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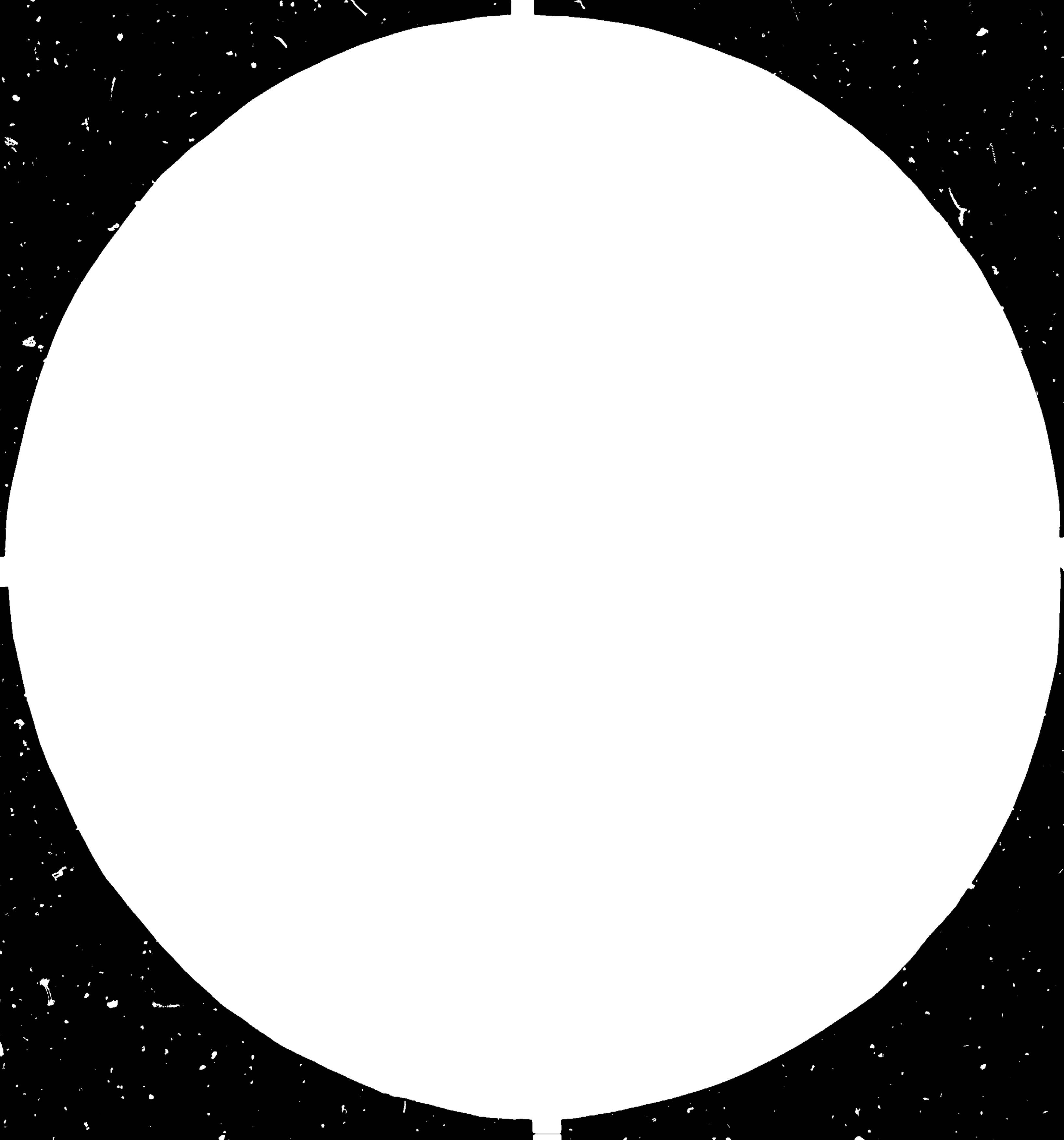

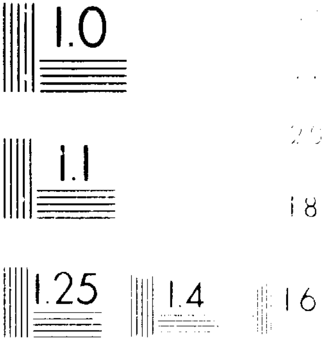
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FINAL REPORT

on an expert mission in Bauxite digestion accomplished
in ZHENG ZHOU, CHINA

Expert on mission: Dr. J. Zámbó

FINAL REPORT

on an expert mission in Bauxite digestion accomplished in ZHENG ZHOU, CHINA

Job number: DP/CPR/81/034/II-01/31.8A

Date of mission: 03.04 - 26.04.1984

Expert on mission: Dr.J.Zámbó

CONTENTS

	Page
Abstract	1
Introduction	3
Chronology of the activities carried out during the mission	5
Accomplishment of tasks set out for the mission	8
List of lectures	8
Conclusions of lectures	11
Analysis of the possibilities of improving the existing digestor line in the Zheng Zhou Aluminium Plant and establishment of an advanced digesting system	15
1. Chemo-technological problems	15
2. Energo-technological problems	17
2.1 Installation of slurry preheaters	17
2.2 Installation of multi-flash systems	19
2.3 Reduction of the strong liquor concentration	19
2.4 Complete reconstruction	20
Recommendations	22
APPENDICES	
A. Visits related to the job	A-1
B. Persons contacted during the mission	B-1

	Page
C. The list of some documents supplied to the staff of ZLMRI	C-1
D. Consultations upon a design and testing program of pilot scale testing facilities for bauxite digestion within the frame of the Research Institute	D-1
ANNEXES	
1. Suggestions for setting up an experimental commercial scale pilot unit in the existing plant for testing the adaptability of tube digestion for diasporic bauxites	1-1
2. Proposal for organizing a UNIDO Group Training at ZLMRI in Zheng Zhou, China	2-1
3. Preliminary estimation for setting up a Carbon Laboratory in the Zheng Zhou Light Metals Research Institute	3-1
4. Possibilities of cooperation in the field of white bauxites	4-1

ABSTRACT

The aim of this project was to reduce the energy consumption in alumina production by raising the awareness about some of the latest achievements of research and technology in the field of digestion of diasporic bauxite.

The main trends and results in bauxite digestion, the theory and practice of the processing of diasporic bauxites, new advanced technologies for heat recovery such as indirect heating in the autoclaves and new tube heat exchangers for pre-heating and digestion were analysed in 10 lectures. Wideranged and detailed recently published technical literature (34 copies including 3 studies and 1 book) was supplied to the participants.

After familiarization with the technical data and with the operation of the existing digestors in the Zheng Zhou Aluminium Plant the possibilities of adaptation of advanced technology for the reconstruction of the existing equipment and the establishment of a brand-new digesting line had been discussed with the managers and specialists of the Zheng Zhou Light Metals Research Institute and the Zheng Zhou Aluminium Plant.

