
ANODE EFFECT VOLTAGE (Volts)	28 - 30	< 20
EMF (Volts)	1.72	1.41
Al_2O_3 (%)	4.0	5.6 - 8.9
ELECTROLYTE TEMPERATURE (°C)	978 - 980	990

Main purpose of skipping alumina feeding was to eliminate large amount of sludge from the cathode bottom. Crust breaking was done without alumina feeding in order to cool the cell and keep proper side freeze .

Sludge was observed to decrease and no anode effect occurred during next 20 hours on experiment cells. Due to increased cell voltage noise was normal, anode effect voltage was observed to increase upto 30 volts and EMF also increased. Electrolyte temperature decreased to 975 - 980°C.

The concept on which measurement was based was verified by the practice. It is established that sludge removal is possible with skipping of alumina feeding. The three experimental cells were not regulated by [illegible] because our earlier measurements showed some discrepancies, such as beam regulation after stud pulling and before anode effect.

The AVC regulation doesn't take into account resistance increase after stud pulling and before anode effect. Partly removal of sludge results in decrease of metal/bath level. This action is needed to remove the solid bath from deck plate to avoid its feeding to bath. The crust and broken bath increase the risk of sludge formation.

To achieve a better cell operation some modifications are to be done in the first step, as was proposed by JNARDDC:

The scheduled program of modification is as follows:

- To remove sludge, skip the alumina feeding and wait for the anode effect.

- To keep proper side freeze crust breaking should be done every hour and broken bath of size 5 mm max should only be added if required.

- This process should be continued till all sludge is dissolved

- If all the other cell voltage components are constant, decrease the cell voltage by 100 mv.

- The dissolution of sludge results in increase of cathode cavity

REMARK: This process was used successfully to dissolve sludge in experimental cells.

- Metal level should decreased 26 - 28 cm very slowly (1 to 1.5 weeks time) this value depends on thickness of deposit layer

The purpose of this process is to decrease the bath level below deck plate and to remove solid particles from deck plate. Large amount of cold crust and large particles of broken bath should not be added to liquid bath.

- The height of bath and metal should be chosen such that level of bath is 6 cm below deck plate level. The total height of deposit, metal and baht should 47cm.

Electrolyte : 19 cm

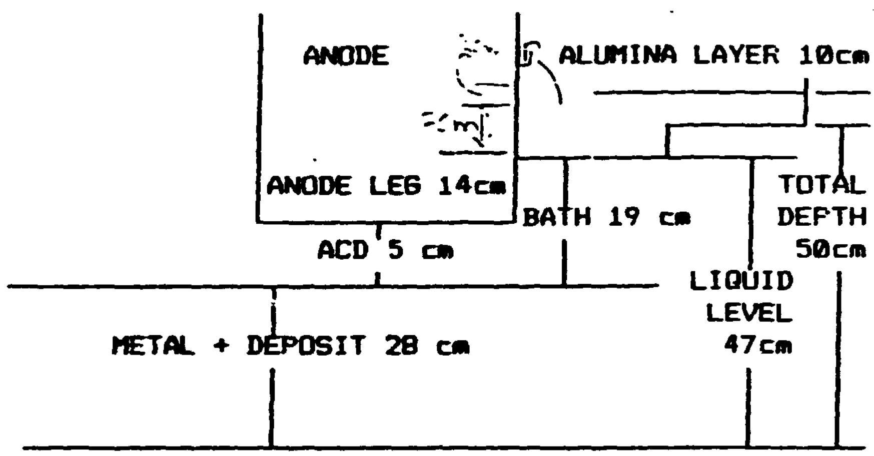
Metal + deposit : 28 cm

AC distance : 5 cm

Anode immersion depth : 14 cm

- keep the anode skirt 7 cm above the electrolyte level.

Very fine control/accurate measurements are needed to achieve the position shown in the sketch below :



- Fresh alumina feeding and leveling is also needed
- If the no. of anode effect increases, it is necessary to increase the no. of scheduled crust breaking. The increasing of alumina layer is not proposed in this period.
- After crust breaking it is necessary to feed alumina as early as possible and alumina leveling should be done as shown in the sketch.
- After achieving this position crust breaking system is to be modified.
- The crust breaking system should consist of two parts, scheduled crust breaking and crust breaking during anode effect

- Three anode effect per day should be kept in three experimental pots during initial period in order to avoid sludge formation.

- Two scheduled crust breaking should be done in every shift and third crust breaking should be done only during anode effect. This crust breaking is different from scheduled crust breaking. Both the long sides should be broken during crust breaking after anode effect and the cell voltage should be raised by 100 mv in order to supply necessary energy for alumina dissolution.

- If the time interval is less than one hour for the next scheduled crust breaking, next scheduled crust breaking should be skipped.

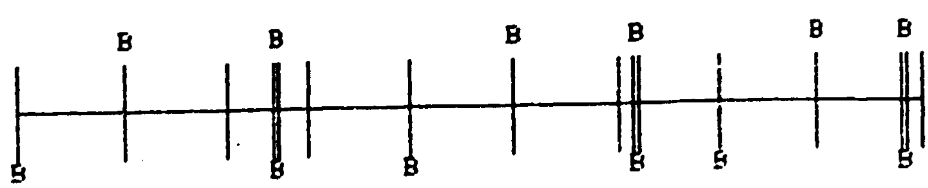
PROPOSAL FOR SCHEDULE CRUST BREAKING AND ALUMINA FEEDING IN COMBINATION WITH CRUST BREAKING AFTER ANODE EFFECT

<u>Principle</u> : One anode effect per shift per cell is to be achieved in order to avoid sludge formation during initial period of experiment

<u>Demand</u> : 1200 Kg alumina per day + short side crust breaking

<u>Schedule program for crust breaking</u>

<----Ist shift---><----II shift---><----III shift--->



B ——— : Schedule crust breaking

B ═══ : Crust breaking during anode effect

Crust breaking after anode effect is carried out on both the long sides and cell voltage should be raised by 100mv in order to supply necessary energy for alumina dissolution. If the interval between schedule crust breaking and crust breaking after anode effect is less than one hour, scheduled crust breaking should be skipped. If the interval between schedule crust breaking and crust breaking after anode effect is more than one hour schedule crust breaking should be done as usual.

FOR BALCO

FOR JNARDDC

DTD : 27 JUNE, 1992

ANNEXURE - VI.

MINUTES OF MEETING HELD BETWEEN JNARDDC, NAGPUR AND BALCO, KORBA ON 29 JUNE, 1992

BALCO	JNARDDC
1. SHRI S.C. BHATTACHARJEE	1. DR J. HORVATH
2. SHRI P.K. GAIROLA	2. SHRI G.S. SENGAR
3. SHRI S. NAG	3. SHRI A. AGNIHOTRI

Following points were discussed :

1. As decided earlier, detailed measurements for determination of electric, thermal and magnetic state of BALCO's cells were carried out in close co-operation with BALCO experts from 4.JUN to 26, JUN, 1992.

2. JNARDDC experts gave a preliminary report on status of BALCO's cells along with conclusions/recommendations for improvement at the end of experiments. Modified technological parameters were implemented on three experimental pots (514, 515, 516). Sludge has been observed to dissolve and cathode bottom was found to be much cleaner. BALCO agreed to continue these experiments based on recommendations by JNARDDC. A detailed report will be submitted to BALCO afterwards.

3. BALCO found these measurements very useful and requested JNARDDC to carry out these measurements after implementation of improved work routines. BALCO also requested JNARDDC to train their operating personnels for improvements in work routines at JNARDDC, Nagpur. JNARDDC will inform about this at a later date.

4. JNARDDC experts gave a presentation on improvement in technological parameters and determination of electric, thermal and magnetic state of cell at M.T.I., BALCO on 29. JUN, 1992.

5. BALCO requested JNARDDC to spare Data-Acquisition System for carrying out noise analysis of BALCO cells. JNARDDC experts expressed their inability to spare Data-Acquisition System because measurements are already planned at other site.

6. As decided earlier, all the equipments for carrying out measurements (as per list enclosed) is being handed over to BALCO for safe custody. These equipments will be taken back soon.

7. JNARDDC/BALCO experts tested Nitride bonded Silicon Carbide tubes (supplied by GRINDWELL NORTON INDIA LIMITED) for their corrosion resistance against cryolite melts.

8. A very useful discussion was held between JNARDDC experts and ECIL, Hyderabad experts for development of pot controllers in India.

JNARDDC experts are extremely thankful to BALCO team for their excellent co-operation and help.

FOR BALCO

FOR JNARDDC

S.No.	Name of Equipment	Cost
1.	16 Channel data acquisition and Processing system	US$ 87,590
2.	Heat flow meter	US$ 34,400
3.	Thermovision	US$ 136,526
4.	X-Y recorder	US$ 2,743
5.	Infrared tele thermometer	US$ 2,531
6.	Magnetometer-I	US$ 4,204
7.	Power supply unit	US$ 1,343
8.	Magnetometer-II	US$ 5,000
9.	Temperature measuring unit.	US$ 450

A N N E X U R E - VII.

INTRODUCTION

The International experts and scientists of the Jawaharlal Nehru Aluminium Research Development and Design Centre Nagpur carried out measurements on thirteen experimental cells at BALCO in collaboration with the engineers of BALCO in June 1992 in order to assess the present state of the cells and to suggest possible measures for their improved performance. Based on these measurements, evaluation of the results and international experience, a proposal is made to the BALCO management - this envisages a two stage operation. the first involving improvement of the existing situation by improving the plant discipline without any financial input and the second by introducing additional equipment (pot controllers and bar breakers) for improved parameters.

The important parameters of cell operation after various stages are summarised below (Table I):

Table I : Parameters of cell operation after proposed modification

Parameter	Present	Value I stage	II stage
Cell voltage(V)	4.72	4.50	4.53
Current Efficiency (%)	80	85	90
Energy consumption (kWh / kg)	17.6	15.8	15.0

The plan of action necessary to implement stage I is presented in detail in this report.

EXPERIMENTAL MEASUREMENTS, EVALUATION AND INFERENCE

The following parameters were measured on the pots in order to characterise their present status:

- noise analysis
- development and peak value of anode effect
- electromotive force (EMF)
- cell resistance as function of time
- voltage distribution in anode-cathode gap

(All the above parameters were measured with the Data Acquisition System)

- anode-cathode bus bar voltage drop
- anode-cathode current distribution
- electrolyte composition and temperature
- magnetic field induction
- heat losses on construction elements of pots
- anode-cathode distance (ACD)

The results of the measurements and their evaluation are provided in a separate report. Some important conclusions arising from these studies are given below.

- THE SET CELL VOLTAGE IS ABOUT 0.3 V LOWER THAN WHAT IT SHOULD BE ACCORDING TO VOLTAGE BALANCE OF CELLS- THIS INDICATES LOW ACD.
- THE CELL OPERATION IS UNSTABLE (HIGH ELECTROLYTE TEMPERATURE, LOW ANODE EFFECT VOLTAGE, LOW EMF AND FREQUENT SHORT CIRCUITING)
- THE ALUMINA LAYER ON THE CRUST IS NONUNIFORM: LARGE QUANTITIES OF SOLID PARTICLES ARE FOUND ON THE DECK PLATE. THE ALUMINA FEEDING IS NOT PROPER AND THIS HAS CONTRIBUTED TO CONSIDERABLE AMOUNT OF SLUDGE ON THE BOTTOM OF THE CATHODE.
- CATHODE AND ANODE CURRENT DISTRIBUTION ARE NONUNIFORM AND THE VALUES OF ANODE AND CATHODE VOLTAGE DROPS ARE ABOUT 100 - 150 mV HIGHER THAN NORMAL.
- FREQUENCY OF ANODE EFFECT IS HIGH (0 - 11 PER DAY PER CELL) AND ITS DISTRIBUTION WITH TIME IS IRREGULAR
- CALCULATED AND MEASURED VALUES OF CURRENT EFFICIENCY ARE LOW (70 - 75 %)
- CURRENT FLUCTUATION IS CONSIDERABLE (IN THE RANGE 85 - 103 kA)

STUDY OF EXISTING CELL OPERATION

The first step of normalisation is to remove the sludge formed on the cathode bottom. This can be done by skipping alumina feed as concluded from the observations on a pot deprived of alumina feeding for 29 hours where no anode effect was observed. Crust breaking was carried out periodically to cool the cells and the side freeze was kept in proper condition by adding broken bath. During this period approximately 1000 - 1200 kg of alumin^ was removed from the sludge. Simultaneously the cell voltage was raised from 4.42 to 4.72 V

- anode-cathode bus bar voltage drop

- anode-cathode current distribution

- electrolyte composition and temperature

- magnetic field induction

- heat losses on construction elements of pots

- anode-cathode distance (ACD)

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Table II: Change in measured parameters after raising cell voltage

Parameter	Value	
	experimental	Traditional cells
Noise	Normal	Low
Anode effect voltage (V)	28 - 30	< 20
Al_2O_3 (%)	4.0	5.6 - 8.9
Electrolyte temperature (C)	978 - 980	990

Partial removal of sludge (1000 - 1200 kg) results in decreasing metal/bath level. We prefer decreasing metal level as it gives a better chance for sludge dissolution.

Details of cell voltage balance of the experimental and traditional cells are provided in Table III. It is clearly seen from the data presented in the table that current efficiency, power consumption, energy efficiency are superior in the case of the experimental cells.

Our observations indicate that it is also necessary to improve the current distribution in order to decrease the longer current path. This can be accomplished by exercising better care in anode stud pulling and replacement.

On the basis of these observations it is clear that there is scope for improvement of cell operation. As a first step we recommend a programme of action which does not involve any investment but only calls for disciplined approach towards minimising some of the existing problems.

SCHEDULED PROGRAMME

REMOVAL OF SLUDGE:

- skip alumina feeding and wait for anode effect
- raise the cell voltage by 200 mV
- crust breaking to be done every hour to maintain proper side freeze and broken bath of size below 5 mm should be added only when required; maintain constant bath level by removing excess bath.

- above steps to be continued until all the muck is dissolved

- decrease the cell voltage by 100 mV if all other cell voltage components are constant.

- if the anode quantity does not change, skimming should preferably be once in two days immediately after the occurrence of the anode effect.

SCHEDULED PROGRAMME OF MODIFICATIONS

IMMEDIATE ACTION WITHOUT INVESTMENT

BY REMOVAL OF SLUDGE

- To remove sludge/hard muck, skip the alumina feeding and wait for anode effect.

- raise the cell voltage by 200 mv.

- to keep proper side freeze, crust breaking should be done every hour and broken bath of size below 5 mm should only be added if required. Any excess bath should be removed so as to maintain constant bath level.

- this process must be continued till all the sludge is dissolved.

- if all the other cell voltage components are constant, decrease the cell voltage by 100 mV.

- the dissolution of sludge results in increase of cathode cavity

- if the anode quality does not change skimming should preferably be done once in 2 days immediately after the onset of the anode effect.

- skimming removal should be carried out on the short-side (vehicles for short-side breaking are needed)

- simultaneously with this action it is necessary to improve current distribution, by controlling stud replacement.

IT IS NECESSARY TO MENTION HERE THAT THESE STEPS WERE SUCCESSFULLY USED TO DISSOLVE THE SLUDGE IN THE EXPERIMENTAL CELLS.

REMOVAL OF SOLID PARTICLES FROM THE DECK PLATE:

The purpose of this process is to decrease the bath level below deck -plate and to remove solid particles from deck plate. Large amount of cold crust and large particles of broken bath, should not be added to liquid bath as these materials increase the risk of sludge formation. The following steps are of importance.

- Big lumps of bath, after removal, must be crushed and screened to below 5 mm; these could be used for cooling of side freeze.

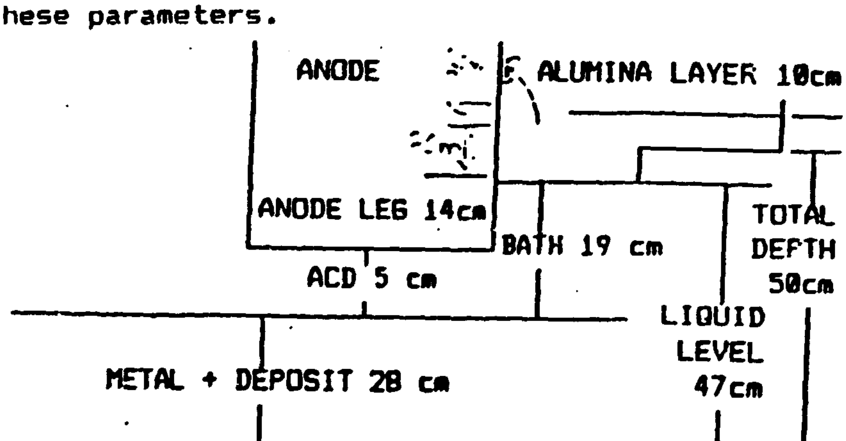
- metal level should be decreased to 26-28 cm very slowly (1 to 1.5 weeks time)

ADJUSTMENT OF METAL AND BATH HEIGHT:

The height of bath and metal should be so chosen that the level of bath is 6 cm below deck plate. The levels of various constituents should be as follows:

Electrolyte	:	19 cm max
Metal + deposit	:	28 cm (before tapping) & 26(after tapping)
ACD	:	5-5.5 cm
Anode immersion depth	:	14 cm

Very fine control/accurate measurements are needed to achieve these parameters.



Details of proposed measuring methods and drawings of tools were handed over to BALCO (e.g. ACD, METAL/BATH height, anode leg). Following these standard procedures,maintenance of proper parameters as shown in Fig. 1 are to be ensured.

MODIFICATION OF CRUST BREAKING AND ALUMINA FEEDING TECHNOLOGY

The aim of modification of alumina feeding technology is to avoid sludge formation for which purpose the following steps are suggested:

- Fresh alumina feeding and leveling
- If the no of anode effect increases, it is necessary to increase the number of scheduled crust breaking. Increasing alumina layer is not proposed in this period, as large amount of alumina causes big fluctuations in cell operation. If the bath temperature is not sufficiently high, the risk of sludge formation is also increased.
- After crust breaking it is necessary to feed alumina as early as possible and alumina leveling should be done as shown in Fig. 1.
- After achieving this position crust breaking system is to be modified.
- The crust breaking system should consist of two parts, scheduled crust breaking and crust breaking during anode effect.
- During the modification stage time interval between the scheduled crust breaking is 2 hours 40 minutes
- 9 times crust breaking per day on long side represents 1266 kg alumina compared with the calculated value of 1366 kg (based on 85% CE) - the difference must be fed from short side.
- in this case the feeding of broken bath and large solid particles is forbidden
- It is necessary to modify the alumina quality. The basic requirement is to decrease line particles to max 20% below 45 μm

TRAINING PROGRAMME

The main task of training program is to provide theoretical understanding of electrolysis process specially relating to BALCO condition and practical experience in data measurement and evaluation. The training programme will be organised in JNARDDC at Nagpur for 18 persons (middle level officers) of BALCO. This will be followed by demonstration on the use of various equipment for measuring cell parameters at KORBA. In addition a training programme for foremen level persons would be organised at Korba to enable them appreciate the significance of various operations that are being suggested to improve the cell parameters.