The research necessary for adaptation of laboratory scale, bench scale, pilot plant and factory scale testing methods was also taken into consideration, as well as the investigations needed to introduce modern technology on a commercial level and some comprehensive methods for organizing the research and development activities.

As a result of common analysis and thorough discussions there are recommended in the report some methods, proven in general practice for diasporic bauxites and a testing programme in order to introduce a tube digestor

system, which has been applied so far only for boehmitic bauxites. Introducing these new procedures the steam consumption is expected to decrease compared to the present state by at least 20-25 % if the existing digestors will be reconstructed and by 40-50 % when realizing a modified system.

As requested by Dr.E.T.Balázs, the topics of a Group Training planned in China and establishment of a new Carbon Laboratory in the Research Institute were also discussed. (For details see Annexes 2 and 3.)

The possible joint beneficiation and marketing of white Chinese bauxites was also discussed. (See Annex 4.)

INTRODUCTION

The duties to be fulfilled during this mission were as listed in the six clauses below:

1. Look into the technical data and operation of the existing digestors.
2. Recommend new technology including indirect heating of digestors, tube digestion, etc. to be incorporated in order to reduce steam consumption by at least 15-20 % in bauxite digestion.
3. Advise on the design and improvement of the bench scale experimental facilities.
4. Advise on the experiment/testing of the experimental facilities.
5. Assist in the execution of the programme of bench scale testing/investigation including trouble-shooting, selecting of optimal conditions, etc.
6. Recommend the necessary technical literature for energy consumption of bauxite digestion.

When starting out for the present mission the following background information was available:

China now possesses significant resources of bauxite and a large and developing alumina-aluminium industry. However, the mineralogical charachter of China's bauxites is mostly diasporic and this is the most problematic type for industrial processing. The technology of processing this type of bauxite is not widespread, and international experience is relatively new and scarce. For this reason, the specific fuel/energy consumption in the alumina plants of China is, in the case of steam, almost double, and in the case of fuel oil for calcination, almost 25-30 % higher than the levels in countries which are the most advanced in this field. New advanced technologies such as indirect heating of autoclave digestors and tube digestion have been developed in some of the developed countries, but these new achievements have not yet been tested or applied in the alumina plants in China. The same refers to the new achievements in significantly reducing fuel oil consumption in the calcination of alumina. It is anticipated that by the application of these new developments, the steam consumption may be reduced by at least 1 to 2 tons per ton of alumina. However, their introduction on an industrial level needs detailed and sophisticated adaptation research with bench-scale testing on the specific type of diasporic bauxite. Similarly, the application of new developments in equipment and technology for calcining alumina is expected to lead to a decrease of up to 25-30 % of fuel oil consumption from the present level of more than 100 kg/ton alumina. These changes may be introduced by direct development activities in the form of a detailed reconstruction/application study related to the alumina calcining operations of the Zheng Zhou alumina refinery.

UNDP/UNIDO has already assisted the R+D activities of the aluminium industry of China through the project CPR/80/047 (Assistance to the Bauxite/Aluminium Industry) by transferring some of the newest research and technological developments in this field through the provision of experts, training and modern equipment. The Government of the People's Republic of China now wishes to receive further technical assistance from UNDP/UNIDO in the field of energy conservation in the aluminium industry.

CHRONOLOGY OF THE ACTIVITIES CARRIED OUT DURING THE MISSION

Arrival in Beijing on the 3rd April, 1984.
Visit to the local UNPD office in the afternoon.

4th April, national holiday
Visit to the Great Wall and Ming Tombs.

5th April
Departure from Beijing to Zheng Zhou by train.

6th April
Arriving in Zheng Zhou at 8 o'clock in the morning, meeting the directors of the Institute and Aluminium Plant.
Visit to the Institute and its laboratories in the afternoon.
In the evening attending a dinner with some of the managers.

7th April
In the morning delivering a lecture.
In the afternoon visit to the Alumina Factory.

8th April, holiday
Excursion to the Yellow River and to Zheng Zhou City.

9th April
In the morning giving a lecture.
In the afternoon discussions in the Institute.

10th April
In the morning reading a paper.
In the afternoon discussions with some engineers in the Institute.

11th April
In the morning delivering a lecture.
In the afternoon transfer to Zheng Zhou City and seeing a local opera in the evening.

12th April
In the morning giving a talk.
In the afternoon visit to the smelter.

13th April
In the morning visit to one of the bauxite mines.
In the afternoon discussing some problems about the training suggested to be organized in the Research Institute.

14th April
In the morning delivering a lecture.
In the afternoon discussions with the managers and engineers of the Alumina Factory.
In the evening invited to attend a dinner.

15th April, holiday
Excursion to Kai Feng City.

16th April,
In the morning discussions with some specialists of the Alumina Factory.
In the afternoon meeting the managers of the Institute and Factory and having a dinner with them.

17th April
In the morning discussions in the Research Institute about the optimum utilization of white bauxite.
In the afternoon working on the report.

18th April
Excursion to Luo Yang City.

19th April
In the morning discussing with some engineers of the Institute about the testing methods of tube digestion.
In the afternoon consultations concerning the theory and practice of processing and digesting diasporic bauxites.

20th April
Working on the report.

21st April
In the morning discussion with some managers and engineers of the Factory.
In the evening departure from Zheng Zhou to Xian by train.

22nd April, holiday
Sight-seeing in and in the surrounding of Xian, getting familiar with its cultural and historical monuments.

23rd April
Leaving Xian by train for Beijing.

24th April, 14 h
Arrival in Beijing.

25th April
In the morning visit to the UNDP office for final discussions.
In the afternoon discussions with the representatives of the China National Non-Ferrous Metals Industry Corporation in their Beijing office.

26th April
Departure from China for the trip back to Europe.