The intense training at Nagpur and Korba should be followed (for some of the more promising persons) by a programme in one of the major smelters abroad where the smelters are similar to those in BALCO. The following possibilities exist in this regard:

- Hydro aluminium Kosmoy -Norway
- Hungalu Inota smelter Hungary
- Nag Hamadi Smelter Egypt
- Golden dale Smelter USA
- UNO-Preto Smelter Brasil

The aim of the training is to understand the proposed modifications in practice of cell operation and to carry out the proposed modification. After training the modifications must be carried out immediately. Simultaneously some preparatory action is also needed, such as removal of sludge, and solid particles from the deck plate. The duration of normalisation process including the training programme is expected to be about six months.

PROPOSAL FOR SCHEDULED CRUST BREAKING AND ALUMINA FEEDING WITH CRUST BREAKING FOR A DE EFFECT PREDICTION

In order to prepare for the automation of cell operation (stage II) the following alumina feeding technology must be used on the 51 experimental pots.

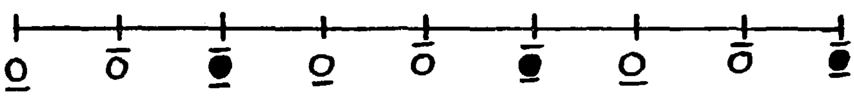
- The earlier scheduled (2h 40 min) crust breaking interval will be same, but the alumina layer on the crust may be decreased to 7.5 cm.
- three anode effects per day should be kept in cell operation during the initial period in order to avoid sludge formation and adjust the technology for purpose of cell automation (This procedure must be done without pot controller).
- Two Scheduled crust breaking should be done every shift and the third crust breaking should be done only during anode effect. This crust breaking procedure is different from the scheduled crust breaking. In this case both long side will be broken and the cell voltage be raised by 100 mv in order to supply necessary energy for alumina dissolution. After one hour cell voltage should be brought back to the original level.

- One anode effect per shift per cell is to be achieved in order to avoid sludge formation during initial period.

- Taking into account that calculations indicate a demand of 1200 kg alumina /day, short side breaking is needed.

- The 7.5 cm alumina layer provides 100 kg. alumina feeding to bath (Keep this layer thickness on the crust)

- 9 crust breaking operations are to be carried out every day on 3 shifts as shown below



0- scheduled crust breaking (The two lines represent the window and aisle sides)

\- crust breaking during anode effect.

- If the time interval between schedule crust breaking and crust breaking for anode effect is less than one hour, scheduled crust breaking should be skipped. Crust breaking during anode effect will be done by pneumatic hammer crust breaker)

- If the time interval between scheduled crust breaking and crust breaking after anode effect is more than one hour, then the scheduled crust breaking should be done as usual. After installation of pot controllers the crust breaking after anode effect will be replaced by crust breaking before the onset of anode effect as measured from resistance-time data.
 (If the alumina feeding technology without pot controllers is proceedoing smoothly, after installation of pot controller the results will be very attractive,)

- Keeping the heat balance of cell operation is very important. Changing of bath level and volume causes problems in alumina feeding. It is always necessary to minimum deviation in bath level.

It is necessary to mention that the proposal relating to the alumina feeding technology already takes into account the modernisation of smelter,i.e. it is to beconsidered as the first step of modernisation.

THE SCHEDULED TIME FOR CARRYING OUT THE ABOVE FUNCTIONS IS ABOUT SIX MONTHS.

IT MAY ALSO BE NOTED THAT ALL ASPECTS NOT COVERED IN THIS REPORT WOULD BE CARRIED OUT IN ACCORDANCE WITH THE TECHNOLOGICAL INSTRUCTIONS WHICH SHOULD BE CONSTANTLY UPDATED BASED ON EXPERIENCE AT THE SMELTER.

PROPOSAL FOR COOPERATION BETWEEN JNARDDC AND BALCO FOR MODERNISATION CARRIED OUT BY FOREIGN COMPANY

We feel that the foreign company would also carry out the activities mentioned in our proposal. Therefore, JNARDDC is ready to carry out measurements and evaluation of data from the cells.

JNARDDC can adopt the measuring methods of technological supplier and carry out the measurement at site with close cooperation of BALCO experts. The Institute can be participate in the installation of software and realisation of cell process control, adaptation of alumina feeding technology, evaluation of energy and voltage balance.

On the basis of measurements JNARDDC would be able to help the automation process, with tuning of software, determination of time constant of process.

ANNEXURE - VIII.

EVALUATION AND ANALYSIS

OF

MEASURED DATA

AND

TRANSFER OF

KNOWLEDGE

JNARDDC, NAGPUR
AUGUST 1992

INTRODUCTION

The energy consumption of aluminium electrolysis is expressed by following equation :

$$E_{cell} = 2.98 \frac{Vcell}{x}$$

where Vcell = cell voltage
x = current efficiency

The main effort is to decrease the energy consumption. There are two possibilities to decrease energy consumption:

- Decreasing the cell voltage
- Increasing the current efficiency

Measuring procedures and complete evaluation methods were elaborated to determine the energy and voltage balance of cell and improve the parameters of the existing aluminium electrolysis cell. The evaluations use general theoretical relationships, so the complete measuring methods and evaluation are suitable for both Soderberg and prebaked cells.

Here we consider only the evaluation methods and conclusions relating to 100 kA Soderberg cell.

1. ELECTRO MAGNETIC FORCES AND MAGNETO HYDRODYNAMICS

The electromagnetic forces are responsible for the circulation of the metal and electrolyte, static deformation of metal-bath interface and waves on this interface.

This effect means a limitation on decreasing AC distance; the minimum ACD is the so called critical AC-distance. Below this ACD the interaction between the metal and anode gas causes sharp decrease in current efficiency.

The purpose of measuring methods is to determine this critical AC distance as function of current efficiency. The determination of critical AC - distance gives the minimum cell voltage for given cell operation.

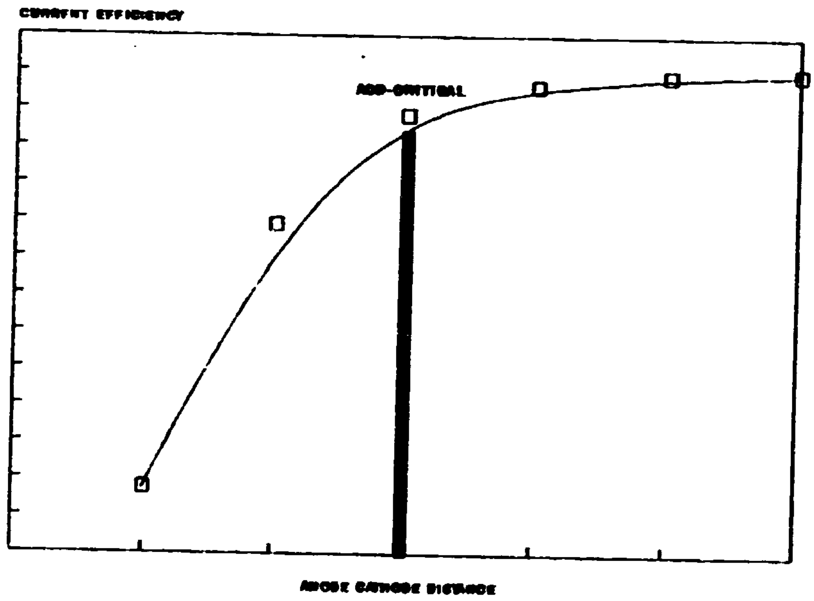
Some measuring methods are used to determine this "critical ACD" distance.

- Current efficiency measurements on the basis of CO_2/CO analysis as function of AC - distance.

- To identify different part of magneto hydrodynamic curve following measurements are made:

* the magnetic field induction of component is measured
* EMF measured by current sinking
* Anode effect value
* Instability of cell (noise) ; interaction between the anode gases and metal.

MAGNETO-HYDRODYNAMIC CURVES
(THEORETICAL CURVE)



Characteristics of different parts of MHD curve are :

I. - Vertical component of magnetic field B_z is stable.

- EMF is close to the calculated value (1.65-1.7V)

- Normal anode effect (~ 30 V)

- Instability of cell is normal (noise is normal).

II. - Vertical component of magnetic field B_z is not stable.

- EMF value is lower than the calculated one (1.1 - 1.4 V) because of depolarisation effect of dissolved metal.

- Anode effect value is low and it's value 20V

- Instability level is high (waves, spikes)

- Electrolyte temperature is high which is caused by exothermic nature of re oxidation process.

For given cell operation and technology the minimum AC - distance is determined by these complex measurements

2. VOLTAGE DROP IN ACD GAP

The calculated results give a theoretically value, which is to be achieved at the given ACD - distance. Practically this value can't be achieved because of the deviation of the current line from the vertical direction. This deviation depends on :

- The position of anode carbon which influences the magnitude of horizontal current components.

- The cathodic electric design is characterised by.

• ledge profile which strongly influences the horizontal current components in the metal layer as well as having a major influence on the hydrodynamic behaviour. Side ledge profile is dynamically varying parameter and proper control of its dynamic behaviour can assure electromagnetic stability of the cell.

For determination of horizontal current component the metal touching method was developed. Comparing the measured electrolyte voltage drop with the calculated value gives a useful indirect information about the value of horizontal current. The measured value includes the bubble layer resistance i.e.

$$R_{bubble} = t_a / (A(1-1.26\phi)\cdot\lambda$$

where ta = bubble layer thickness
A = anode surface
ϕ = anode covering with bubble
λ = electrical conductivity

When difference between the calculated and measured value is high, it means, that the side freezing is not proper, or significant sludge is present on cathode bottom. This indicates, that it is necessary to adjust a new thermal state of cell by increasing or decreasing set voltage. This decision is determined by other measuring results, such as noise analysis, anode effect analysis, EMF value.

- If the amplitude of fluctuation in noise analysis is low, anode effect value is low & EMF value is also low, this means the cell is in warm thermal state. Magnetic field measurements indicate a high value in vertical component. In this case cell voltage (ACD) must be increased. If the difference in the calculated and measured IR drop is high the cell voltage should be raised by 200 - 300 mv, and the measured data has indicated the above mentioned value.

- If the difference in calculated and measured IR drop is large, but the above mentioned parameter are normal, in that case cell voltage can be decreased step by step.

3. <u>TO DETERMINE OPTIMUM CELL OPERATION FOLLOWING MEASURING METHODS ARE USED</u>

- Determination of the ACD vs CE curve (MHD) for given cell operation

- Determination of critical "ACD" point on MHD curve

- ACD is determined by metal touching method

- Determination of horizontal current (longer current path) from $IR_{calculated}$ and $IR_{measured}$ difference.

- Energy and heat balance calculations are used

- Difference of the calculated and measured EMF is used to determine the current efficiency in an indirect way.

To determine the failure cell operation the following measured methods are used :

- Noise analysis measurements (fluctuations, waving, spike)

- EMF analysis

- Anode effect value and its duration
- Alumina content trend monitoring

To determine the heat losses of cell, current efficiency must be kept at constant level .

3.1 Evaluation of MHD curve

The composition of the anode gas from industrial aluminium electrolysis cell was measured to determine the effect of cell operation on the current efficiency. Anode gases were allowed to flow without any induced draught from 15 cm diameter steel pipe or (aluminium pipe) in the anode of the cell. The CO_2 and CO were determined by infrared gas analysis. (Hartmann and Braun).

The current efficiency can be determined by Pearson - Waddington equation. This equation is valid for providing accurate current efficiency data for industrial reduction cell.

$$CE = 0.5\ CO_2\% + 50$$

If the flow of gas out of the steel pipe of anode is sufficiency large, the Boudoud reaction which take place between CO_2 in the anode carbon is too slow to effect the current efficiency . If however the gas flow is reduced freezing in the steel pipe in that case will become significantly large and it results in large decrease in the current efficiencydue to Boudoud reaction.

In order to avoid this effect, outer pressure is used to decrease the bath level in the tube. The used equipment has a gas pressure measuring unit which indicate variations in gas flow and pressure.

This measuring method is suitable to correlate cell's current efficiency and the operational condition of cell for one hour.

The theoretical EMF and practical, measured EMF is also used for determination of current efficiency, in an indirect way on the basis of following equations.

$$4.4\,(1-x) = 2.98\,(EMF_{theo} - EMF_{measured})$$

- 4.4. kwh/kg = enthalpy changing of re oxidation process.

- EMF_{theo} = the calculated EMF for given electrolyte composition and temperature

- $EMF_{measured}$ = measured EMF by current sinking method

- x = Current efficiency

During measurements for determination of current efficiency the anode gas analysis technique is preferred. For longer time measuremnets gold isotope dilution technique is used.

On the basis of preliminary studies and actual BALCO measurements the MHD curve was recorded. The MHD curve can be seen on Fig. 1

The curves were described by following equation :

$$CE = B\,(1 - A\,\exp^{-\cdot\,2.77\,ACD})$$

B - value is proportional with the vertical component of magnetic field induction

For evaluation the average absolute value of vertical component is used.

If this value is high the B value is low

If this value is low the B value is high.

A - value depends on the so called "horizontal current" value and its value is determined first of all by frozen shape profile and sludge.

2.77 - value is determined by laboratory modelling study

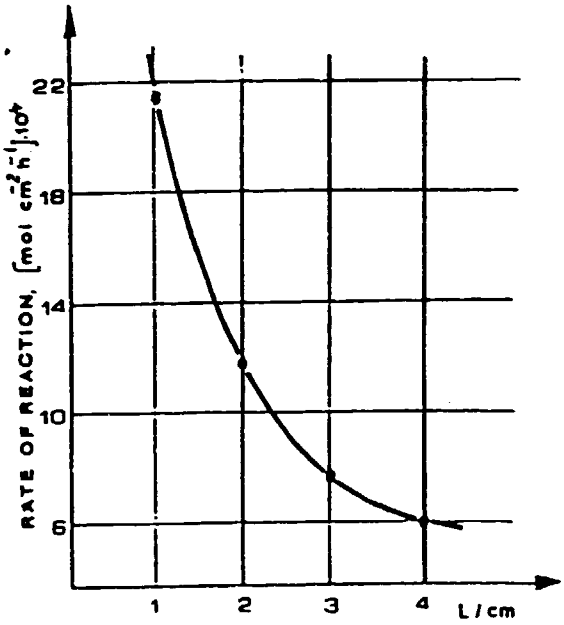


Fig.4 Distance between CO_2 entrance and metal surface

On the basis of our measurements it was found that curve I give the MHD relationship for BALCO existing cell. This curve was determined by Magnetic field induction measurement, metal touching, noise analysis and EMF - Measurement).

The anode effect value is also low, indicating depolarisation effect of dissolved aluminium.

The anode effect value and its duration and increasing period can be found in **FILE NO. 3 (with JNARDDC).**

For good cell operation typical graphs for increasing period and anode effect value can be seen in fig. 2a, 2b.

For bad cell operation typical graphs for increasing period and anode effect value can be seen in fig. 3a, 3b & 3c.

The EMF is also low due to the re oxidation process.

The average EMF value for each experimental cell were summarised on the table I (EMF Table).

Summary of the applied measuring methods can be seen in chart 1.

These complete measuring system and evaluations are used for determination of MHD - curve of given cell operation.

After determination of MHD curve the determination of actual ACD distance, the construction elements voltage drop, and evaluation of the "horizontal current component" value gives the losses of cell voltage component in AC gap. This losses are very high in the unstable area of MHD curve.

On the stable area of MHD curve the losses are less. Our effort is, to minimise the difference between the IR measured and IR calculated value. The main target is to found that point on the MHD curve, where IR bath ~ IR calculated value.

4. THE DETERMINATION OF CELL VOLTAGE AT GIVEN CELL OPERATION

The MHD curve is used to determine the ACD, where the cell operation is stable. The question is how to determine the optimum cell voltage value.

In this chapter this will be described.

In general electrolyte composition is considered (molar ratio, additions) as a constant parameter for cell operation.

For this electrolyte composition, the saturated alumina concentration & liquidus temperature are calculated.

The liquidus temperature varies as a function of alumina content in the bath. In case the electrolyte composition is constant, the liquidus temperature depends only on the alumina content as shown in fig 4.

The superheat value depends on quality of used alumina.

It is well known, that rate of alumina dissolution process is determined by heat transport, and the chemical dissolution takes place very fast at low alumina concentration . In this case driving force is high.

The sandy type alumina gives a more dispersed alumina in bath, and the decreased liquidus temperature gives enough heat supply for dissolution.

The floury type alumina gives a less dispersed alumina in bath, risk of lump formation is higher. the decreasing in liquidus temperature is less, because of not enough heat for dissolution. In general it is accepted, that the superheat is 7°C for sandy alumina and 15°C for floury alumina.

The question is the determination of liquidus temperature.

For determination of the cell resistance as a function of crust breaking monitoring mode is needed. If after the crust - breaking the cell resistance is decreased (monitoring mode) it means the alumina concentration is low. In this case the for calculation of liquidus temperature the low alumina concentration is to be taken into account. Detail data for this study can be found in FILE NO. 4 (with JNARDDC).

The operating temperature must be 15°C higher than the liquidus temperature for the floury alumina. The reason is more heat is needed for the dissolution process.

The liquidus temperature should be calculated always taking into account the average alumina content in the bath.

The alumina content (low, medium, high content) can be determined by monitoring of resistance - time curves. The typical graphs of resistance time curves as a function of crust breaking are given in fig. 5a, 5b & 5c.

At given alumina content, taking into account the type of alumina used, the operating temperature is calculated.

At given ACD the electrolyte voltage drop and the EMF is calculated. The sum of these voltage components gives the total voltage in ACD gap.

The measured anode, cathode & bus-bar voltage drop plus voltage drop in ACD -gap gives the cell voltage .

5. DETERMINATION OF HEAT LOSSES

To determine heat losses of cell current efficiency must be kept constant. Typical heat losses are shown in table II.

CONCLUSIONS

On the basis of these measurements and data evaluation the following conclusions are made:

The horizontal part of MHD curve is determined by vertical component of magnetic field. This value is proportional with the maximum current efficiency which can be achieved. The vertical component of magnetic field , which is causing the metal circulation is high and non-symmetric. It's value is 31 gauss. (absolute average value of vertical component). Typical magnetic field measurement are shown in fig 6. (Software programme "magnetic.bas" with JNARDDC)

The vertical component is the most important parameter for the stable pot operation. Unfortunately for existing cell operation the vertical component indicates a high value. The measured vertical component of magnetic field in a similar bus-bar arrangement shows a lower value and those pots are operated in a more stable zone. The bus-bar arrangement is considered to be a good as magnetic field is well compensated. The main reason for high value of B_z is the non-uniform current distribution. In the FILE NO. 5 and 6 (with JNARDDC) measured data for anode current and cathode current distribution can be found. The deviations are high in the anode-and cathode current distribution, some typical distribution are shown in fig 7 and 8. (Software for anode current and cathode current distribution with JNARDDC)

The so-called "metal touching" method was used for determination of voltage losses in ACD-gap. Fig. 9 shows the typical graph for metal touching method. It is well known, that the sludge on cathode bottom and the improper side freeze shape cause a deviation of the current line from the vertical direction. The deviation increase the current path, (horizontal currents) in metal, causing a larger rotation of molten metal. The proportional voltage with the horizontal currents were measured. These results indicate a large horizontal currents in metal. The voltage losses in ACD gap is to be 200-300 mv. The calculation for voltage and energy balance are given in software "UNIDO1 & UNIDO2" (with JNARDDC).