ACCOMPLISHMENT OF TASKS SET OUT FOR THE MISSION

One of the main instruments used in my mission to achive the goals put forward was to elucidate the core of the technical problem in lectures and discussions based on these. I delivered altogether 10 lectures under the titles listed below:

1. Present state and perspectives of the world's aluminium industry. (2 h)

2. Information about the activities of the Hungarian Aluminium Corporation and its Research and Developments Centre (ALUTERV-FKI) (1 h)

3. Method of analysing the heat and material balances of the Bayer cycle and evaluation of the technical/economical level of an alumina refinery. (3 h)

4. Recent developments in the theory and practice of digesting diasporic bauxites. (2 h)

5. The advanced digestor line and the tube digesting system. (2 h)

6. Possible arrangement and expected economic characteristics of an up-to-date digestion system for Chinese diasporic bauxites. (2 h)

7. Possibilities to improve the existing digestors and considerations directing the selection of a new digesting system in the Zheng Zhou Alumina Factory. The basic methods to be used in testing such a system. (2 h)

8. Alternative ways of saving energy in the Bayer cycle (calcination, evaporation and precipitation). (1 h)

9. Some aspects of the realization of the proposed digesting system. (1 h)

10. Methods of organizing the solution of research and development tasks in the Hungarian Aluminium Corporation. (2 h)

All the questions and topics proposed by the project director Mr.Liu Ying were handled in detail in the lectures. These were as follows:

- The advanced technology of digestion in alumina industry and its trends of development.
- Development of tube digestion technology and its main techno-economic achievements.
- Development and experience in indirect heating of digestors, tube digestion tests, etc. in Hungary.
- New equipment, instruments and process automation for digestion.
- The possibility and expected economic results of using new digestion technology to deal with Chinese diasporic bauxite.
- New development in the theory of digestion for diasporic bauxite.
- The basic methods of digestion tests, relationship between differently scaled tests and how to enlarge the testing scale properly.
- Technical characteristics, methods and equipment of tube digestion tests; the main technical parameters and their measuring methods.
- Measurement of heat utilization ratio and how to raise the heat efficiency.
- Investigation of scaling: the mechanism of formation; the prevention of scaling and cleaning methods; measurement of thermal conductivity.
- Data processing and evaluation for the tests.
- Research methods in tube digestion theory.
- Consultation on design and testing program of pilot scale testing facilities of bauxite digestion. The lay-out of the facilities, the design of the main equipment, the

determination of the main technical parameters; the measuring methods and instruments, etc.

- Recommendation for new technology and research methods of bauxite digestion, suitable for the Chinese diasporic bauxite, to be introduced in order to reduce energy consumption.

The conclusions of the lectures were:

1. Further development of the alumina industry can be predicted in those areas of the world where bauxite and energy resources exist together. For developing aluminium smelters the deciding factor is the price and availability of electric energy.

2. Regarding bauxite and energy resources in China the development of alumina industry and aluminium smelters has a good prospect. On the basis of latest achivements of the theory and progress in the alumina industry (compared to other types of bauxite) the diasporic ore can be processed competitively. At the same time electric energy generated from coal is available for a favourable price.

3. The main trends in the development of the Bayer process in the past 25 years are the following:
   - increasing the digesting temperature,
   - reducing the caustic soda concentration in the digesting liquor,
   - reducing the specific volume of evaporated water.

4. To improve the heat recovery in the Bayer cycle the plants were retrofitted by heat exchanging facilities for:

steam-liquor, steam-slurry,
liquor-slurry, slurry-slurry

phases, eliminating at the same time the direct heating.

5. In respect of heat exchange it seems to be better to use a liquor-slurry or slurry-slurry system, however, because of difficulties in actual apparatus, the steam-slurry system is the most wide-spread for the heat recovery of digested slurry and plate heat exchangers for that of the pregnant (aluminate) liquor.

6. For diasporic bauxites the range of digesting temperature is between 240 °C and 250 °C but the advantages of higher temperatures (up to 280 °C) were confirmed in the kinetics and energy consumption as well. However, if a digestion temperature higher than 250 °C is required, the use of a tube system instead of digestor lines is economically justified.

7. Some kinds of additives like lime or hydrogarnet may improve the digestibility of diasporic bauxites especially when the possibilities for increasing the temperature are limited.

8. If processing a medium grade bauxite, soda losses can be reduced by the caustification of the red mud. In this way the Bayer process became more economical than sintering even for a bauxite with a module of 5.

9. For the better recovery of heat it can be recommended to use as many flash steps as economically possible.

In order to improve the heat transfer coefficient in the heat exchangers it is reasonable to use high slurry or liquor velocities in the tubes.

10. Because of scaling problems, the traditional pre-heater can be used only up to 150-160 °C. For the indirect heating of a slurry up to 250 °C the heat exchanger tubes built inside the digestors and the system with three tubes (switching over periodically the slurry and liquor streams, respectively) proved to be advantageous in the practice.

11. The necessary condition for efficient research and development work in the industry seems to be an organization ensuring:

    - matching the medium and long term plans of the corporation, as well as coordinating the expansion of production and reconstruction of existing processes in the plants and the research and development projects,
    - efficient co-operation between the research organization, the design centres and the specialists of the factories,
    - preparation of a working program for the whole process of development and evaluating this before the start. The actuality and validity of the conditions for the project should be controlled periodically. At the end of each stage of the development process an elaborate reconsideration of the project by the organization and the corporation should be made.

12. In order to save money and time during the realization of the research and development project, the scale of testing (laboratory, bench-scale, pilot-plant, factory-scale) must be carefully selected. Economic benefits can be achieved if pilot-plant facilities and experiences existing in other parts of the world are utilized as much as possible.

ANALYSIS OF THE POSSIBILITIES OF IMPROVING THE EXISTING DIGESTOR LINES IN THE ZHENG ZHOU ALUMINIUM PLANT AND ESTABLISHMENT OF AN ADVANCED DIGESTING SYSTEM

Analysing the results of advanced methods applied for the processing of diasporic bauxite in the world, having become aquainted with the present technology and equipment of the Factory and having discussed the subject with the specialists of the Institute and the Plant we have found some possibilities to improve the chemical efficiency and heat recovery of the digesting lines. Nevertheless, some limitations must be taken into consideration as follows:

- the steam pressure might be max. 33 bar,
- the pressure in the digestors is limited to 28 bar,
- the space for new equipment is very limited,
- the desilication efficiency before digestion is only about 25 %,
- the aged digestors can not be retrofitted with heat exchanging tubes.

The following desription highlights the problems, their possible solutions and the ways leading to these.

1. Chemo-technological problems

The 75 to 80 % digestion yield regularly attained in the digestion unit of the Bayer section of the Alumina Factory is to be considered quite low when taking into consideration the excellent chemical composition of the bauxite processed (68-70 % Al_2O_3; 7-8 % SiO_2; 3 % Fe_2O_3; 3 % TiO_2). With this quality in mind, an extraction yield close to 90 % should be aimed at. This would

a) increase the proportion of the Al_2O_3 extracted from the bauxite in the more economic Bayer section of the alumina plant and reduce the proportion extracted in the less economic sintering section,

b) reduce the amount of red mud to be washed and filtered by some 20 to 25 %, thereby improving the efficiency of the mud settlers, washers and filters,

c) reduce the amount of red mud to be sintered to the same extent.

The low extraction yield attained can be a result of

a) inadequate grinding, resulting in a high proportion of coarse grains,
b) inadequate retention time and/or uneven retention time distribution in the digestors,
c) other reaction-kinetical problems.