The electrical measurements were used to determine the interaction between the anode and molten metal. The small decrease in anode - cathode distance causes very strong interaction (waving, spike). The instability level of cell operation is very high, some spikes, waving and fluctuations were measured. These measurements have indicated, that the cell operation is in a unstable area. All the measuremnets data for the noise analysis can be found in FILE NO. 1(with JNARDDC). Some typical graphs are shown in fig 10a, 10b, 10c, 10d. 10e & 10f.

The low fluctuations of noise, low EMF value (electromotive force) and low anode effect value imply the reason for instable cell operation is the low AC distance. The electrolyte temperature was also high which is caused by exothermic reaction at low ACD. Data for the EMF can be found in FILE NO. 2 (with JNARDDC). Some typical values are shown in fig 11a & 11b.

On the MHD curve the line I shows the operating range of the existing cells. In summary it was established that the main reasons for the low performance level are :

The voltage balance indicate low AC-distance

The cell operation is unstable due to low AC-distance.

The electrolyte temperature (superheat) very high which is caused by exothermic nature of re oxidation process.

Because of non uniform current distribution the vertical field of magnetic induction is higher that the normal.

High horizontal currents in metal were caused by large amount of sludge and improper side freeze profile.

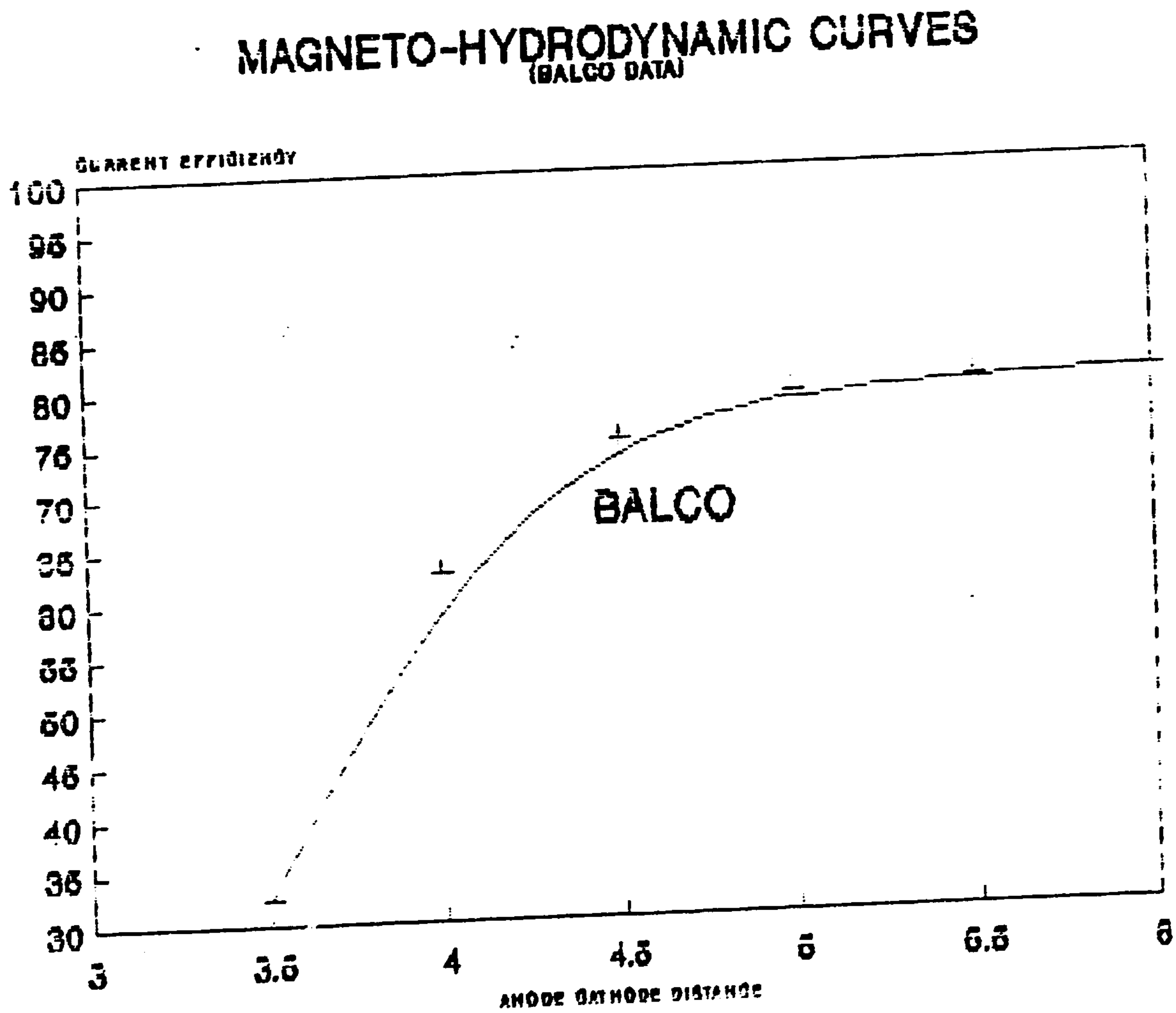

MAGNETO-HYDRODYNAMIC CURVES
(BALCO DATA)
100
90
80
70
60
40
30
BALCO
3
4
4.5

Figure 1

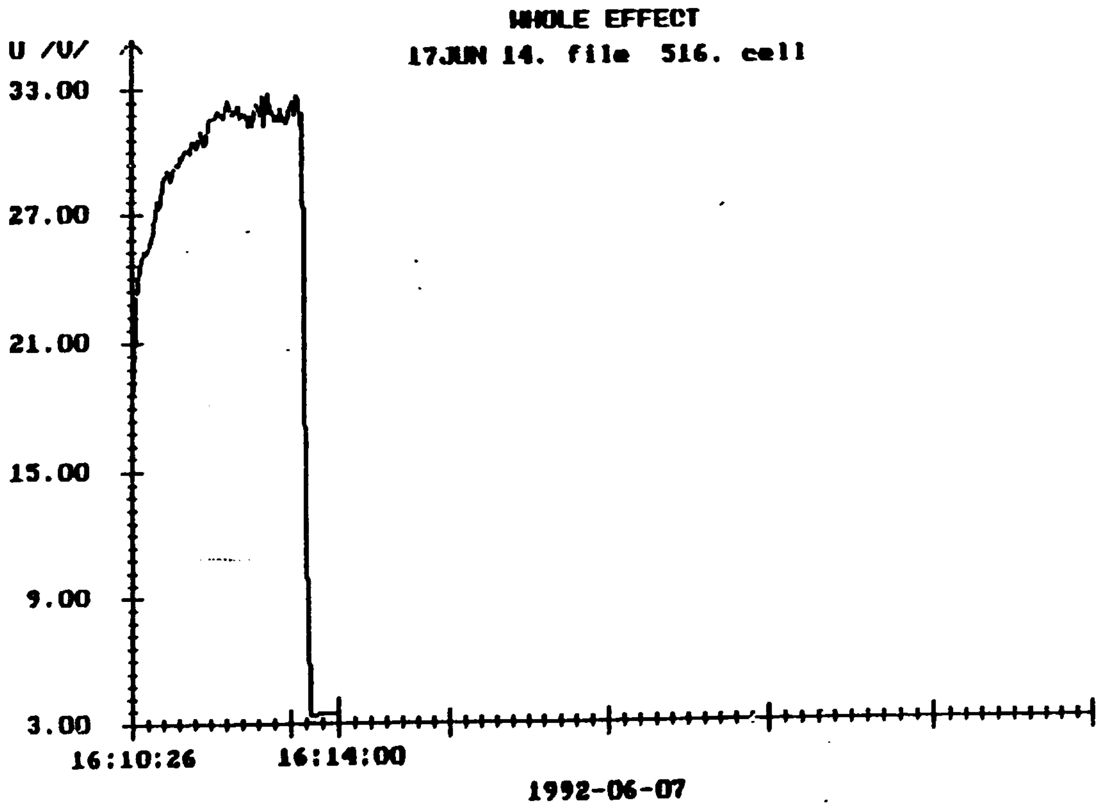


Figure 2a **NORMAL ANODE EFFECT**

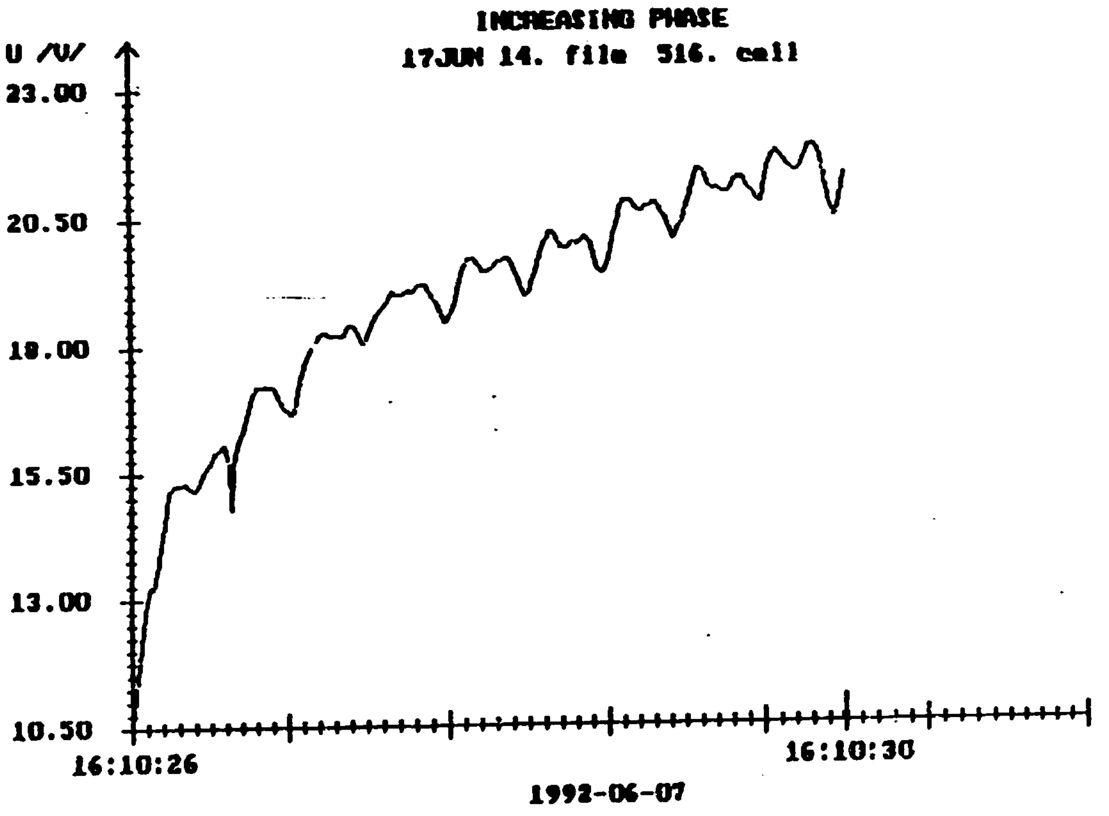


Figure 2b NORMAL ANODE EFFECT

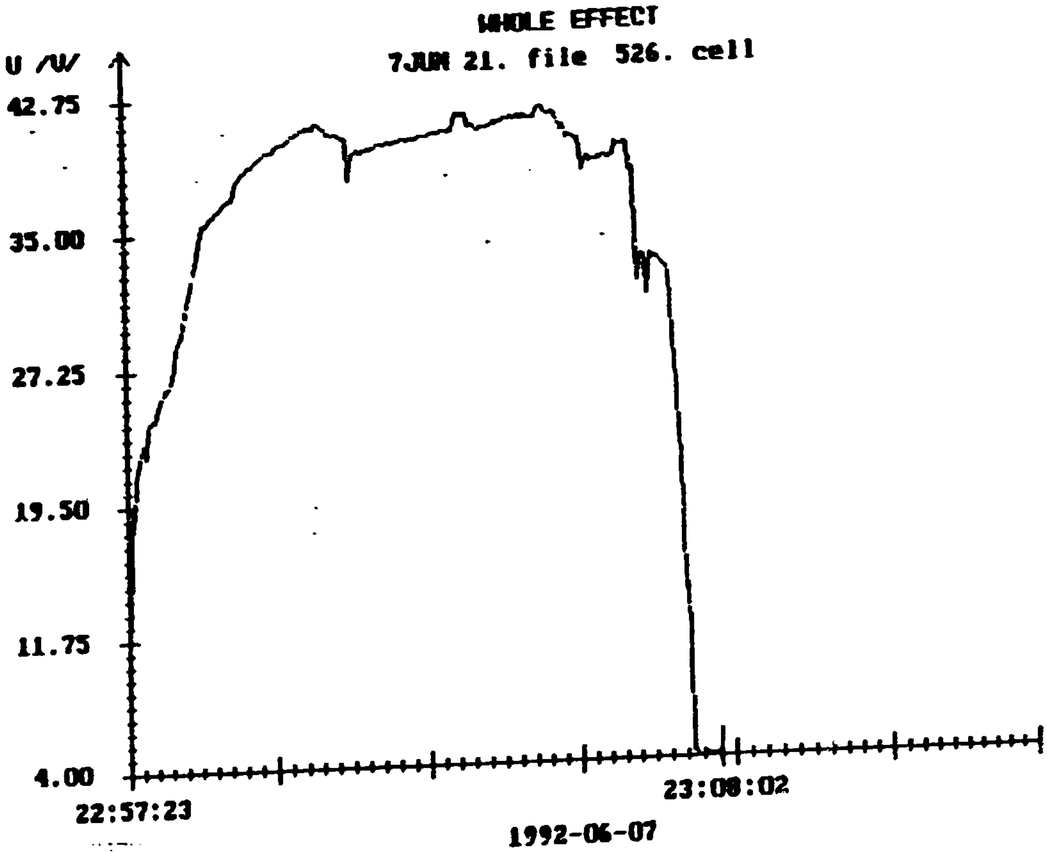


Figure 3a HIGH ANODE EFFECT

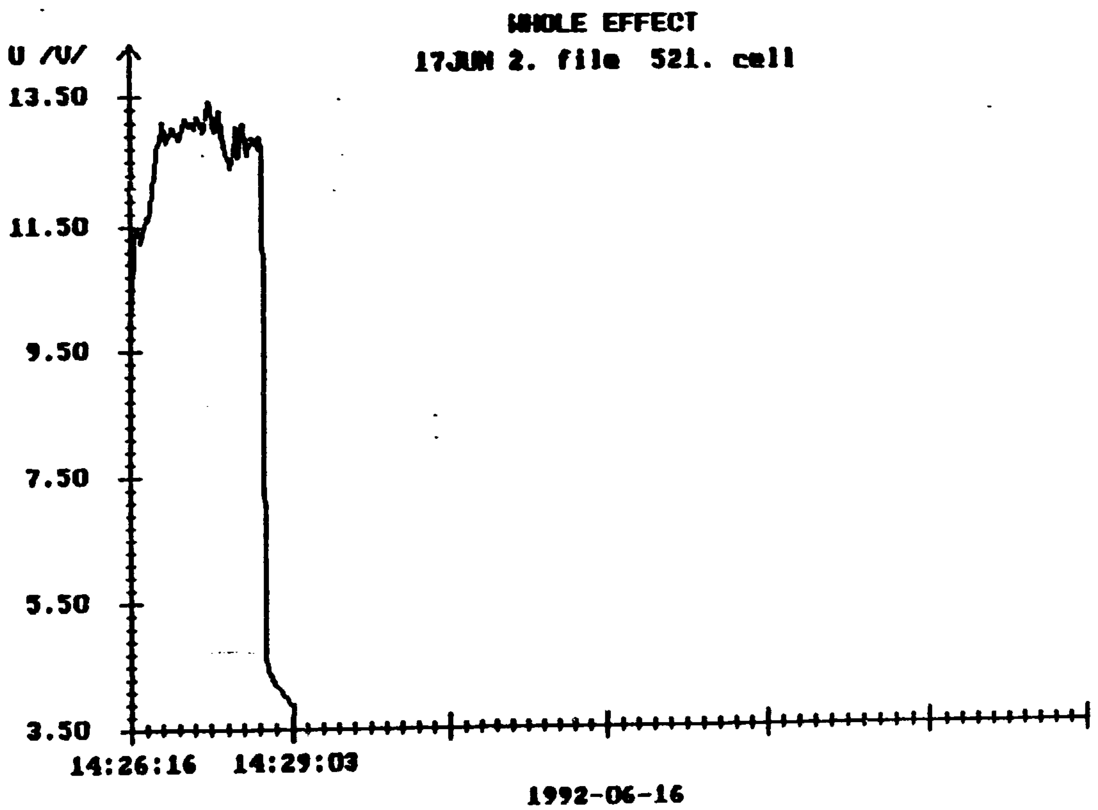


Figure 3b SICK POT

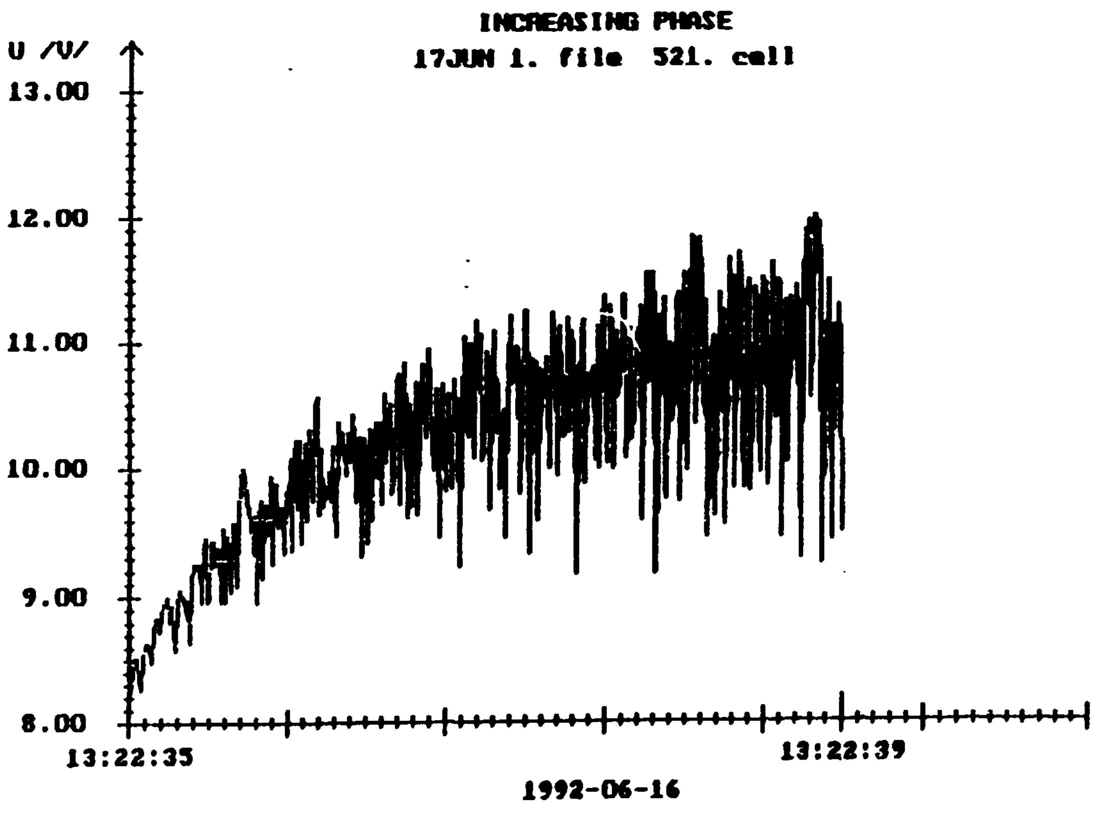
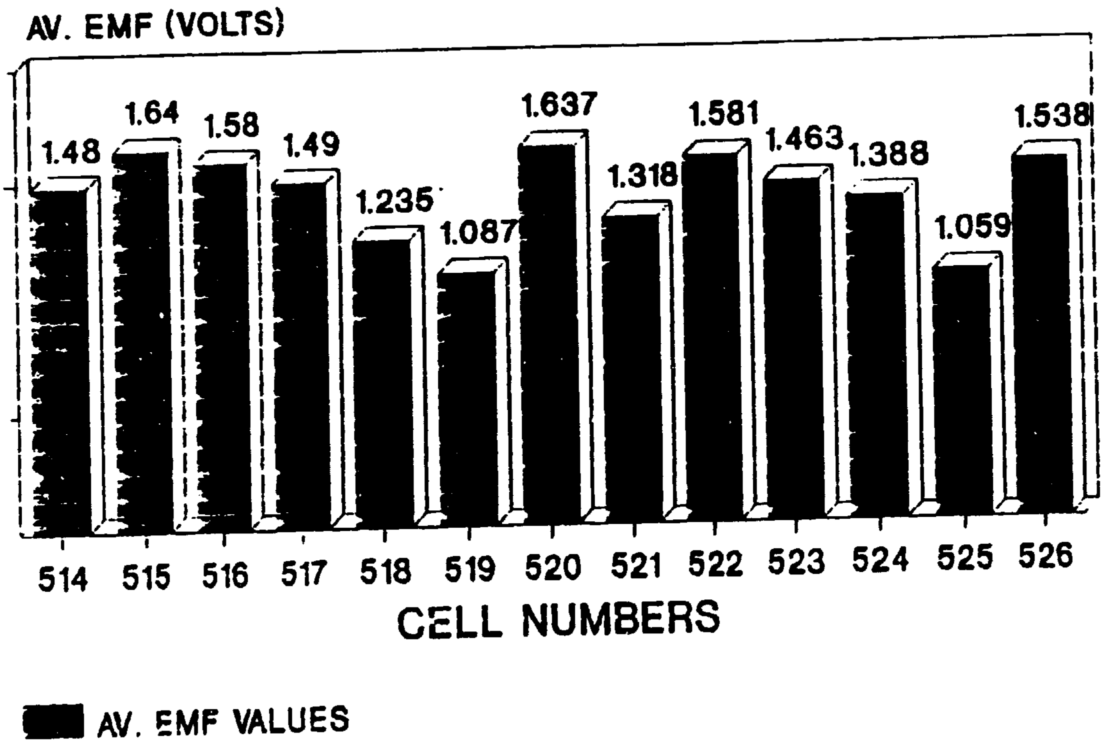


Figure 3c SICK POT

EMF VALUES
(BALCO CELLS)



JNARDDC

Table I

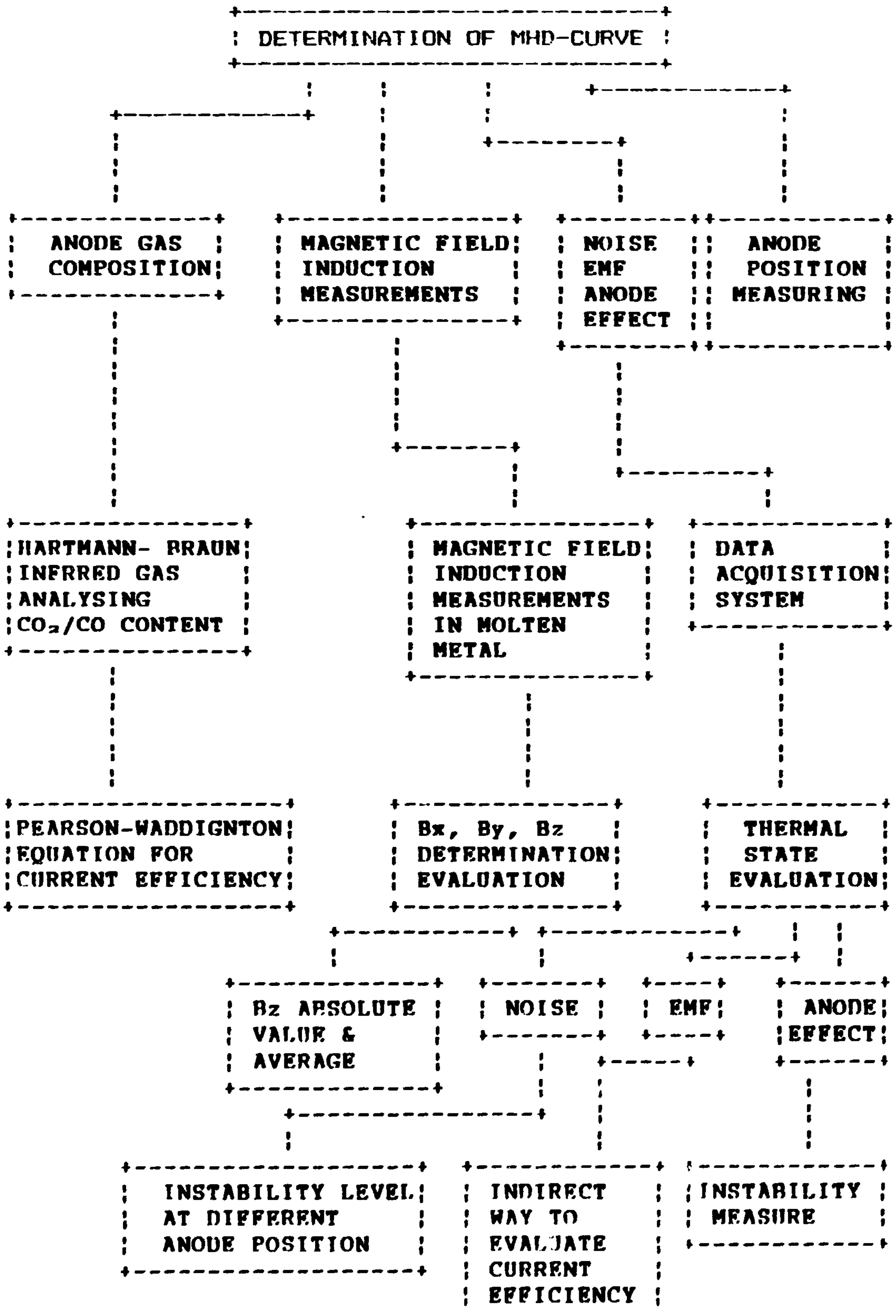

DETERMINATION OF MHD-CURVE
ANODE GAS COMPOSITION
MAGNETIC FIELD INDUCTION MEASUREMENTS
NOISE EMF ANODE EFFECT
ANODE POSITION MEASURING
HARTMANN- BRAUN INFRRED GAS ANALYSING CO_2/CO CONTENT
MAGNETIC FIELD INDUCTION MEASUREMENTS IN MOLTEN METAL
DATA ACQUISITION SYSTEM
PEARSON-WADDIGNTON EQUATION FOR CURRENT EFFICIENCY
Bx, By, Bz DETERMINATION EVALUATION
THERMAL STATE EVALUATION
Bz ABSOLUTE VALUE & AVERAGE
NOISE
EMF
ANODE EFFECT
INSTABILITY LEVEL AT DIFFERENT ANODE POSITION
INDIRECT WAY TO EVALUATE CURRENT EFFICIENCY
INSTABILITY MEASURE

Chart 1

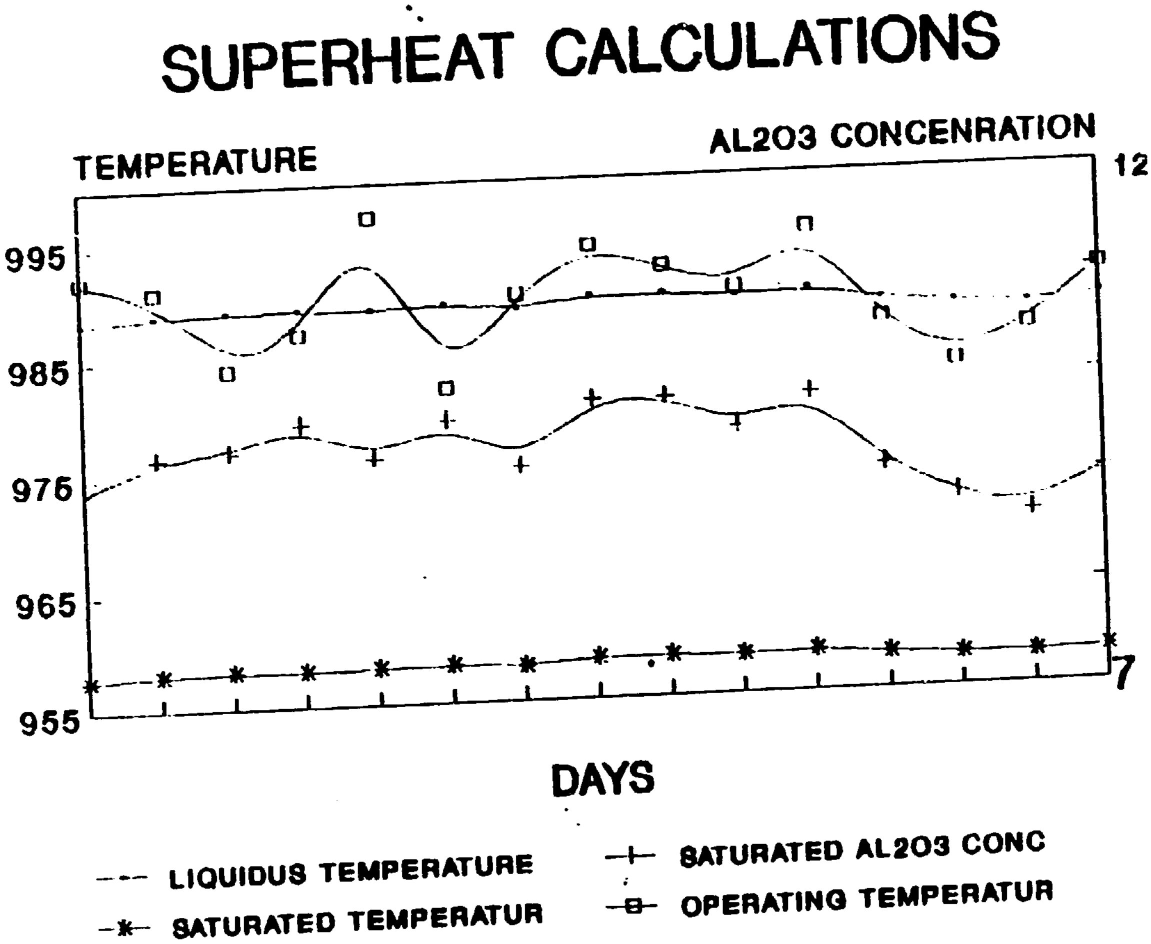

SUPERHEAT CALCULATIONS
TEMPERATURE
AL2O3 CONCENRATION
12
995
985
975
965
955
7
DAYS
LIQUIDUS TEMPERATURE
SATURATED AL2O3 CONC
SATURATED TEMPERATUR
OPERATING TEMPERATUR