A detailed research program should be carried out in order to pinpoint the most important causes of the inadequate extraction yield. This should include, but not be restricted to the following:

a) laboratory digestion tests under various conditions (digestion temperature, liquor concentration, retention time, molar ratio, lime addition, the use of other catalysts which can improve the digestibility of diasporic bauxites, especially at lower temperatures) using uniform bauxite grinds of different grain sizes and the usual bauxite grind available in the plant,

b) measurement of the actual retention time distribution curves in the Alumina Factory itself, both for the bulk of the digestion slurry and for two or three grain size fractions of the bauxite.

On the basis of the above tests detailed suggestions can be elaborated.

2. Energo-technological problems

The digestion plant unit consumes about 2 tonnes of live steam per tonne of Bayer alumina produced. This figure is at least 50 % higher than the optimum consumption. The low efficiency of the existing digestion system exerts a very strong influence on the steam consumption of the other units of the Alumina Factory. The total steam consumption of the Bayer plant could be reduced to about 4 t/t of Bayer alumina from the present 7 to 8 t/t if the whole energo-technological system of the alumina plant were reconstructed. Partial measures would result in lesser savings but could be realized more rapidly and at significantly lower costs. The suggested solutions are in increasing order of sophistication the following:

2.1 Installation of slurry preheaters to the existing digestion lines for indirect high-pressure steam heating

By indirectly preheating the digestion slurry to a temperature of 205 to 220 °C 60 to 75 % of the live steam could be prevented from entering the process liquor cycle. (If the steam pressure is limited to the present level (33 bar), indirect heating is possible up to 220 °C only and for further heating the plant has to use live steam directly.) The advantage of this solution could be harnessed in two possible ways:

a) by maintaining the concentration of the strong liquor at its present value a higher blow-off concentration could be attained and more water could be used for red mud washing without reducing the concentration of the diluted slurry (result: better mud washing); the retention time in the digestors would be increased by some 15 % (result: better extraction yield); the equilibrium molar ratio would be reduced by about 0.06 to 0.08 (result: higher liquor productivity or better extraction yield or both);

b) by maintaining the concentration of the blow-off liquor at its present value a lower strong liquor concentration (about 230 to 240 g/l caustic Na_2O) would be required and the evaporation of 1.2 to 1.5 t/t of water could be saved (result: 0.7 to 0.8 t/t steam saving in the evaporation).

In the latter variant the throughput of the slurry [illegible] of the existing preheaters would have to be increased by some [illegible] to 20 [illegible]. The preheaters to be applied would preferably be of the tube-in-tube, single pass type. The novel tubular preheaters were tested in practice until now only for boehmitic bauxites. Consequently for diasporic bauxites the system needs further examination or development in respect of scale formation and corrosion. The development and testing of such preheaters should be made in close cooperation with the Chinese side. An experimental preheater should be installed as early as possible to an existing digestion line of the Zheng Zhou Aluminium Plant in order to collect the necessary experience for the development of the final ones. (See Annex I.)

2.2 Installation of multi-flash systems and of flash-steam-heated preheaters to the existing digestion lines

The temperature of the preheated slurry could be increased to about 180 to 190 °C from the present 145 °C. This would result in a net saving of about 0.7 to 0.9 t/t of live steam, when using 6 to 8 stage flashing systems. Additional advantages would be similar to those described in para 2.1. The two solutions could be combined, i.e. the slurry would be preheated by flash steam to 180-190 °C and by indirect high pressure steam from this temperature to 205-220 °C. In this case the savings could be combined.

The use of tube-in-tube preheaters would be recommended for flash steam heating, too. The early installation of an experimental preheater would also be advisable.

2.3 Reduction of the strong liquor concentration by installing a new digestion line parallel to the existing ones

By installing a Magyaróvár-type and -size tube digestion system (capacity about 120 m^3/h) the evaporation of a similar amount of water could be saved (steam saving: 66 t/t i.e. some 1.5 t/t of Bayer alumina). The concentration of the strong liquor would be about 200 g/l. The heating of the tube digestion system would require the equivalent of about 12 t/h (0.3 t/t of Bayer alumina) of steam. The existing boilers of the plant can not provide the minimally required 55 to 60 bar steam, therefore, it has to be generated in a separete high pressure boiler to be installed, or mechanically compressed to the required pressure, or replaced by some other heating medium like diphenyl/diphenyloxide or some fused salt.

The installation of such a unit would prepare the way for the complete reconstruction of the digestion plant unit by providing the required experimental data for designing the latter. On the other hand, the installation of a tube-in-tube preheater to one of the existing digestion lines (see para 2.1) would be necessary before designing the experimental tube digestion line.

This solution could be combined with those described in paras 2.1 and 2.2. In this case the savings would also be combined.

2.4 Complete reconstruction of the digestion plant unit

Since the equipment of the Zheng Zhou Alumina Factory is about 25 years old, a complete reconstruction of it seems to be timely. There are two main alternatives for such a reconstruction:

a) The use of conventional digester lines consisting of flash-steam-heated preheaters, of autoclaves indirectly heated by flash and high pressure boiler steam, of unheated autoclaves providing retention time for the extraction of alumina and of a series of flash tanks. The digestion temperature would be between 245 and 260 ^{o}C. For the envisaged digesting line, the comprehensive knowledge in respect of heat consumption of digesting lines (Saint Nicolas in Greece, Tulcea in Rumania) could be taken into account. The experience and data available internationally for this system are sufficient to prepare a feasibility study.

b) The use of tube digestion systems with tube-in-tube preheaters for heating with flash and high pressure boiler steam, with empty tubes or autoclaves for providing the necessary retention time and with a series of flash tanks. The digestion temperature would be between 260 and 280 °C. The most advanced technology for the Chinese diasporic bauxites could be the tube digestion system. Plant scale experiences had been accumulated in the Federal Rep. of Germany and in Hungary but the decision of applying this technology for diasporic bauxites can be made only on the basis of results gained by further testing and development.

The complete reconstruction of the digestion plant unit - though quite expensive - would bring the greatest advantages. The amount of steam saved could be as high as 2.5 to 3 t/t of Bayer alumina. If combined with the expansion of the Alumina Factory, savings of the same order of magnitude could be made, since the evaporation capacity set free by the reconstruction of the digestion could be utilized for the expansion and the capacity of the Alumina Factory could even be doubled without installing new evaporators.

After discussing the various possibilities we concluded, that:

1. The parameters of the existing digesting lines can be improved and sound information available about methods established worldwide allow to select for the new system one or more from the advanced technologies such as:

- multyflash heat recuperation
- traditional pre-heaters up to 150-160 °C
- indirect heating in digestors up to 250 °C.

2. As an alternative solution it would be necessary to organize a project for the adaptation and development of the tube heating system.