Figure 4

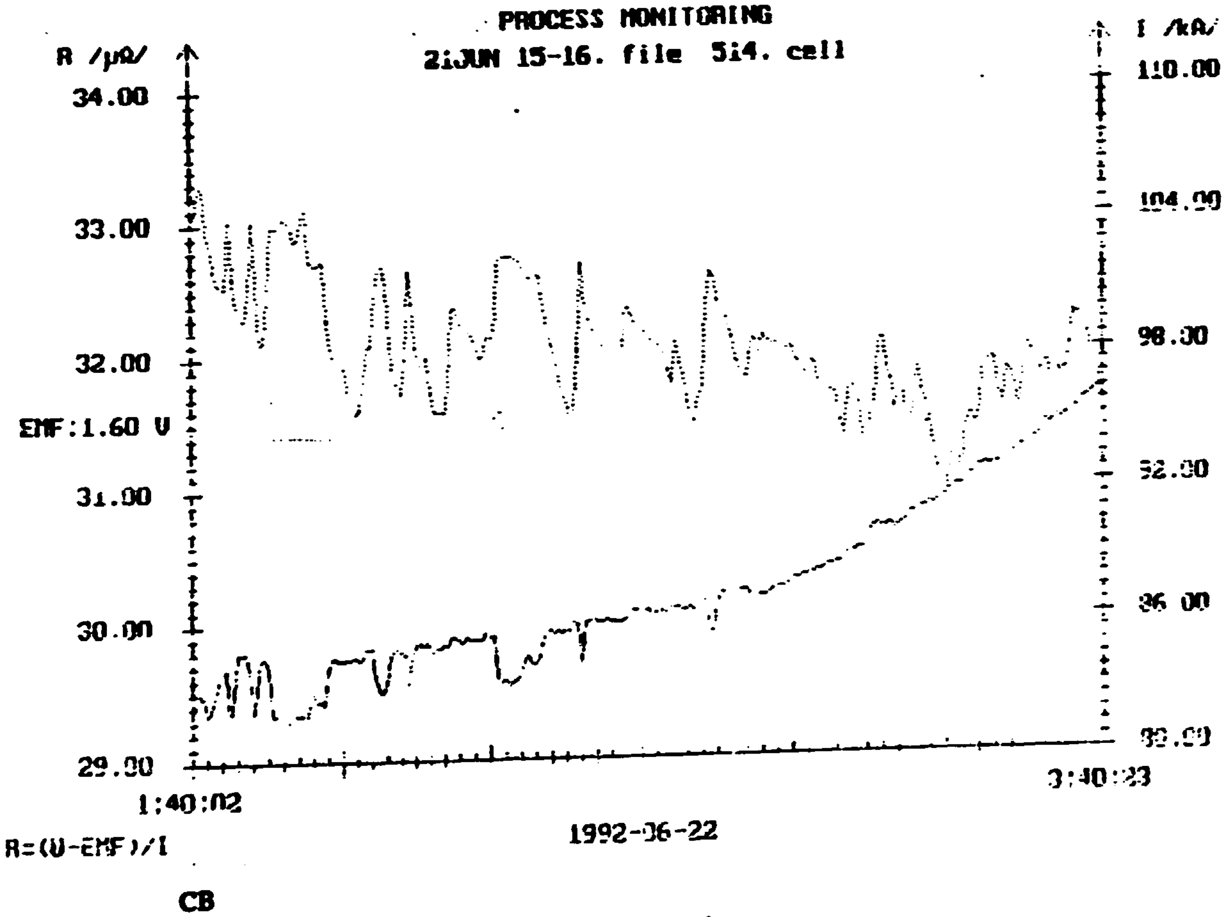


Fig. 5a Resistance going up

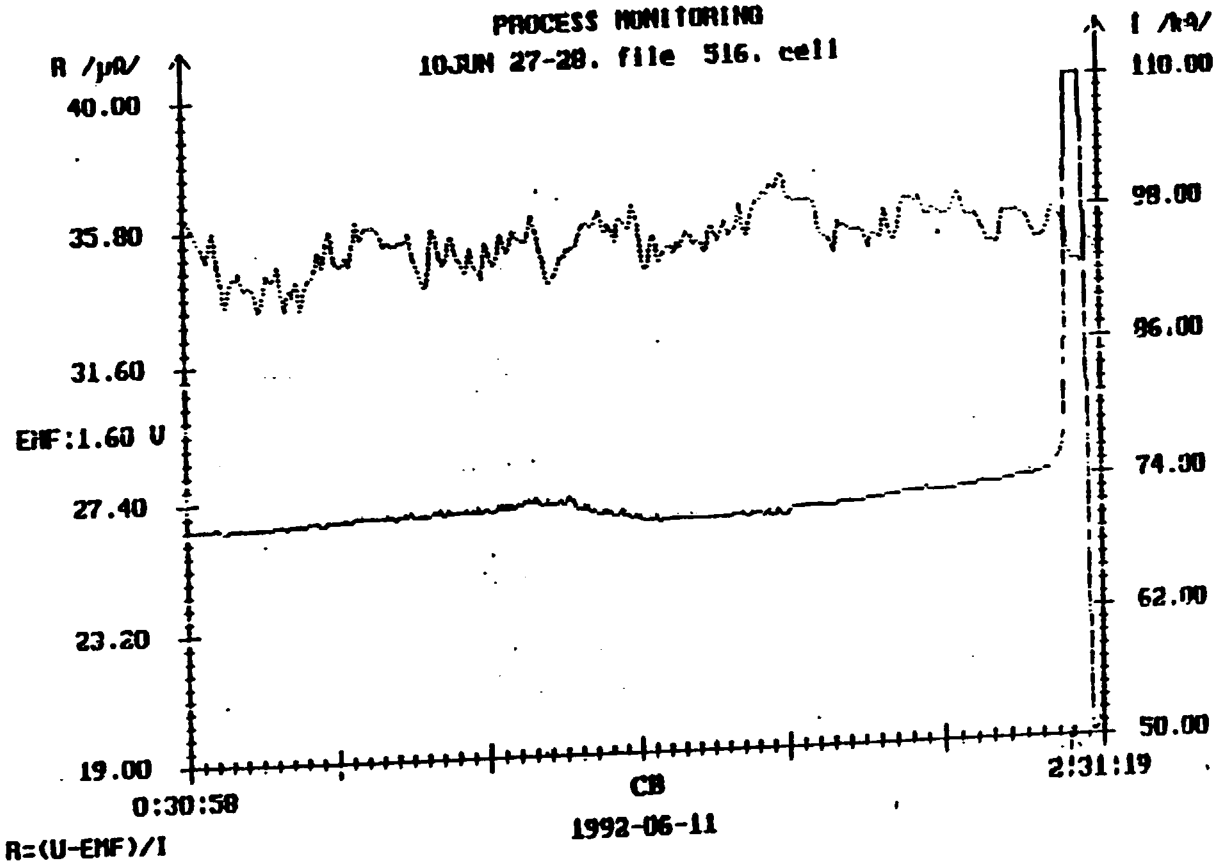


Figure 5b Resistance constant

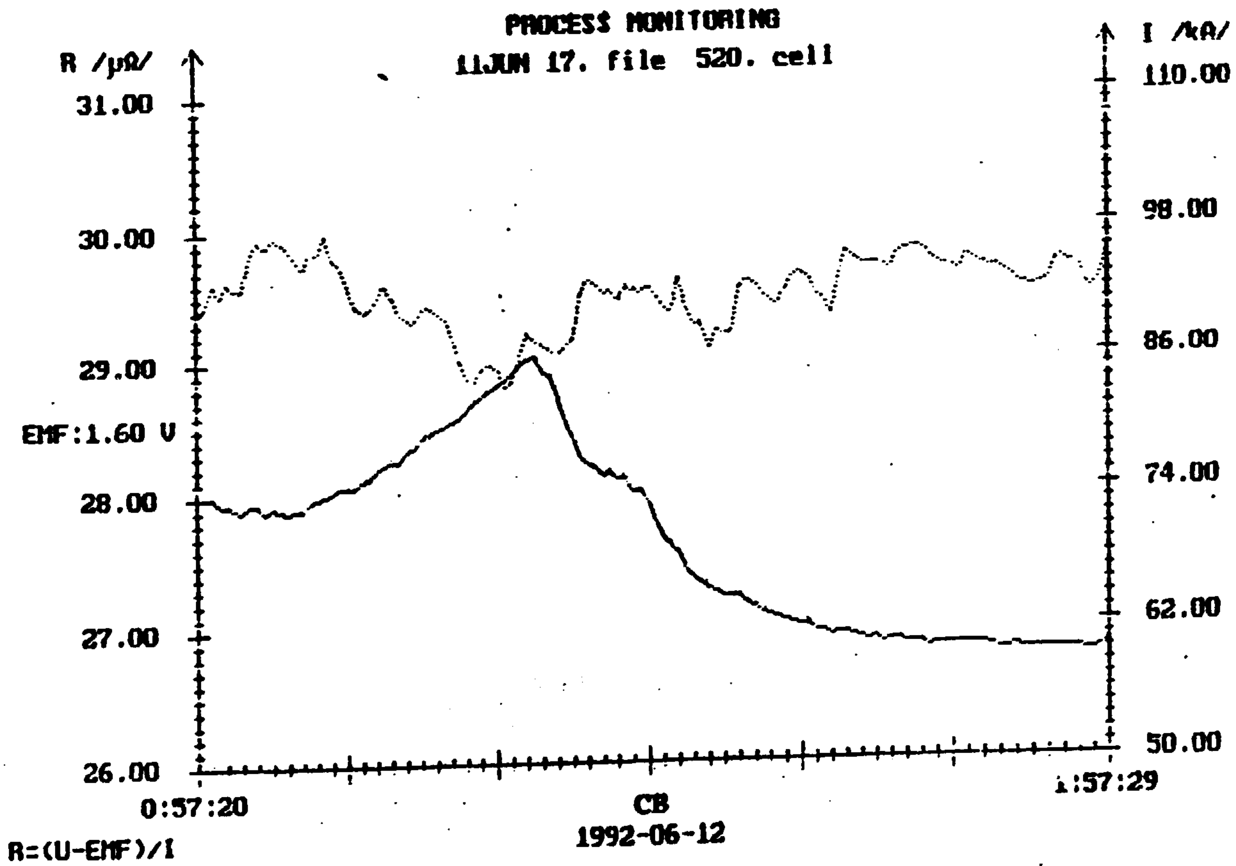


Figure 5c Resistance going down

[1]HEAT LOSSES IN BALCO CELLS

CONSTRUCTION ELEMENTS	HEAT LOSS (W/m²)	AREA (m²)	TOTAL HEAT LOSS (kW)	% HEAT LOSS
CATHODE SHELL BOTTOM	348.83	27	9.5	4
UPPER CATHODE SHELL (LONG SIDE)	1929.33	16	31	13
UPPER CATHODE SHELL (SHORT SIDE)	1929.33	5.4	10.49	4.3
LOWER CATHODE SHELL (LONG SIDE)	542.43	7	3.8	1.5
LOWER CATHODE SHELL (SHORT SIDE)	542.43	2.31	1.25	0.5
ANODE CASING (LONG SIDE)	3611.95	25	90.3	38
ANODE CASING (SHORT SIDE)	3611.95	6.5	23.5	10
ANODE TOP	944.00	15	14.16	6
ALUMINA LAYER, STUD LOSSES ETC.	-	-	54.00	22.7
TOTAL	-	-	238	100

Table II

[1]Data from Balco cell
Measurements were done by KEMTHERM HEAT FLOW METER
Upper & lower of the cathode shell is the area above the collector bar and below the collector bar respectively

MEASURED VALUES

	1	2	3	4	5	6	7	8
Bx	2.7	1.8	3.6	1.3	-1.0	-1.9	-2.5	-1.6
By	-5.8	-5.4	-4.5	-5.1	-5.0	-6.1	-6.9	-6.9
Bz	2.9	0.3	-3.2	-5.4	1.7	-1.4	-4.7	5.7
Angle	34.4	35.2	28.4	39.2	38.9	46.6	41.9	37.2

CALCULATED VALUES

	1	2	3	4	5	6	7	8
BX	-3.9	-1.6	-1.6	2.4	0.3	-2.3	-5.0	2.2
BY	5.8	5.4	4.5	5.1	-5.0	-6.1	-6.9	-6.9
BZ	0.9	-0.8	-4.5	-5.0	2.0	0.4	-1.8	5.5
BXY	7.0	5.6	4.8	5.6	5.0	6.5	8.5	7.2
αXY	-33.7	-16.9	-20.1	25.3	-3.3	20.8	35.9	-17.5
BXYZ	7.0	[illegible]	6.6	7.5	5.4	6.5	8.7	9.1
αXYZ	82.9	-82.0	-46.6	-48.4	68.7	86.3	-77.9	52.7
z	45.6	51.3	54.0	50.7	43.9	56.1	59.0	41.1
δx	76.3	76.7	59.5	89.1	83.2	90.8	83.5	86.5

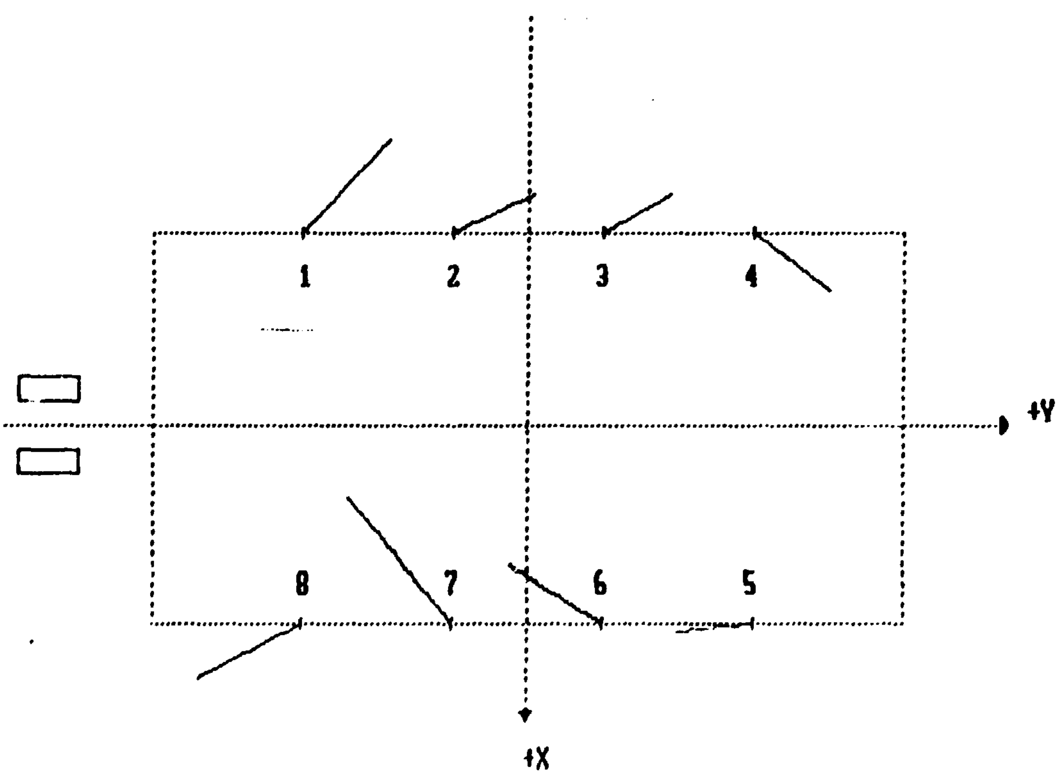
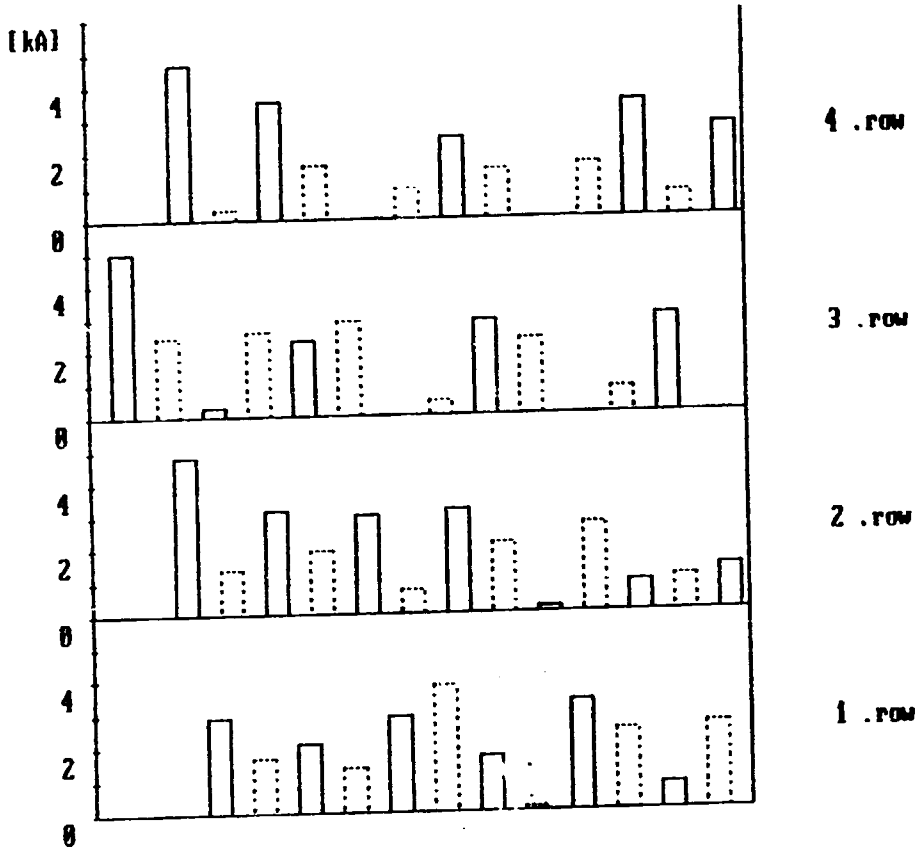


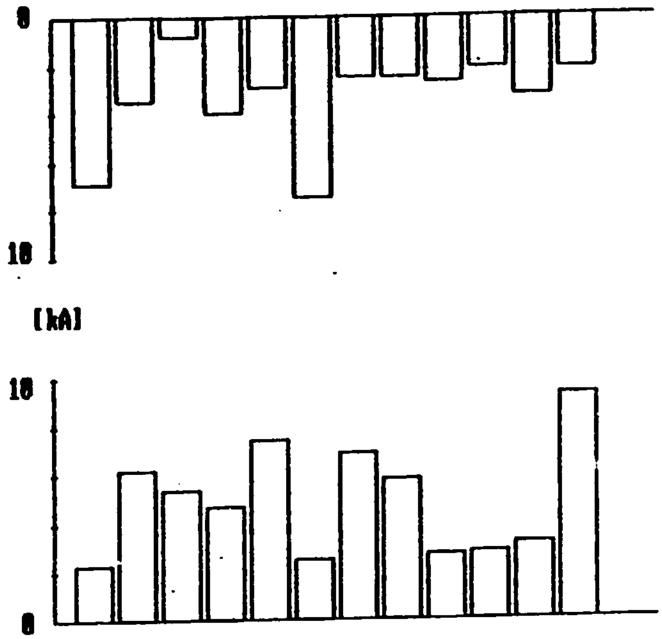
Figure 6

526-0609.ACD



	1. level [kA]	2. level [kA]	Σ level [kA]	Average [kA]	St.dev [kA]
4.row	6.66	16.71	23.37	1.67	1.43
3.row	11.41	13.45	24.86	1.78	1.40
2.row	9.92	16.44	26.36	1.88	1.29
1.row	11.96	13.45	25.41	1.81	1.19
Σ row	39.95	60.05	100.00	1.79	1.36
Average	1.43	2.14	1.79		
St.dev	1.03	1.53	1.36		

Figure 7



	Σ current [kA]	Average [kA]	St.dev [kA]
North	40.89	3.41	1.87
South	59.11	4.93	2.18
Σ	100.00	4.17	2.17

Figure 8

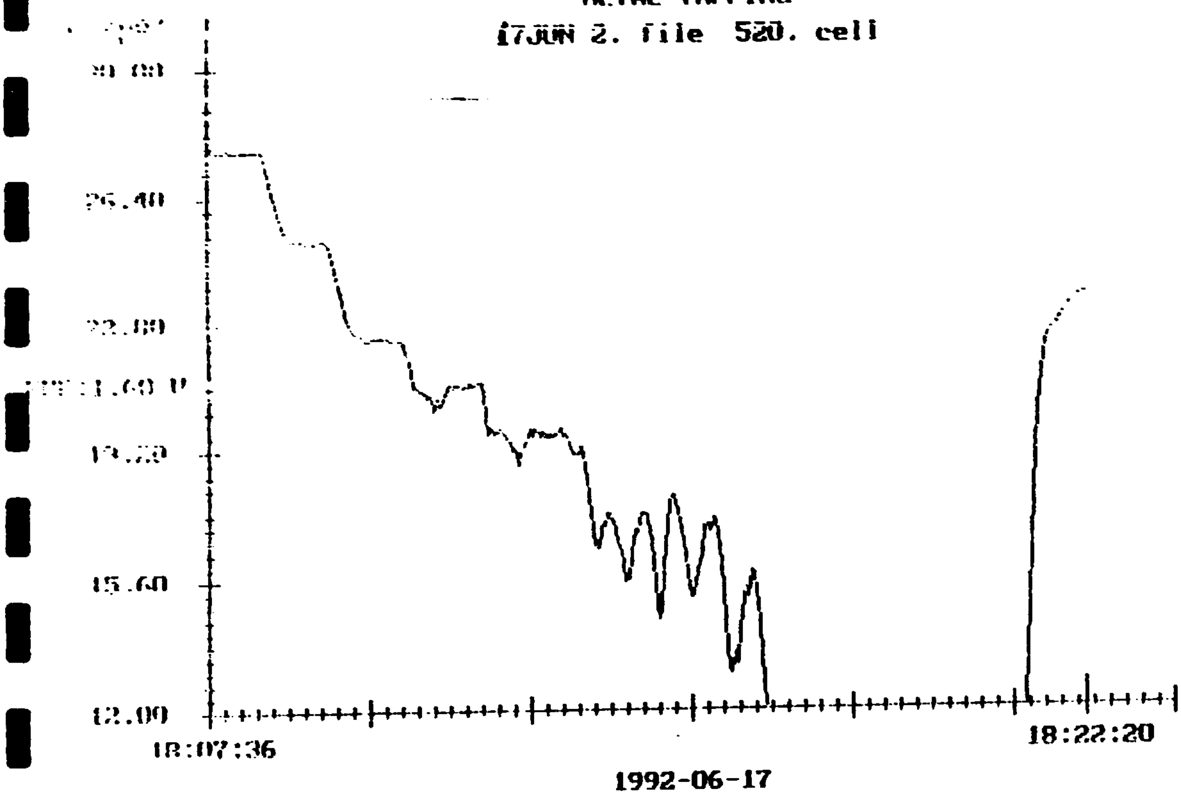


Figure 9   Metal touching

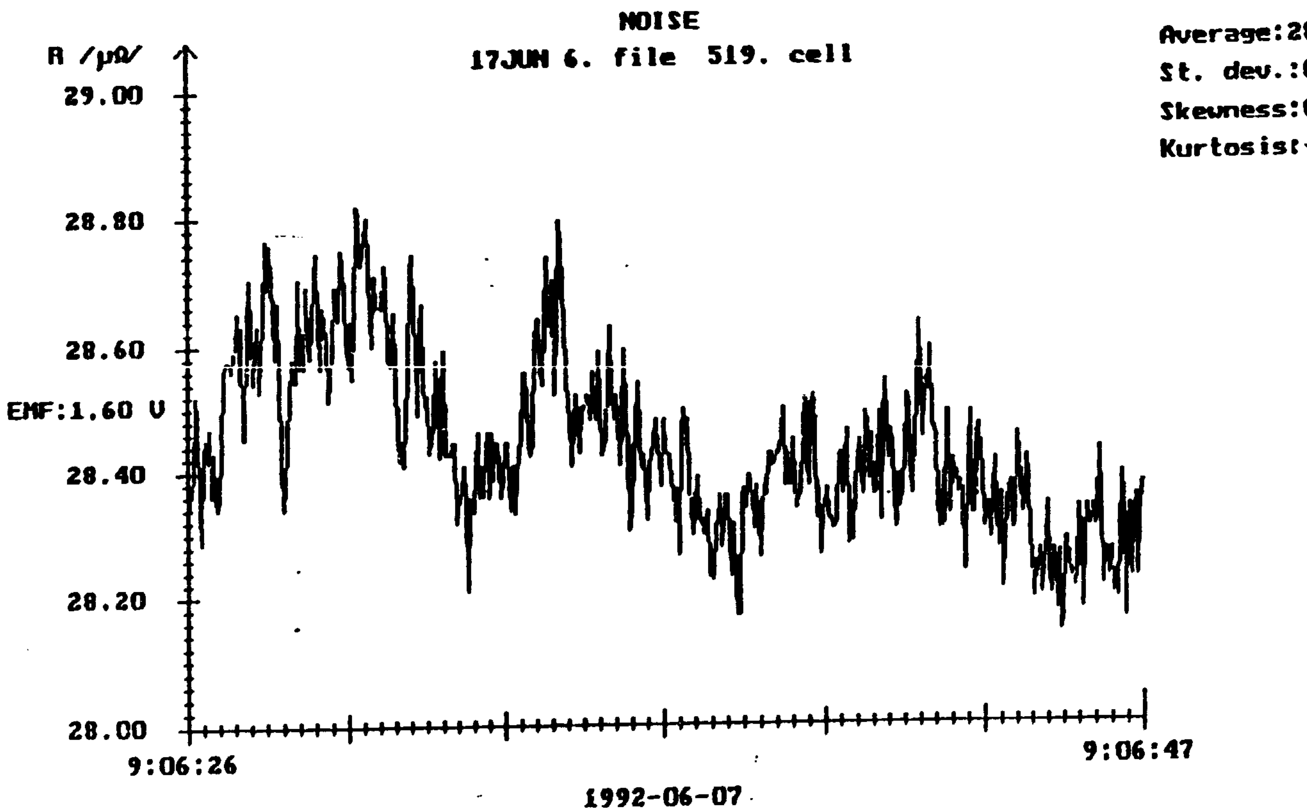


Figure 10a WAVING

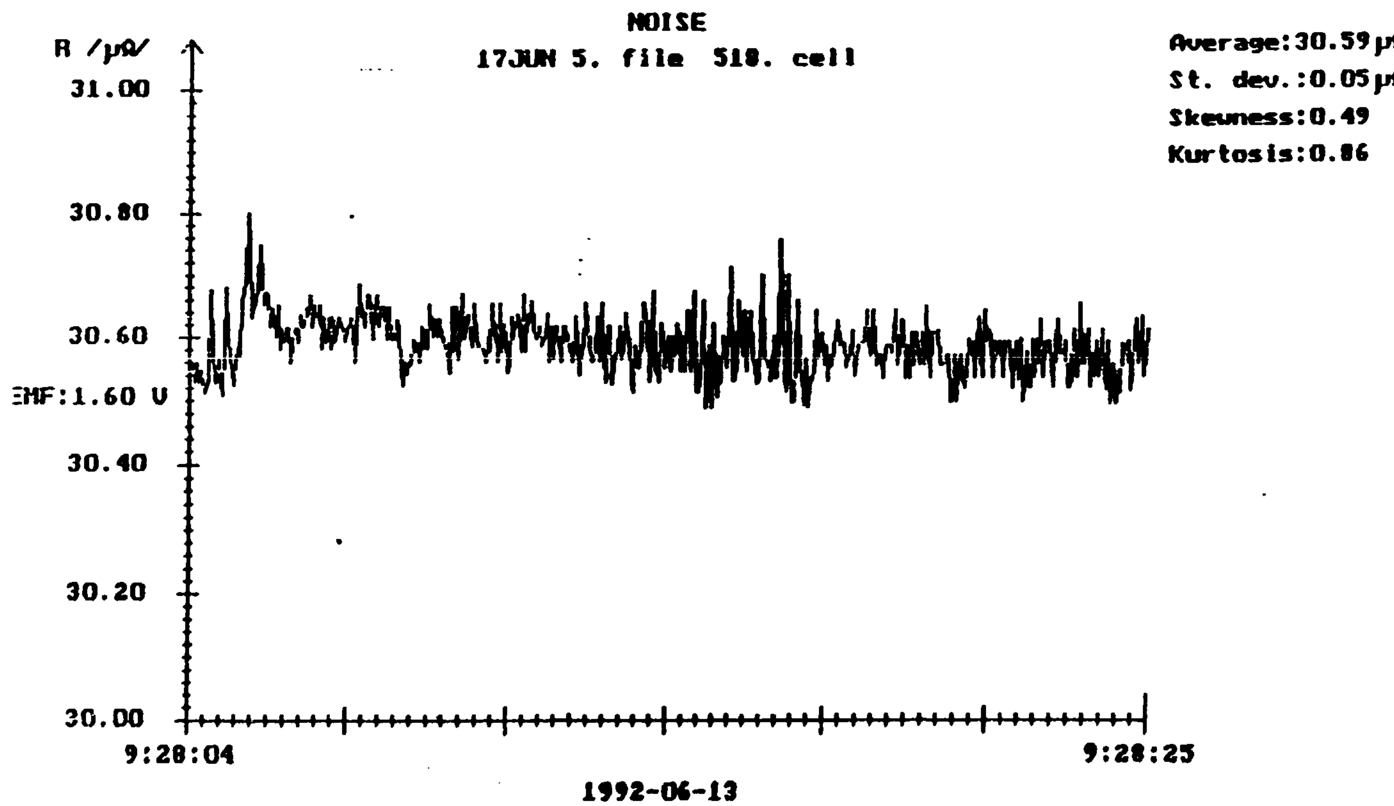


Figure 10b NORMAL NOISE

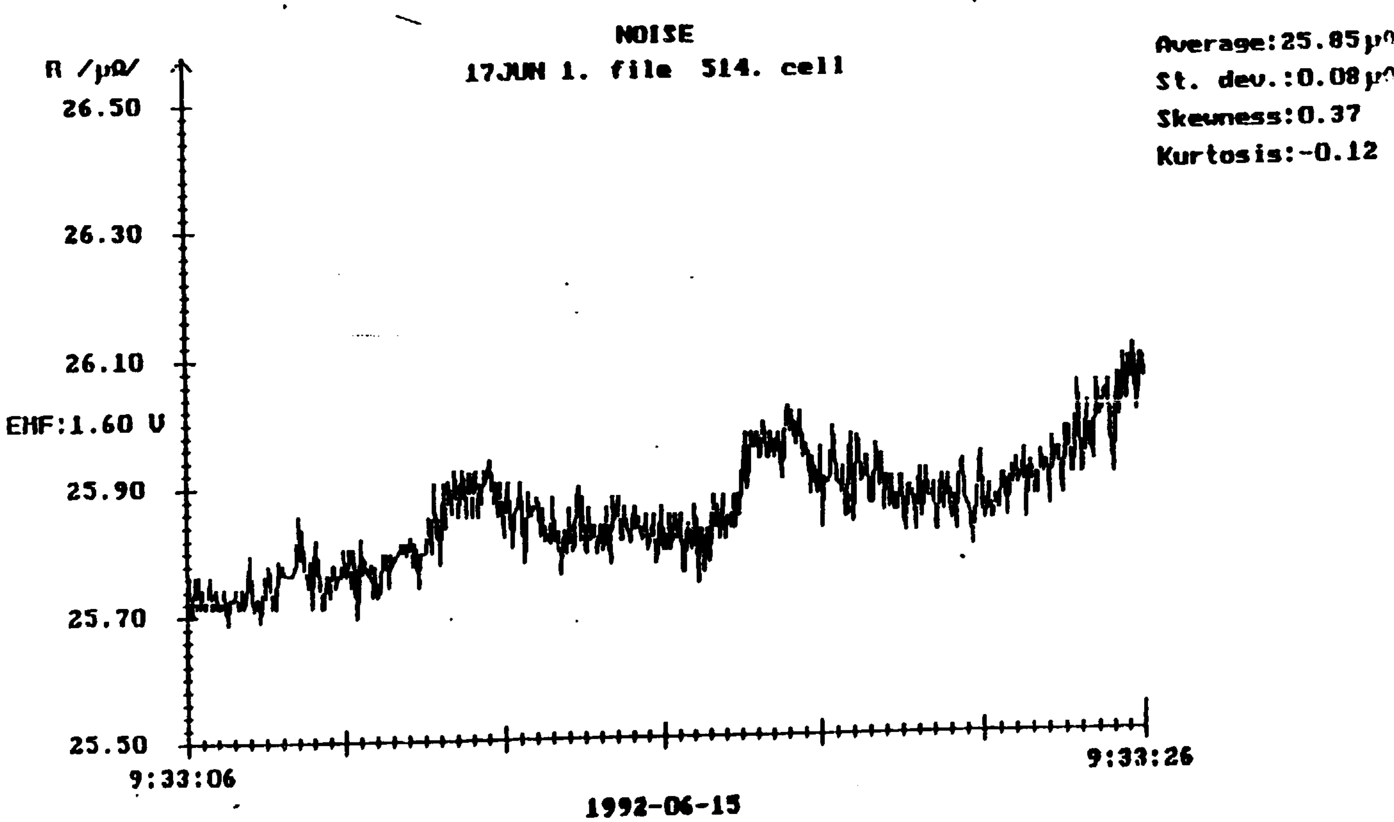


Figure 10c **WAVING**

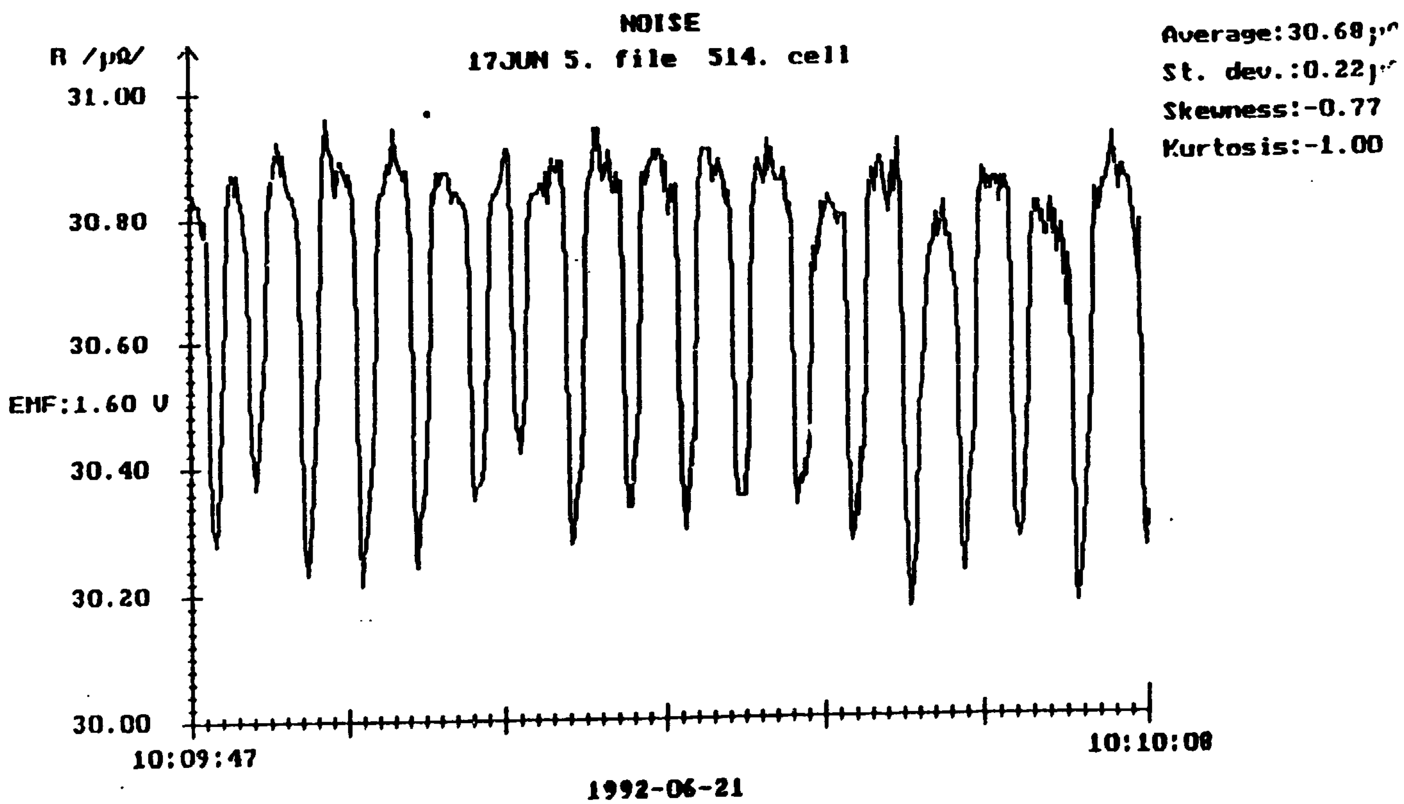


Figure 10d NOISE IS CAUSED BY SPIKE

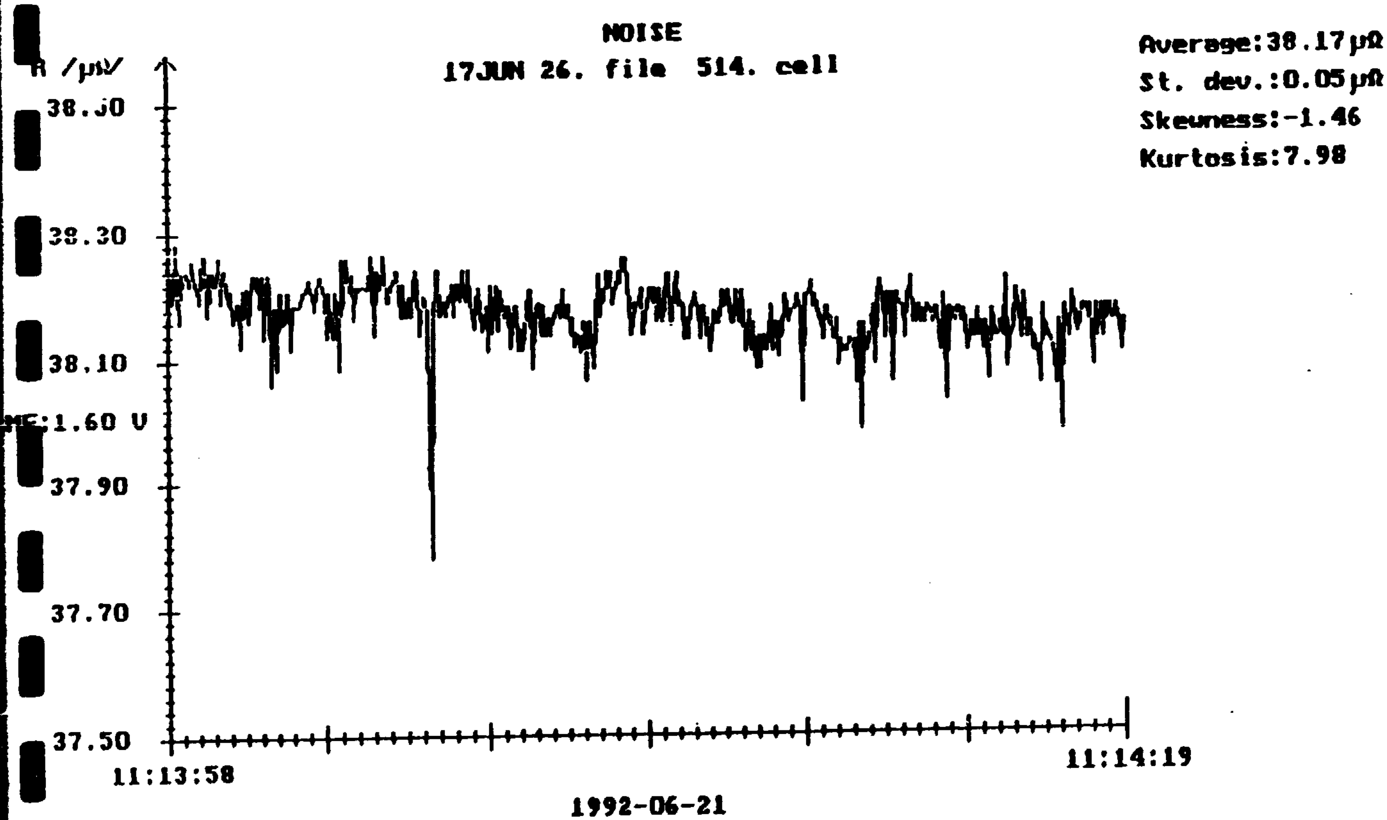


Fig.10e NOISE AFTER LIFTING OF ANODE

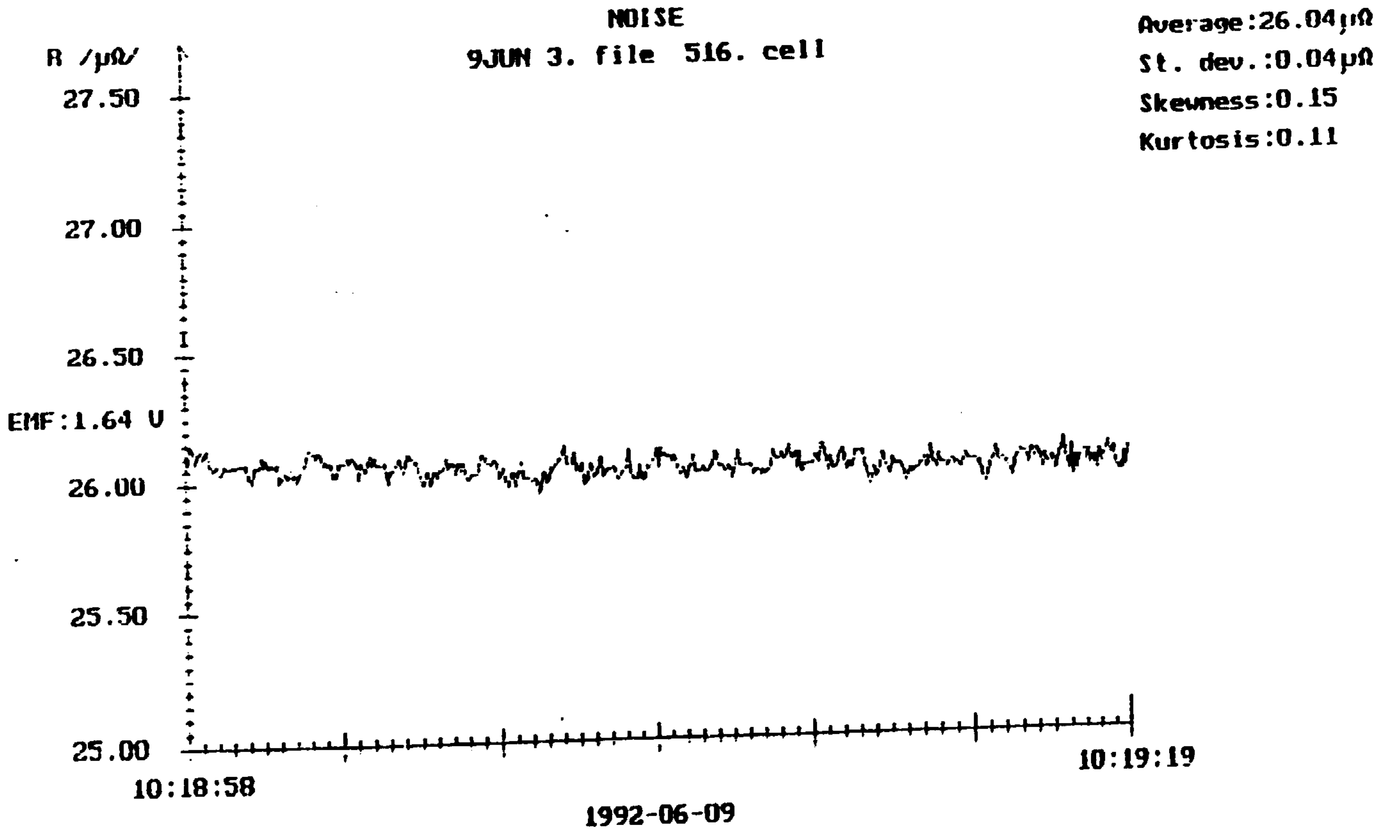


Figure 10f WARM CELL

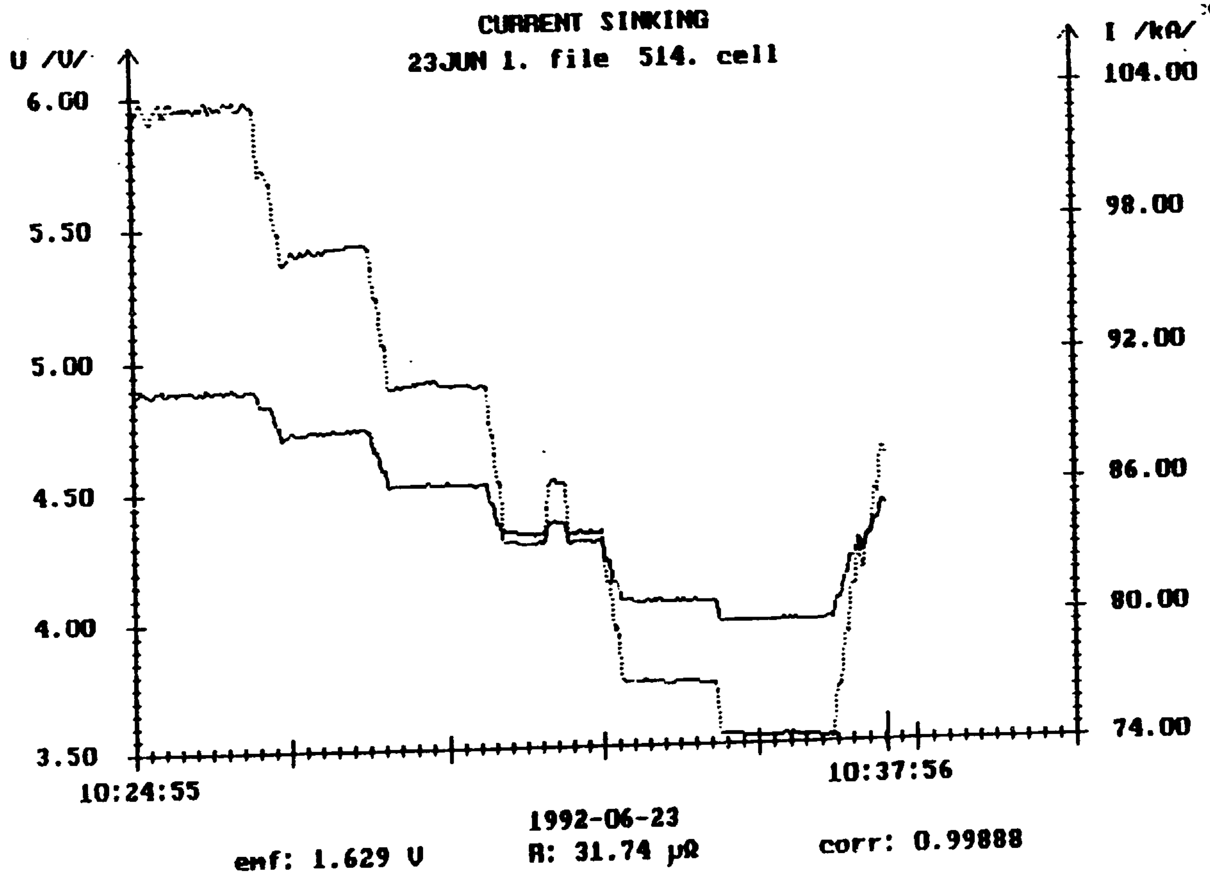


Figure 11a NORMAL EMF

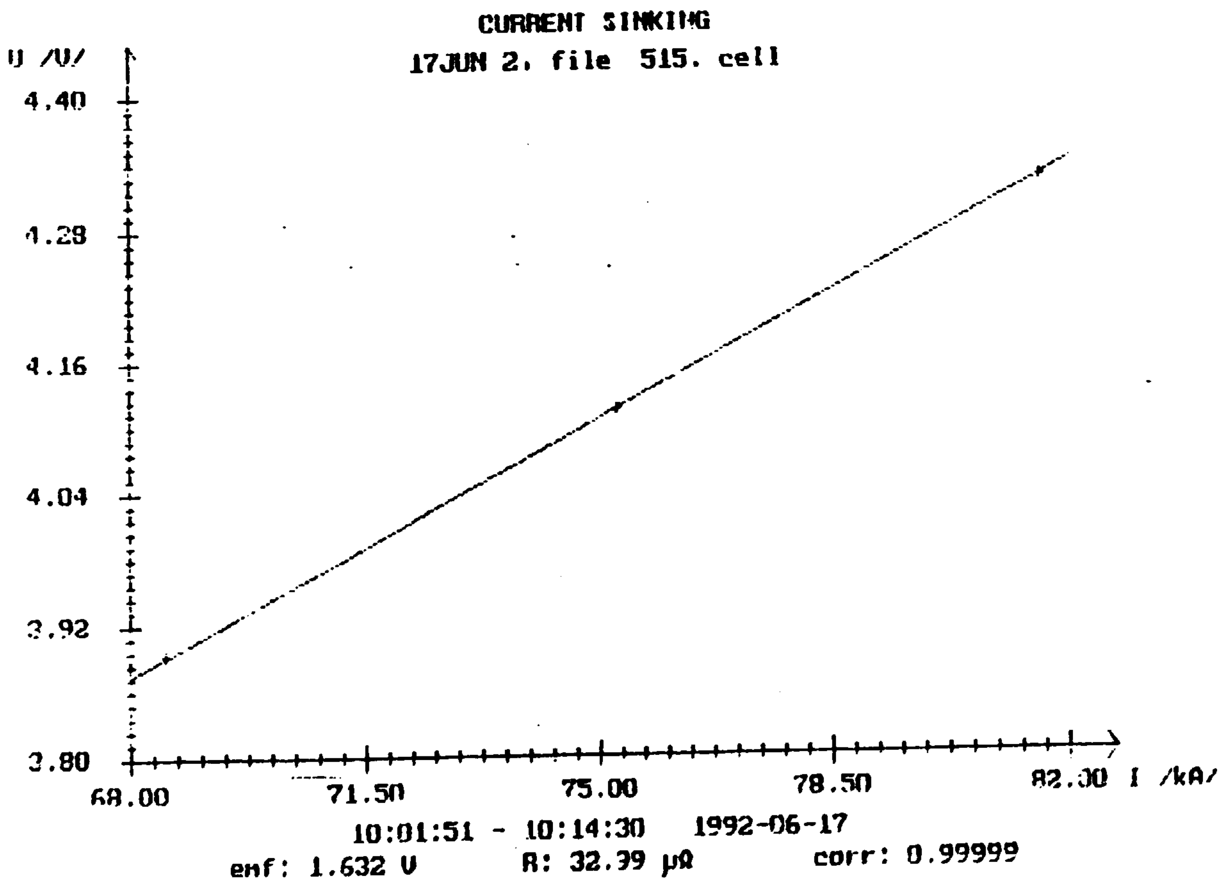


Figure 11b NORMAL EMF

VOLTAGE COMPONENTS IN AC GAP

TYPE OF CELL : SODERBERG

MEASURED DATA	UNITS	TRADITIONAL	EXPERIMENTAL
CRYOLITE RATIO		2.85	2.85
AVERAGE ALUMINA CONTENT	%	10.00	4.00
CALCIUM FLUORIDE CONTENT	%	4	4
ELECTROLYTE TEMPERATURE	°C	990	975
MEASURED EMF	V	1.4	1.72
AC DISTANCE	CM	4.2	5.2
LINE CURRENT	kA	100	100
ANODE WIDTH	CM	230	230
ANODE LENGTH	CM	650	650
CELL VOLTAGE	V	4.42	4.72
CURRENT EFFICIENCY	%	78	85
ANODE VOLTAGE DROP	V	0.50	0.50
CATHODE VOLTAGE DROP	V	0.40	0.40
BUSBAR VOLTAGE DROP	V	0.30	0.30
VOLTAGE DROP OF SHORT CIRCUIT	V	1.20	1.20
CALCULATED DROP OF FROM PLANT DATA			
EQUILIBRIUM POTENTIAL		1.18	1.24
CATHODIC OVERVOLTAGE	V	0.06	0.058
ANODIC REACTION OVERVOLTAGE	V	0.47	0.47
ANODIC DIFFUSION OVERVOLTAGE	V	0.008	0.015
CALCULATED E.M.F.	V	1.73	1.78
SPECIFIC RESISTANCE OF BATH	OHM·CM	0.46	0.42
REISTANCE OF ELECTROLYTE	μ·OHM	13.23	14.58
ELECTROLYTE VOLTAGE DROP	V	1.32	1.46
VOLTAGE DROP BETWEEN AC GAP	V	2.72	3.18
CALCULATED CELL VOLTAGE	V	3.92	4.38
CALCULATED DATA FROM THE MEASURED E.M.F. AND METAL TOUCHING METHOD			
VOLTAGE DROP BETWEEN AC GAP	V	3.22	3.52
ELECTROLYTE VOLTAGE DROP	V	1.82	1.80
DEPOLARISATION VOLTAGE COMPONENT BECAUSE OF REOXIDATION REACTION	V	0.325	0.058
CALCULATED OF ENERGY BALANCE			
LIQUID TEMPERATURE	°C	929	972
SUPERHEAT	°C	61	3
VOLTAGE DEMAND OF Al PRODUCTION	V	1.78	1.894
ENERGY DEMAND OF Al PRODUCTION	kW	178.5	189.4
ACTUALLY HEAT LOSSES	kW	263.4	282.6
THEORETICAL HEAT LOSSES	kW	213.7	248.4
ACTUALLY ENERGY EFFICIENCY	%	29.2	29.8
THEORETICAL ENERGY EFFICIENCY	%	32.9	32.1
ACTUALLY DAILY PRODUCTION	kg	628.6	685.0
THEORETICAL DAILY PRODUCTION	kg	805.9	805.9
ACTUALLY ENERGY CONSUMPTION	kwh/kg	16.8	16.5
THEORETICAL ENERGY CONSUMPTION	kwh/kg	11.6	13.0

A N N E X U R E - IX.

PROPOSAL FOR MODERNISATION OF BALCO SMELTER AT KORBA

PREPARED BY
JNARDDC / BALCO

NAGPUR - KORBA
MAY 1992

CONTENT

EXECUTIVE SUMMARY

A proposal for the modernisation of the Korba Smelter has been prepared by the experts of Jawaharlal Nehru Aluminium Research Development and Design Centre in cooperation with their counterparts at BALCO - the basic premise of the proposal is to achieve maximum benefits with minimum change in cell construction laying emphasis on improvements in technology and or work routine. The latter would involve special efforts to train operators and foremen.

Major changes such as replacement of rectifiers, alumina transportation and distribution systems, introduction of point feeders, installation of new cranes and end crust breaking vehicles have been the main factors for the modernisation of similar smelters elsewhere in the world. However, these are not envisaged in the present proposal due to high investment and operational costs. It is proposed to make some changes in the anode stud pulling system to decrease the anode voltage drop - this can be considered as the first phase of introduction of the so called "dry anode paste technology".

The salient features of the proposal are the following :

- installation of controllers and bar breakers for the improvement of existing operational parameters

- modification of technology and operational routine without introducing changes in cell construction.

There are two possibilities for the procurement of the controllers - either to import the ones presently available in the closed/closing down smelters of HUNGALU or from indigenous sources based on the software purchased from an outside agency. If the HUNGALU controllers are to be installed, negotiations, contracting, shipment, delivery, reinstallation at the BALCO smelter and training of the BALCO staff are required. The

present proposal envisages that the staff members of BALCO and the Centre and the international experts attached to the Centre would play a prominent role in installation, measurement and evaluation of data. It is also necessary to carry out measurements on the present state of the cells at Korba; preliminary work in this direction has already been started by the staff members of BALCO and the Centre. Keeping this in mind, the following schedule is suggested for the completion of modernisation.

SCHEDULE FOR THE MODERNISATION OF BALCO SMELTER
BASED ON HUNGALU CONTROLLERS

Activity	Period	Responsibility
Measurement on cells at Korba	14/4 - 5/7 1992	JNARDDC/BALCO
Negotiations, contract, shipment, delivery, installation, training	July-Dec 1992	BALCO/HUNGALU
Experimental study	Jan-Jun 1993	BALCO/JNARDDC with assistance of international experts
Voltage regulation	July-Dec 1993	---"---
Technoeconomic evaluation	Jan 1994	---"---

It should be noted that since the number of controllers offered by HUNGALU is limited (about 100) it would be necessary to produce the others through an indigenous source taking the know-how from HUNGALU. This process can be carried out simultaneously with the ordering/delivery of controllers from Hungary. If the decision is to go in for a whole lot of indigeneously made controllers, purchasing the know-how from abroad, the total time period of 13 months for the experimental study, voltage regulation and technoeconomic evaluation would commence from the time of installation of the controllers at Korba.

Crust breaking would be carried out by the bar breakers already developed at BALCO. It was made clear to us during our discussion with the BALCO staff that these could be manufactured/procured from indigenous sources. The time schedule for the installation of bar breakers would be as follows :

Activity	Period	Responsibility
Tendering, contract, and procurement	July-Dec 1992	BALCO
Installation	Jan 1993	BALCO/SUPPLIER
Anode casing modification	Nov-Dec 1992	BALCO/JNARDDC/ SUPPLIER
Observation on cells	Jan-July 1993	BALCO/JNARDDC
Technoeconomic analysis	Aug 1993	BALCO/JNARDDC

The existing and expected values (after modernisation) of various parameters are summarised below :

CELL PARAMETERS AT BALCO

Parameter	Present	Expected
Molar ratio	2.75	2.65
Average alumina content	4.00%	4.00%
Calcium fluoride content	4.00%	4.00%
AC - distance	4.00 cm	5.5 cm
Cell voltage	4.62 V	4.57 V
Avg. line current	97 kA	97 kA
Current efficiency	81%	88.0%
Anode voltage drop	0.50 V	0.40 V

Cathode voltage drop	0.39 V	0.35 V
Bus bar voltage drop	0.30 V	0.30 V
Voltage drop on construction elements	1.19 V	1.05 V
Voltage demand for aluminium production	1.83 V	1.94 V
Voltage drop on ACD-gap	3.44 V	3.52 V
Electromotive force	1.65 V	1.65 V
Voltage drop in electrolyte	1.78 V	1.87 V
Energy for Al production	177.6 kW	188.32 kW
Heat losses	270.5 kW	254.97 kW
Energy efficiency	39.6%	42.5%
Energy consumption	17.00 kWh/kg	15.48 kWh/kg