Recommendations:

A techno-economical evaluation should be prepared for the reconstruction of existing digesting lines in order to reduce the energy consumption in Zheng Zhou Aluminium Plant using advanced procedures already approved in the practice. Taking into consideration the limitations in steam pressure, the allowable pressure in the digestors and in the new facilities, the order of expected energy saving is 0.7 to 3 ton of steam per tonne of alumina produced depending on the degree of rearrangement.

The most sophisticated method for the new digestion technology in Zheng Zhou could be the tube digestion system. For the adaptation tests the operating pilot plant in the Fed. Rep. of Germany or that in Hungary could be used, however, factory scale tests in the existing Zheng Zhou Aluminium Plant could diminish the costs and enhance the reliability of the project. (For details see Annex 1.) The results of this project could be used for the reconstruction of the existing system as well, using the tube system for preheating.

A laboratory test series should be carried out to investigate the effect of the main technological parameters and of some additives on the digestibility of Chinese diasporic bauxites.

In preparing the techno-economical evaluations and working on the development projects cooperation is advised with companies, possessing the experiences and advanced technology. On behalf of the Hungarian Aluminium Corporation the readiness was expressed to take part in a common development project.

For further recommendations see Annexes 2 through 4.

APPENDICES

The following appendices form part of the final report:

Appendix A
Visits related to the job

Appendix B
Persons contacted during the mission

Appendix C
The list of some documents supplied to the staff of ZLMRI

Appendix D
Consultations upon a design and testing program of pilot scale testing facilities for bauxite digestion within the frame of the Research Institute

Appendix A

VISITS RELATED TO THE JOB

1. Briefing at the UNIDO Headquarters in Vienna. 12.-13.03.

2. Visit to the UNDP office in Beijing. 03.04.

3. Visit to the Zheng Zhou Light Metals Research Institute. 06.04.

4. Visit to the Alumina Factory of Zheng Zhou. 07.04.

5. Visit to the Aluminium Smelter of Zheng Zhou. 11.04.

6. Visit to one of the bauxite mines of the Zheng Zhou Aluminium Plant. 13.04.

7. Visit to the digestion plant unit of the Alumina Factory. 20.04.

8. Visit to the China National Non-Ferrous Metals Industry Corporation in Beijing. 25.04.

9. Visit to the UNDP office in Beijing. 25.04.

10. Debriefing at the UNIDO Headquarters in Vienna. 10-11.05.

PERSONS CONTACTED DURING THE MISSION

In China:

Hwang Chi-Chun	Vice General Manager China National Nonferrous Metals Industry Corp (CNNC), Beijing
Li Guodong	Manager, CNNC
Niu Yinjian	Deputy Manager, CNNC
Yu Yong Lan	Co-worker and interpreter, CNNC
Hou Jie	Director of the Aluminium Plant
Xu Shu-Tian	Chief engineer of the Aluminium Plant
Li Yuan-Jie	Vice chief engineer
Bao Zemin	Deputy chief engineer
Li Wenjie	Deputy chief engineer
Zhu Xiande	Deputy manager of Alumina Factory
Zhao Yunfeng	Engineer of the technical department
Chen Huaming	Engineer of the technical department
Xu Xiang	Vice Director, ZLMRI
Huang Zhi-Gao	Vice Director, ZLMRI
Liu Ying	Vice Director, ZLMRI
Zhu Ying	Administration department chief
Gan Yi-Ren	Engineer
Chen Wan-Kun	Chief of alumina laboratory

- x -

A.W.Sissingh	Senior industrial development field adviser UNDP Beijing

In Vienna:

Zhang Xianwu	Permanent Representative of China to UNIDO, Vienna

- x -

Dr.E.Balázs	Head of department UNIDO, Vienna
Shen Wenrong	Senior officer, UNIDO, Vienna

THE LIST OF SOME DOCUMENTS SUPPLIED TO THE STAFF OF ZLMRI

1. Aluminum Recycling - Potential and Problems
   - by Robert F. Testin

2. Energy Balance of Aluminum - From Production to Application - by C.N. Cocharn

3. Price and Availability of Energy in the Aluminum Industry - by Stewart R. Spector

4. Energy Savings in Aluminum Production, Use and Recycling - by Allen S. Russell

5. Energy Balance of Aluminum From Production to Application - by C.N. Cochran

6. Pitfalls and Pleasures in New Aluminum Process Development - by Allen S. Russell

7. U.S. and World Energy outlook - Implications for the Aluminum Industry
   - by Robin G. Adams

8. The Aluminum Industry in 1982 and Outlook for the 80s
   - by Kenneth I. Brondyke

9. Aluminum: The Next Twenty Years
   - by M.Desmond Fitzgerald and Gerald Pollio

10. 1983: un Anno Storico per L'industria dell'Alluminio. La Crescita Continua

11. Advances and Prospects in Alumina Technology
- by K.W. Perry and A.S. Russel

12. Impact of Alternative Processes for Aluminium Production on Energy Requirements

13. Trends of Technological Development in Alumina Production and some Hungarian Results
- by Dr.K. Solymår

14. New Possibilities for Processing Diasporic Bauxites
- by Dr.K. Solymår and T. Ferenczi
(ICSOBA Congress, Athens, 1978)

15. Light Metals 1981 Edited by Gordon M. Bell

16. Energy Savings in the Bayer Process
- by D.J. Donaldson

17. Energy and Technological Advantages of Tube Digestion and Digestion with Additives
- by Dr.K. Solymår
(Proceedings of Bauxite Symposium, No. V. June 21-24, 1982)

18. Processing of Diasporic Bauxites

19. Digestion Kinetics of Monohydrate Bauxites

20. Practical Experiences with the Tube Digester
- by K. Bielfeldt

21. Alkaline Treatment of Diaspore-Type Bauxites
- by E. Delyannis

22. Influence de l'addition de chaux à l'attaque alcaline en voie humide des bauxites à diaspore
- by H. Mercier, R. Magrone
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23. Sur les particularités du diaspore bauxites
- by S. Caillère, Th. Pobeguin
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24. ТРУДЫ ВАМИ № 47
Боксит Китай
- by Beneslawsky

25. Technological Evaluation of Monohydrate Bauxites
- by Dr.K. Solymâr

26. Processing Diasporic Bauxites: the Greek Bauxite Case
- by Prof. dr.G. Coumoulos
(Bauxite Symposium, Los Angeles, 1984)

27. World Review on Energy Conservation in the Bauxite/ Alumina Industry - UNIDO Study

28. Laboratory Practice in Alumina Production - UNIDO Study

29. World Review on Environmental Aspects and Protection in the Bauxite/Alumina Industry - UNIDO Study

30. Alumina Production Until 2000 - Proceedings of ICSOBA Symposium, Tihany, 1981

31. The New Alusuisse Process for Producing Coarse Aluminum Hydrate in the Bayer Process

32. Evaluation of Soviet and Hungarian Bauxite Reference Standards from the View of the Bayer Cycle, ALUTERV-FKI

33. Research of Pressure Leaching of Ores Containing Precious Metals

34. Movements in Vertical Intergration within the Aluminium Industry

- by M. Castera

(AIME 113th Annual Meeting, Los Angeles, 1984)

CONSULTATIONS UPON A DESIGN AND TESTING PROGRAM OF PILOT SCALE TESTING FACILITIES FOR BAUXITE DIGESTION WITHIN THE FRAME OF THE RESEARCH INSTITUTE

The layout of the facilities, the design of the main equipment, the determination of the main technical parameters, the measuring methods and instruments to be used in a research/pilot unit were discussed in accordance with the Job Description with the co-workers of ZLMRI.