It may noted that after modification, the current efficiency would go upto 88% (as against the present figure of 81%) and energy consumption reduced to 15.48 kWh/kg (present figure 17 kWh/kg).

The setting up of a joint team with participants from the Centre and BALCO for the formulation and implementation of the modernisation proposal is likely to result in a relatively low investment cost. The cost of manufacture of each bar breaker is estimated by the BALCO staff to be Rs. 230,000; presently available estimates from HUNGALU suggest that each controller would cost between $ 5000-6000 (average cost including micro and Central Computers and training programme).

INTRODUCTION

Many of the smelters world-wide are now more than 20 years old. Plant retrofitting and modernization are strongly needed for these cell lines in order to increase current efficiency and reduce cell voltage so that the total energy consumption could be reduced.

About half of the world's aluminium production is made in Soderberg cell. The "best" and "industrial average" data for current efficiency and energy consumption for these cells are summarized in Table I :

TABLE I: ENERGY CONSUMPTION AND CURRENT EFFICIENCY FOR SODERBERG CELLS

	BEST		INDUSTRIAL AVERAGE DATA	
	ENERGY(kWh/kg) CONSUMPTION	CURRENT EFFICIENCY (%)	ENERGY(kWh/Kg) CONSUMPTION	CURRENT EFFICIENCY (%)
1964	14.4	90	16.0	86.0
1976	14.5	90	15.0	86.0
1988	13.5-14.0	90.5	14.5	87.0
2000	13.0-13.5	92.5	14.0	89.0

Bharat Aluminium company plans to modernise its aluminium smelter (Korba), commissioned in 1975. A proposal from JNARDDC for the preparation of detailed energy and voltage balance was discussed with Balco experts at site and it was agreed, that a joint proposal will be prepared for the modernization of the whole plant. The main stress of this modernization proposal is to improve the operational parameters and to achieve the predicted industrial average data and to meet the more strict environmental requirements.

2. EVALUATION OF VOLTAGE AND ENERGY BALANCE TO DETERMINE THE MAIN ELEMENT OF MODERNIZATION PROJECT

On the basis of observations and preliminary calculations, the values estimated for the existing cell operation parameters by the experts of the Centre are given in Table II. Using these values the energy and heat balance were calculated. The results are also summarized in Table II.

The results show that the main energy losses are in the anode-cathode gap and these losses are increased by the number of anode effects and their duration. At this AC - distance the electrolyte voltage drop should be 1.12 V instead of 1.78 V. At low AC - distance the heat generation is increased by exothermic reaction of reoxidation process. The other main reason for losses is the bottom deposit and sludge formation.

3. PROPOSAL FOR MODERNIZATION OF KORBA SMELTER EXPECTED RESULTS

In this section the development possibilities, improvements in operational parameters and requirements have been studied in the light of the modernization concept.

TABLE II: OPERATING PARAMETERS FOR THE BALCO ELECTROLYSIS CELL

Parameter	Existing	Expected
Molar ratio	2.75	2.65
Average alumina content	4.0%	4.0%
Calcium flouride content	4.0%	4.0%
Line current	97 kA	97 kA
AC - distance	4.0 cm	5.5 cm
Cell voltage	4.62 V	4.57 V
Current efficiency	81.0%	88.0%
Anode voltage drop	0.5 V	0.40 V
Cathode voltage drop	0.39 V	0.35 V
Bus bar vòltage drop	0.30 V	0.30 V
Voltage components :		
Voltage drop on construction elements	1.19 V	1.05 V
Voltage demand for aluminium production	1.83 V	1.94 V
Voltage drop in ACD - gap	3.44 V	3.52 V
EMF (Electromotive Force)	1.65 V	1.65 V
Voltage drop in electrolyte	1.78 V	1.87 V
Energy components :		
Energy for aluminium production	177.6 kW	188.32 kW
Heat losses	270.5 kW	254.79 kW
Energy efficiency	39.6%	42.5%
Energy consumption	16.997 kWh/kg	15.48 kWh/kg

In general, it is known, that low energy consumption and high current efficiency cell operation are characterized by:

- Compensated magnetic fields
- voltage and/or resistance regulation and automation
- efficient alumina feeding technology
- stabilized bath composition
- good frozen profile
- low superheat

To achieve the improvement of the operational parameters the above components will be analysed in more detail :

Compensated magnetic field - The magnetic field and electric current through the bath and metal will give rise to electromagnetic forces, causing circulation of the bath and metal. This circulation promotes the rexodation of the dissolved metal and decreases the current efficiency.

The vertical component of the magnetic field is a very important factor for stable pot operation. This vertical component is determined by cell construction and bus bar arrangement. In order to decrease the value of this magnetic component some modification should be done in the bus bar arrangement, but its benefit will be limited, therefore it is not proposed.

<u>Voltage and/or resistance regulation and autowation</u> - Now-a days, controllers based on microprocessors are used in the aluminium smelter. They measure cell voltage and line current, and check the possible errors like cell instability and control the necessary operations e.g. anode stud replacement, starting of alumina feeding. The measured data are displayed and are helpful in predicting the occurence of an anode effect. Sometimes, the Controller can follow the operational events e.g. automatic anode adjustment during metal tapping. A set of the controllers (say 11) would be controlled by a separate microcomputer.

The main functions of pot controller are the following :

i) Noise analysis - waving, pulsating and fluctuating - suitable for detection of cell failure operation. The appearance of waving noise indicates hydrodynamic instability of the melt. The circulation and fluctuation of the melt changes the actual anode-cathode distance and results in a waving cell voltage. Pulsating cell voltage can be recognised when the cell has certain anode bottom problems (spike, large amount of skim). Temporary anode-cathode short circuits cause sharp falls in the otherwise normal cell voltage. Fluctuations characterise the thermal state of a cell. The relatively warm cell has a noise of small amplitude and in case of a relatively cold cell, fluctuations are larger, then the cell is called "noisy". Computer control requires a special algorithm for detection of different kinds of noises.

ii) Prediction of anode effect through an appropriate algorithm. The latter is based on the change of the slope of the resistance - time curve.

To reach a more stabilized cell operation it is necessary to adjust the target cell voltage. Adjustment of target cell voltage results in stabilized heat balance which leads to improvement in operational parameters.

Special metal tapping procedure will be introduced to stabilize the thermal state of the cell.

Efficient alumina feeding technology - Alumina content of the bath is one of the most important parameters of the process and therefore regulation of alumina feeding is of great significance. Old aluminium plants with horizontal and vertical Soderberg cells are not usually provided with automatic feeders, so the alumina feeding can hardly be regulated. Some years ago bar-breakers and point feeders were developed for the Soderberg cell, to improve the alumina feeding technology.