Since the procedures developed by the Research Institute the new technology to be adapted and the processing of new types of raw materials must be introduced into industrial practice it is imperative to conduct bench scale or preferably pilot plant and/or factory scale tests. ZLMRI wishes to realize a pilot plant covering all phases of the Bayer cycle using even autoclaves and tube digestors alternatively. The requested capacity is stated as 1000 to 5000 t alumina/year.

According to our opinion the construction of a pilot plant or at least of certain sections of it is justified. The advantages of such an establishment inside of the Alumina Factory using the necessary materials from the Bayer cycle was stressed and advised definitely. The rational planning of such a system exceeds the expertise of ZLMRI, therefore the help of UNIDO is required.

ANNEXES

On course of the mission the necessity of certain special services and supplies to the Chinese partner further some cooperation possibilities have arisen.

The following annexes deal with these matters:

Annex 1

Suggestions for setting up an experimental commercial scale pilot unit in the existing plant for testing the adaptability of tube digestion for diasporic bauxites.

Annex 2

Proposal for organizing a UNIDO Group Training at "ZLMRI" in Zheng Zhou, China

Annex 3

Preliminary estimation for setting up a Carbon Laboratory in the Zheng Zhou Light Metals Research Institute

Annex 4

Possibilities of cooperation in the field of white bauxites

SUGGESTIONS FOR SETTING UP AN EXPERIMENTAL COMMERCIAL SCALE PILOT UNIT IN THE EXISTING PLANT FOR TESTING THE ADAPTABILITY OF TUBE DIGESTION FOR DIASPORIC BAUXITES

The purpose of the installation of this experimental pilot unit would be to observe and determine the maximum permissible slurry velocity for slurries prepared of diasporic bauxites, the rate of erosion of the heating tubes and the effect of cyclical caustic cleaning.

The suggested pilot equipment is shown in the attached "Scheme of Experimental Facility". The slurry to be digested would flow from the last of the four series-connected existing preheaters into the two parallel-connected experimental preheters (1) and from the latter into the first autoclave of one of the existing digestor lines. The experimental preheaters would be heated either with flash steam of the first flash tank or with a 10 bar steam reduced from the 33 bar high pressure steam in a pressure-reducing and steam-cooling unit (4). The scheme also shows the flow of the digestion liquor used for cyclical caustic cleaning of the preheater tubes. The liquor would be transported by a centrifugal pump (3) through a preheater (2) into the experimental preheaters (1). The temperature of the liquor preheated in preheater (2) would be roughly equal to that of the slurry (150 °C).

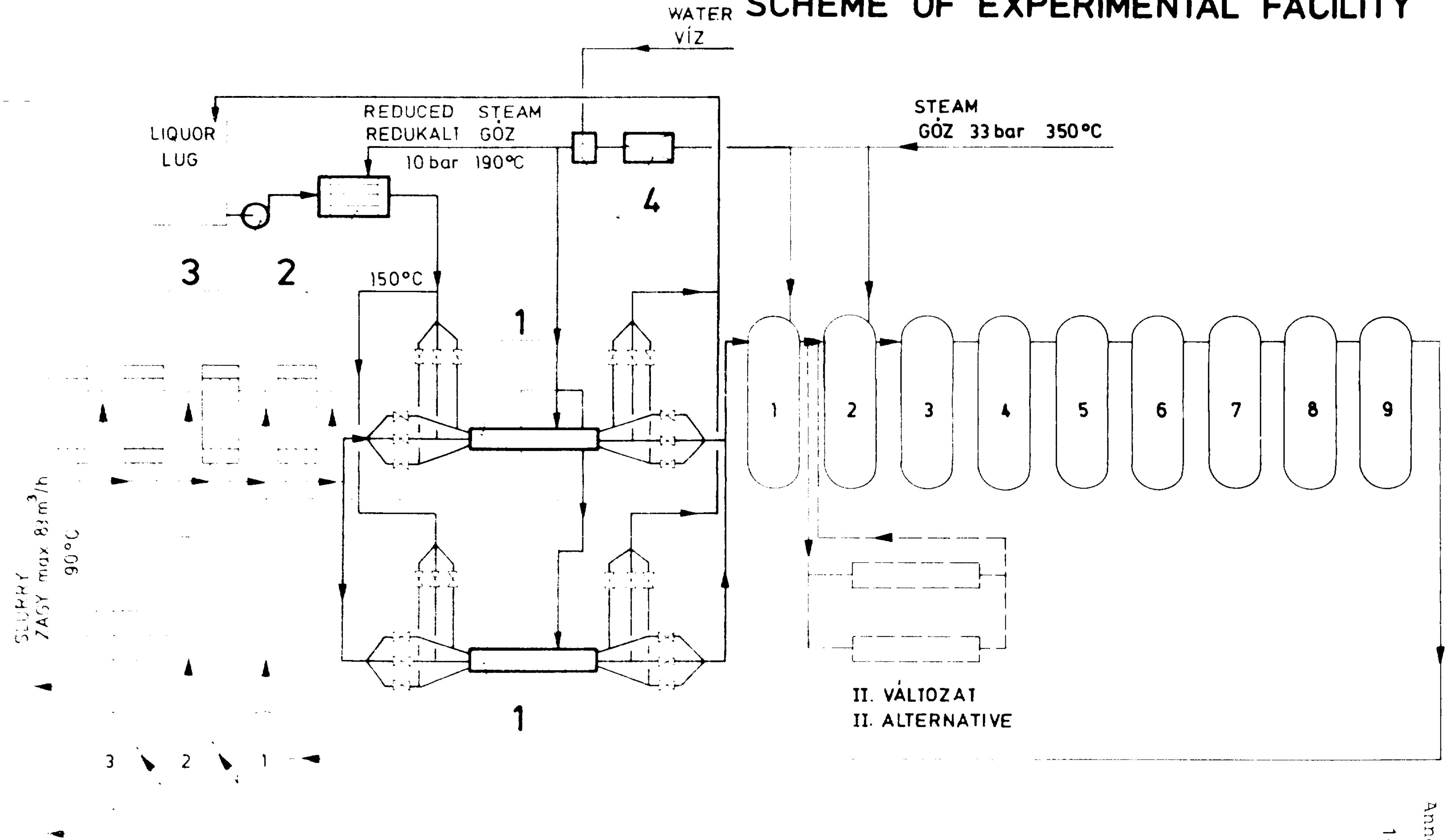
An alternative to the solution shown in the scheme would be to connect the experimental preheaters between the 1st and 2nd autoclaves of the digestion line. In this case units (2), (3) and (4) would be slightly modified for the higher temperatures and pressures and would cost somewhat more. The experimental preheaters would operate at about 200 °C in this case.

The experimental unit would be fitted to an existing digestion line so that it would not reduce the capacity of the latter. It could be bypassed at any time and switched on again for experimentation.

By setting up the suggested experimental unit sufficient data could be collected at relatively low costs for designing tube-in-tube preheating units both for the reconstruction of the existing digestion lines and for the construction of new tube-digestor units.

UNIDO's assistance in setting up the suggested experimental unit would be welcome.

KISÉRLETI BERENDEZÉS SÉMA
SCHEME OF EXPERIMENTAL FACILITY



Annex 1

1-3

PROPOSAL FOR ORGANIZING A UNIDO GROUP TRAINING AT "ZLMRI" IN ZHENG ZHOU, CHINA

Topic of the training: alumina production and aluminium electrolysis with special emphasis on optimum exploitation of R & D facilities.

Aim of the training: transfer of up-to-date knowledge in the fields of bauxite processing and alumina smelting, furthermore of the principles and practice of technological testing, process modelling and application of the results of material research in order to improve the efficiency of R & D activity in ZLMRI based on the equipment installed recently.

Date: October/November, 1984. (6 weeks duration)

Number of participants: 25 persons

Training staff:

Alumina technologist (Bayer technology, industrial evaluation of bauxite, testing of technology, bench scale investigations) 1 person/3 weeks (candidate: Dr.K.Solymár)

Alumina technologist (technology related calculations, feedback of laboratory and plant data into process development, energetics) 1 person/3 weeks (candidate: Dr.P.Siklósi)

Smelter technologist: (Heroult-Hall process, composition of bath, overvoltages, current efficiency, carbon materials) 1 person/3 weeks (candidate: Dr.J.Horváth)

Smelter technologist (instrumentation, automation, process control) 1 person/3 weeks (candidate: L.Tikász)

Expert on testing of technology (experimental methods and evaluation of data) 1 person/3 weeks (candidate: Dr.D.Bulkai)

Materials scientist (physico-chemical and chemical investigation of raw , auxiliary and intermediate materials) 1 person/3 weeks (candidate: dr.L.Tomcsányi)

Materials scientist (apparatus, testing of bauxite and alumina, application of results, organization of research and development) 1 person/6 weeks (candidate: dr.P.Gadó)

Tentative program of the Group Training

The Group Training will be divided into two parts according to subjects:

A. Alumina (15 participants)

B. Aluminium (10 pa.ticipants)

Lectures will be given every morning from 9h to 12h parallelly in these two sections. The lectures will be followed by discussions, experimental or calculation practices in the afternoon.

A. Alumina

1st week

Lectures
- Fundamentals and chemistry of the Bayer process
- Special problems of processing diasporic bauxite

Experiments
- Chemical and mineralogical analysis of bauxite
- Conclusions drawn for the technology (discussion of the lectures)

2nd week

Lectures
- Process stages of the Bayer cycle (latest developments in the field of digestion and precipitation)
- Testing methods for the Bayer process (diasporic bauxite)

Experiments
- Chemical and mineralogical analysis of red mud
- Conclusions drawn for the technology (discussion of the lectures)

3rd week

Lectures
- Main tasks in projecting research and development for the Bayer technology
- Requirements and testing related to the quality of alumina

Experiments
- Analysis of alumina hydrate and alumina
- Application of SEM and ED analysis
- Conclusions drawn for the technology (discussion of the lectures)

4th week

Lectures
- Data required for selecting the processing technology
- Energy aspects of the Bayer process

Experimental
- Digestion tests, evaluation
- Calculation practice

5th week

Lectures
- Material and heat balances of the Bayer process

Experiments
- Precipitation tests
- Calculation practice

6th week

Lectures
- Trends in the development of Bayer technology and related apparatus
- Instrumentation and process control

Experiments
- Settling tests
- Calculation practice

B. Aluminium

1st week

Lectures
- Fundamentals of the Hall-Heroult electrolysis
- Structure and properties of the bath
- Alumina properties

Experiments
- X-ray analysis, alfa and gamma content
- Behaviour of the crust

2nd week

Lectures
- Electrode reactions
- Cell voltage
- Anode effect mechanism

Experiments
- Determination of alumina contraction
- Estimation of overvoltages

3rd week

Lectures
- Current efficiency, major losses
- Energy balance
- Carbon materials

Experiments
- Isotope method and analysis of CO/CO_2 gases
- Laboratory testing of carbon materials

4th week

Lectures
- Computer control
- Optimal operation
- Pot failure mechanism

Experiments
- Real-plant measurements
- Identification of the process model

5th week

Lectures
- Electromagnetic interactions
- Modeling of potential and magnetic fields
- Aspects of construction

Experiments
- Current distribution
- Measuring and calculation of magnetic components

6th week

Lectures	Instruments for real-plant measurements Test equipment Environmental protection
Experiments	Fluoride emissions Gas cleaning systems

PRELIMINARY ESTIMATION FOR SETTING UP A CARBON LABORATORY IN THE ZHENG ZHOU LIGHT METALS RESEARCH INSTITUTE

1. Formulation of Requirements for the Laboratory

The staff, equipment and instrumentation of the Carbon Laboratory should be capable of tackling the following tasks:

- regular quality control, grading and establishment of the expectable behaviour during the metallurgical processes of all carbonaceous materials (anode paste, prebaked anode, ramming paste, cathode paste, etc.) used in the aluminium smelter,
- regular checking of the metallurgical anode-processes, in order to reduce specific anode paste consumption, anode resistance and carbondross formation,
- elaboration of economic, material-saving and environmentally less hazardous prescriptions for the composition and formation of the anode carbon. This would at the same time improve the technological parameters.