An important feature of the proposed modernization project is to install bar breakers. To avoid the sludge and deposit formation on cathode bottom the alumina content in bath must be maintained at low value. It is possible to maintain low alumina content in the bath with combination of scheduled crust breaking and crust breaking at anode effect prediction. This procedure is expected to lead to sludge-free cathode bottom.

Stabilized bath composition - The optimum electrolyte composition depends on : cell construction, alumina quality, and understanding of the cell behaviour by the operators. The electrolyte composition should conform to molar ratio of 2.65 with average alumina content of 4.0% and CaF_2 - 4.0% without other additives.

Good frozen profile - One of the most difficult parts of Soderberg operation is the shape and size of the side freeze. Shape depends on parameters like feeding system, cathode insulation, heat balance of cell etc. The main task is to keep the frozen profile approximately to the anode shadow.

As the more difficult part of the proposed modernization process is to maintain a good frozen ledge, it is necessary to train the foremen and cell operators in this regard.

Low superheat - Superheat is defined as the difference between the operating temperature and liquidus temperature. It should be as low as possible to decrease the aluminium solubility in the bath but high enough to provide for heat of dissolution of alumina.

In our opinion the anode voltage drop is too high, because of the practice of the two stage stud pulling arrangement. This should be increased to seven levels by proper adjustment of crane capacity. Such an increase would also be a precursor to introducing the dry anode technology at a later date.

Taking into account the modifications in cell technology the expected heat and voltage balance was calculated and the results are included in Table II.

4. DETAILS OF THE PROPOSED PROGRAMME FOR MODERNISATION OF BALCO SMELTER BY JNARDDC/BALCO ARE AS FOLLOWS

A. PRELIMINARY PROGRAMME FOR BASIC STUDY ON KORBA TEST CELLS

This programme seeks to understand the behaviour of Korba cells in a detailed manner and accordingly a series of measurements are planned. These include the following :

1. Heat balance study
2. Magnetic field measurement
3. Voltage balance measurements
4. Voltage pattern study,

using the Sophisticated equipment available in the Centre.

The study will commence from 1st June 1992 lasting for three weeks. It is necessary to carry out the following preparatory work prior to the start of this study.

1. Preparation of an air-conditioned dust free room where signals for cell voltage and line current are made available
2. Training of BALCO personnel at Nagpur to familiarise them with the techniques of measurement
3. Transportation of equipment to site
4. Installation and commissioning of equipment at site.

Details of the planned programme are provided in Table-III

Table-III : Proposed programme for carrying out measurements

Sl. No.	ACTIVITY	PERIOD	RESPONSIBILITY
1.	Outlining the requirements for site preparation	April 14-18	JNARDDC
2.	Preparation of site	April 18-May 18	BALCO
3.	Training of BALCO personnel at Nagpur	May 11-May 13	JNARDDC
4.	Transportation of equipment from Nagpur to Korba	May 15-May 25	JNARDDC/BALCO
5.	Installation and commissioning of equipment	May 25-May 30	JNARDDC/BALCO O*
6.	Measurement on Korba cells	June 1-June 21	JNARDDC/BALCO
7.	Evaluation of data at Nagpur	June 21-July 5	JNARDDC/BALCO

B. INSTALLATION OF POT CONTROLLER

There are two possibilities for installation of pot controllers.

i) Installation of Pot Controller from HUNGALU

During the period when the Basic Data are being collected, a programme for transfer of pot controllers from HUNGALU will be explored so that by the time these controllers arrive, the required information on Korba cells have been collected; these data would help to modify the softwarfe of these controllers.

The entire lot of pot controllers, microcomputers and the central computer is proposed to be transferred to Korba and immediately installed. As the number of controllers from Ajka is limited, simultaneous action should be taken to have more controllers manufacturered indigenously.

The experimental study will be made on a group of cells ranging from 13 to 51 wherein the following functions will be performed by the pot controllers.

1. Resistance based control of ACD of the cell
2. ACD control during metal tapping
3. Noise monitoring and detection of failure of operation
4. Anode effect prediction, alumina feeding
5. Data logging and historical analysis

By installing the process control system, we estimate that the performance of the cell will improve and current efficiency will go up to 86% while specific power consumption will come down to 15.9 kWh/kg without the use of crust breakers.

The experimental period will extend for six months during which time the operating parameters may be further refined. Some technological parameters such as metal height, bath height, anode immersion depth will also be measured.

ii) Indigeneous pot controllers

The pot controllers can be purchased from domestic market However, if there is any problem in the procurement of Ajka Controllers, then in this case it is necessary to purchase the software separately.

After installation of these controllers, it is proposed to train BALCO personnel in operation and maintenance of the system.

All the necessary knowledge and details of operational practice related to controlled cell operation would be provided by the international experts of JNARDDC. The main activities during this period would be :

- Removal of sludge
- Adjusting bath and metal height
- Controlling anode and current distribution
- Improvement of alumina feeding technology

Assuming that the controllers are procured from HUNGALU, the proposed installation programme is given in Table-IV.

Table-IV : Programme for installation of HUNGALU controllers

Sl. No.	ACTIVITY	PERIOD	RESPONSIBILITY
1.	Submission of offer by HUNGALU to BALCO at Delhi	15 May'92	JNARDDC
2.	Study of proposal by BALCO and decision by BALCO		
3.	Contracting	One month after BALCO's decision	BALCO
4.	Training of JNARDDC/ BALCO personnel in Hungary	One month after contracting	
5.	Delivery	One month after contracting	
6.	Installation by Hungalu experts in cooperation with JNARDDC/BALCO	After delivery	
7.	Experimental study on 13 or 51 pots	Six months	BALCO/JNARDDC

Sl. No.	ACTIVITY	PERIOD	RESPONSIBILITY
8.	Voltage regulation in pots to the extent possible	Six months	BALCO/JNARDDC
9.	Techno-economic evaluation	One month	BALCO/JNARDDC

<u>AUTOMATIC CRUST BREAKING SYSTEM</u>

C. The use of the knife type crust (bar) breaker developed by BAlCO will be the basis of implementation of the mechanisation of alumina feeding. It is proposed that simultaneously with the installation of pot controller, crust breaking facility will be installed on one section of 13 number of pots.

If it is felt necessary, JNARDDC is ready to evaluate the existing design of Korba knife type crust (bar) breaker with the assistance of an international expert. The installation of knife type crust breaking system will not require any shut-down of pots; therefore no loss of metal production will take place due to this modification.

The knife type crust breaker for controlled crust breaking could be easily installed within a short period practically without any risk. Only preliminary experiment would be necessary on the group of experimental pots (13 cells) for ensuring correct design of the construction and technology. Afterwards, the system can be introduced in the whole of smelter. We would like to confirm whether the combination of pot controller and crust breaking system would give more benefits particularly in terms of improved technological parameters.

The experts of the Centre are ready to impart their knowledge and practice to BALCO in this matter. The main activities in this period are as follows :

- Determination of bath volume
- Determination of quantity of alumina fed
- Determination of optimum alumina layer on crust
- Introduction of schedule and anode effect prediction crust breaking system
- Introduction of control and measuring system

To achieve the improved operational parameters, modification in alumina quality is needed. The -45 micron particles should not exceed 20%. The proposed programme for introducing the crust breaking system is given in Table-V.

Table-V : Programme for introducing automatic crust breaking system

Sl. No.	ACTIVITY	PERIOD	RESPONSIBILITY
1.	Tendering action of 13 cells	First week of May 1992	BALCO
2.	Procurement of equipment	December 1992	BALCO
3.	Modification of anode casing & procurement	Nov-Dec'92	BALCO
4.	Installation of equipment	By end of Jan'93	BALCO
5.	Observation of cells	Six months upto July'93	JNARDDC
6.	Techno-economic analysis	One month	JNARDDC

Based on measurements and evaluation on the test cells and evaluation by using pot controllers and knife type breakers, modification of technological parameters and modernisation of remaining cells of Korba will be taken up. This includes the following installation action :

1. Provision of knife type crust (bar) breaker for each cell
2. Further needed modifications such as :
   a) Central computer
   b) Gas burner and gas ducting
   c) Mechanisation such as control of anode, stud pulling and end breaking vehicie

5. TRAINING PROGRAMME

An essential part of the modernisation programme is to make the plant staff appreciate the need for following strict discipline in technological practice and the use of controllers. It, is, therefore, necessary that the plant staff is provided with the necessary training well before the modernisation process is started. They should understand the changes introduced thoroughly and be able to take decisions to vary the parameters as and when the situation demands.

The training could be imparted to a small group (nucleus) of staff who, in turn, will proliferate it in the plant. There would be three phases of training, in the factory of the technology/controller supplier, at the Research Centre at Nagpur and at BALCO Plant at Korba. It would include various components - theoretical aspects of electrolysis and control, operating procedures, details of equipment, maintenance schedule and practice etc. Such an activity would put the plant staff on a solid ground to make the best use of the proposed modernisation process.

6. INVESTMENT COST

- The program will be executed by joint team of experts from BALCO and JNARDDC.

JNARDDC will be responsible for measurements and evaluation of data by involving the international experts and their scientists. The expenses of site preparation, participation of plant personnel and any other expenses emerging in India will be borne by BALCO.

- Modification of the group of test cells consists of two main items :

  - Pot controllers
  - Bar breakers

From our discussion with the BALCO staff we understand that the bar breakers developed by them can be manufactured in India, the estimated cost is Rs. 230,000 per breaker. Preliminary information received from HUNGALU suggests that the average cost of each controller (including computers, training programme and installation) would be $ 5000-6000. However more details can be worked out by extensive discussion with HUNGALU, JNARDDC, BALCO and Indian party prepared to supply the controllers.

If all the controllers are to be procured indigenously, the software is to be bought from an outside agency. In this case the period of 13 months envisaged for experimental study on pots, voltage regulation and technoeconomic evaluation would commence from the date of installation of the controllers at BALCO plant.

ANNEXURE-X.

NATIONAL ALUMINIUM COMPANY LIMITED
SMELTER PLANT
(A GOVT. OF INDIA ENTERPRISE)

NATIONAL ALUMINIUM COMPANY LIMITED
SMELTER PLANT - LABORATORY
ORISSA - 759 145

SUB: RECORD NOTES OF THE DISCUSSION HELD BETWEEN JNARDDC, NAGPUR AND NALCO FROM 20th APRIL TO 23rd APRIL 1992 AT NALCO ANGUL.

Persons present:

JNARDDC,NAGPUR	NALCO , ANGUL
1.Dr.J.Horvath UNDP Expert	1.Mr.M.L.Kampani
2.Mr.G.S.sengar	2.Mr.R.N.Jena
3.Mr.Anupam Agnihotri	3.Mr.P.R.Pavithran
	4. Mr.Srinivas

Referring the meeting between NALCO representative and JNARDDC representative,JNARDDC experts arrived at NALCO,Angul,Smelter Division to discuss the following topics :

A. Characterisation of Electric/thermal state of existing cells with amorphous cathode blocks and modified cells with graphitised cathode blocks.

B. Heat balance of existing cells and cells built with indigineous bricks.

C. Heat balance of anode baking furnace.

The JNARDDC experts observed the status of existing Smelter technology at NALCO and listed all the information necessary to carry out above stated studies (ANNEXURE - 1).

JNARDDC experts proposed to carry out the above mentioned projects as follows.

I.A.Characterisation of electric/thermal state of existing cells with amorphous cathode blocks and modify cells with graphitised cathode blocks :

JNARDDC experts agreed to carryout all necessary experiments required for chacterisation of thermal/electric state of existing/modified cells.Following proposal was made :

i) Characterisation of amorphous/graphitised cathode blocks based on various laboratory facilities available at JNARDDC.

ii)Detailed heat balance of existing / modified cell will be carried out with methodes developed by JNARDDC with the assistant of UNDP.

iii)Thermo electric model will be developed to calculate the location of freezing isotherms in the cathode and position of side freeze.

After evaluation and analysis of data obtained suitable proposal will be made for any change in operating strategy ,if required.

B. Heat balance of existing cells and the cells built with indigeniuos insulation bricks.

JNARDDC has sophisticated equipments such as heat flux meter,thermovision etc.which are suitable to carryout the heat balance of the cells . These equipments will be used for determination of :

i) Cathode heat losses for existing states of cell.

ii)Cathode heat losses for cell with indigeneous insulating bricks will be determined.

iii)The voltage and energy balance will be calculated by JNARDDC experts and operating data will be given by NALCO.

JNARDDC experts informed NALCO that for successful solution of this problem it is necessary to develop mathematical model for determination of cathode isotherm,heat distribution etc.Due to large deviations in heat transfer coefficients between /metal and frozen ledge there are certain limitations to prediction of freezing isotherms,heat distribution etc. by mathematical model . Therefore it is necessary to carry out laboratory experiments to determine the heat transfer coefficients between bath/metal and frozen ledge.

C. Heat balance of anode baking furnace :

i) After close observation of status of the existing anode baking furnace,JNARDDC expressed the opinion that heat flux from the top surface can be determined.It is difficult to measure heat flux from the sides,since no suitable measuring points are accesable on sides of anode baking furnace.However, JNARDDC agreed to measure the heat flux at any accesable points on the side of anode baking furnace as suggested by NALCO.

JNARDDC will do the necessary action in the direction.After the discussion with NALCO they agreed for the programme and mentioned the main efforts to be done with JNARDDC.

II.Procedure for heat flux measurments :

JNARDDC experts propose to carry out the heat flux measurements at the basement of the cell house of selected cell in following way :

i) Long side 30 measurements i.e. 10 at 3 different layers on both sides.

ii)Short side 9 measurements i.e. 3 at 3 different layers on both sides.

iii)Bottom of the cell 30 measurements i.e. 10 at 3 different layers.

III. JNARDDC experts visited the quality control laboratory and collected all the information regarding various analysis methods which are presently being used by NALCO for raw materials and finished products.

IV. For the above mentioned projects, the NALCO team shall comprise of

1. S. P. MAHAPATRA (CMTS)
2.
3.
4.
5.

V. JNARDDC experts in consultations with NALCO prepared a tentative work programme for carrying out above mentioned projects (ANNEXURE -2)

VI. JNARDDC experts during their visit to NALCO were asked to consider few technical problems for making detailed study (ANNEXURE-3)

For JNARDDC, NAGPUR

23/4/9

For NALCO, ANGUL

NATIONAL ALUMINIUM COMPANY LIMITED
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ANNEXURE - 1

LIST OF INFORMATIONS NECESSARY TO CARRY OUT THE STATED PROJECT :

1. Cell drawing with all the dimensional details
2. Characteristics of existing lining material
3. Existing thermal/volatage information
4. Measuring method that is cathode current distribution, anode current distribution, bath height and metal height.
5. Anode bus bar current distribution
6. Specifications of C.P.Coke and Pitch
7. Cell operating parameters
8. Alumina quality
9. Analysis of raw material/finished product
10. Specification of indigeneous bricks.

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ANNEXURE - 2

TENTATIVE WORK PROGRAMME

Sl.No.	ACTIVITY	TENTATIVE SCHEDULE	RESPONSIBILITY
PHASE I			
1.	Formation of joint team.	19-24 April	NALCO
2.	Observation of site and collecting necessary information for the measurements.	19-24 April	JNARDDC/NALCO
3.	MASEARURING HEAT LOSSES AS FUNCTION OF POT AGE.		
a)	Selecting pots for the measurements.	from 1st week Sept-1992	NALCO
b)	Determination of cathode heat losses from bottom and side wall of selected pots.	-	JNARDDC
c)	Using energy balance calcution determine the total heat losses and operating data will be given by NALCO.	-	JNARDDC/NALCO
d)	Total cathode heat losses will be divided in 2 parts i.e. side walls and bottom.	-	JNARDDC
e)	Evaluation/analysis of data.	Last week Sept-1992	JNARDDC
PHASE -II			
4.	MODIFICATION OF INSULATING BRICKS		
a)	Changing of bricks(indegenious) in selected pots.	*	NALCO
b)	Determination of energy balance and heat loss of the cathode similarly as in phase-1.	*	JNARDDC
c)	Evaluation and analysis of the results of phase-1 and phase-2.	*	JNARDDC/NALCO

ANNEXURE - 3

JNARDDC experts during their visit to NALCO were asked to consider following technical problems for making detailed studies :

1. RODDING SHOP :

Induction furnace :

Life of the furnace linning is very low i.e. 2 to 3 weeks.Proposal was made to study the furnace linning and analyse the cause for such low life of furnace lining.

2. QUALITY CONTROL LAB.

a) A proposal was made to prepare a standard secondary samples of bauxite available in India.

b) Literature required for degassing system and purification of metal with different cleaning systems.

3. CARBON AREA DEPARTMENT

a) Low life of refractory meterial in anode baking furnace.

b) Fuel consumption very high.

4. CELL HOUSE

a) Disposal of spent cathode lining.

JNARDDC proposed to collect the all technological knowledge and information in connection with above mentioned technical problems.a detailed report will be prepared by JNARDDC.

5. MODOFICATION OF CATHODE BLOCKS FROM AMORPHOUS TO GRAPHITISED

a)	Installation of graphite blocks in selected pots.	*	NALCO
b)	Determination of heat losses and thermal balance with operating data given by NALCO.	*	JNARDDC/NALCO
c)	Evaluation/analysis and full scale techno-economic study extended for all the existing pots.	*	JNARDDC/NALCO

6. ANODE BAKING FURNACE

a)	Measurement of heat losses from the top of anode baking furnace will be carried out simultaneously with cell measurements.	2nd week Sept-92	JNARDDC/ NALCO

* - depends on decision of NALCO

ANNEXURE-XI.

WORKSHOP ON ALUMINIUM ELECTROLYSIS
(ANGUL JULY 13 - 15 1992)

A workshop on "ALUMINIUM ELECTROLYSIS" was organised at NALCO Angul from July 13 to 15 1992 by the Jawaharlal Nehru Aluminium Research and Development and Design Centre and the National Aluminium Company. The course material was prepared by Drs. J. Horvath. E.A. Ianko and V.I. Krioukovsky. UNDP experts at JNARDDC. Some Salient features of the Workshop are presented below.

PROGRAMME

Monday July 13 1992

9.00 - 10.00 hrs	Inauguration
10.30 - 12.00 hrs	Theoretical Background for Improvement of Aluminium Electrolysis - J. Horvath
14.00 - 15.30 hrs	Raw Materials (Carbon) in Production of Anode Paste. Prebaked Anodes and their Influence on Anode Products - E. Ianko
16.00 - 17.00 hrs	Video on NALCO

Tuesday July 14 1992

9.00 - 10.30 hrs	Hydrodynamics phenomena in the Commercial Hall-Heroult Cells of Different Types and Capacities - V. Krioukovsky
11.00 - 12.30 hrs	International Experience in Improvement of Anode and Cathode Production Technology - E. Ianko
14.30 - 16.00 hrs	Measurements and Data evaluation for Improvements in Cell Operation - J. Horvath
16.30 - 17.30 hrs	Applications of Nitride-Bonded Silicon Carbide in Primary Aluminium Melting - Presentation by V.B. Sople of Grindwell Norton

Wednesday July 15 1992

9.00 - 10.30 hrs	Future Developments of the Hall - Heroult Process for the Soderberg and Prebaked Anodes. High Level Smelter Performance - V. Krioukovsky
11.00 - 12.45 hrs	MicroProcessor in Process Control - S.P. Mahapatra NALCO MECON - O.P.Choudhari Summing Up - T.R. Ramachandran
14.15 - 17.00 hrs	Visit to NALCO smelter