2. Parameters to be Determined, Tests to be Carried out

- for coke materials:
  ash content,
  volatile matter,
  hydrogen content,
  sulfur content,
  real density,
  apparent density,
  grain size distribution,

electric resistance of dust,
activity (in Cr-sulfuric acid),
specific surface area,
porosity,
ash analysis (Fe, Si, V, Ti, Zn);

- for binding materials:
  softening point,
  ash content,
  coking residue,
  sulfur content,
  real density,
  benzene-insoluble substances,
  quinoline-insoluble subtances,
  swelling index,
  wettability,
  viscosity in the range of 120-200 ^{o}C;

- for green pastes (anode paste and ramming paste):
  ash content,
  volatile substance,
  sulfur content,
  anthracene oil-soluble substance,
  additives (AlF_3, B_2O_3),
  plasticity or elongation number,
  rammability (in case of ramming paste only);

- in case of finding out the composition of an unknown paste or in case of elaborating a new type of paste:
  anthracene oil-soluble substance,

- coke mixtures previously freed from binding materials:
  grain size distribution,
  real density,
  sulfur content,
  rammed bulk density of the coke mixture;

- for ramming pastes:
  graphite content,
  the intergranular space of coke mixture,
  binding material requirement of the mixture,
  the optimum temperature of mixing;
- programmed model-burning of pastes, testing of the lower layer burnt out at 1000 °C or of the individual layers at the given isotherms;
- for burnt-out specimens and prebaked anode samples:
  - in case of anode pastes and drilled plant anode specimens:
    bulk density,
    specific resistance,
    reactivity in CO_2 at 950 °C,
    gas-permeability,
    surface water absorbing/adsorbing capacity,
    bulk density by water displacement,
    anode consumption,
    compression strength,
    real density,
    ash content,
    fluoride content,
    shear strength;
  - in case of cathode carbon and burnt-out ramming paste:
    bulk density,
    specific resistance,
    Rapaport test,
    compression strenght.

3. Supplies and Services in case of Entering into a Contract

3.1 ALUTERV-FKI hands over the description of tests enlisted, operating instructions of equipment, and detailed methodology of the prescribed research work on paste production.

3.2 ALUTERV-FKI prepares detailed engineering drawings of non-standard equipment and arranges the manufacture of the latter in required quantities.

3.3 During their 1-month stay with ALUTERV-FKI 2 engineers and 2 technicians can make themselves acquainted with the activity of the Carbon Laboratory, the testing methods and equipment. As to the accommodation and daily allowances of 4 experts ALUTERV-FKI will meet the expenses.

3.4 In the Carbon Laboratory to be erected and equipped according to the Contract 4 Hungarian experts (i.e. 2 engineers and 2 technicians) will provide assistance during their stay in the People's Republic of China in commissioning the laboratory. The costs of their assistance will be included in the contract price.

3.5 ALUTERV-FKI delivers the complete documentation for the erection of the Carbon Laboratory and provides site supervision.

4. Price quotation

Activities listed in Chapter 3 of this Estimation will be fulfilled on basis of the alternatives given in the following List within 18 months calculated from signing of the Contract.

Total value of the equipment and instruments (see Chapter 5) to be forwarded by the Hungarian People's Republic amounts to USD 78,750.

5. List of equipment

S/N a.	Name b.	Specification c.	Manufacturer d.	Approximate price e.
1.	Laboratory jaw crusher	for precrushing of lumpy materials (except for binding material) to sizes less than 10 mm, performance 100 kg/h, power 380 V; 1.5 kW	GFR Fritsch Pulverisette I	$ 2500
2.	Manual grinder	with mangenese steel lining for grinding particles smaller than 10 mm to sizes under 1 mm; 30 kg/h	PRC	$ 125
3.	Vibrating mill	with 6 manganese steel grinding cups for fine grinding non-plastic substances below 1 mm 220/380 V; 0.75 kW	Retsch VM 1 GFR	$ 580
4.	Sample divider	for the averaging of particles crushed to sizes under 1 mm; 100 kg/h	Retsch PT 35 GFR	$ 250
5.	Coarse screen	0.3x0.3 m wooden frame screens with Ø 20; 10; 6; 3; 2 and 1 mm screen plates, moved by a shaking machine, performance 30 kg/h; 380 V; 1.5 kW	non-standard unit PRC	$ 1250
6.	Screen with complete set of sieves	Vibrating screens with openings: 6; 3; 2; 1; 0.6; 0.3; 0.2; 0.12; 0.06 mm; 0.7 kW; 220 V	Retsch 3 D GFR	$ 580
7.	Fine grinding mortar mill	150 ml useful volume, agate and porcelain inserts, vibrating system, 0.7 kW	Fritsch Pulverisette II GFR	$ 580

a.	b.	c.	d.	e.
8.	Decimal balance	measuring range of 100 kg, accuracy 0.1 kg	PRC	$ 570
9.	Quick balance	measuring range of 5 kg, accuracy 0.01 kg	PRC	$ 625
10.	Lathe (with VIDIA turning tools)	for cutting small carbon specimens of max. dia 80 mm and max. 300 mm length to size. Local dust exhaustion. Capacity: 2 pcs/h, 3 kW	HPR	$ 10000
11.	Hardgrove-hardness tester for coke	for the determination of grindability of cokes as per ASTM D409	GFR or USA	$ 3750
12.	Vertical drilling machine	for gripping brace-bits of diameters in the range of 2-30 mm, mounted on stand, stroke 300 mm, 1.5 kW	HPR	$ 3000
13.	Paste rammability tester	for the determination of compaction as a result of impact applied by a definite force to the paste being heated up to max. 200 °C	HPR	$ 300
14.	Drying oven	for preheating paste specimens, 200 V, 1.5 kW	PRC	$ 500
15.	Device for the determination of the elongation coefficient	Cylinders for making specimens; trough with three measuring places, one drying oven, 3 kW, 220 V	HPR	$ 600

a.	b.	c.	d.	e.
16.	Plasticity tester	linked up to a gas-fired waterbath, for the determination of paste deformation under load	HPR	$ 400
17.	Hydraulic press and testing system	jack clamped in a press frame, load about 10 t, lifting height about 100 mm. To be used by the application of various chucks for the measurement of electric resistance of coke dust under pressure and forming test specimens from paste at a pressure of max. 140 MPa. Complementary instruments and a 10 Ah rectifier	non-standard unit HPR	$ 2000
18.	Model furnace for programmed baking of paste	heat-insulated furnace with a cross section of 180x200 mm, SiC heating elements reaching 200 mm into the furnace, to be used up to max. 1100 °C for modelling the baking conditions of the self-baking anode. Temperature and heating program control, 3-phase transformer, primary 380 V, secondary 100 V, 30 A for each phase, about 14 kW; furnace located under an exhaust hood	non-standard unit HPR	$ 10000

a.	b.	c.	d.	e.
19.	"Rapaport" equipment	to measure changes taking place during the electrolysis in cathode carbons and baked ramming paste specimens. Heat-insulated furnace having a cross section of 300x500 mm and inside depth of 500 mm. The furnace is heated from inside by means of SiC rods. Temperature control. Heating transformer: 380 V, three-phase, 50 A, 25 W each. Rectifier: secondary side 10 V, 25 A. The furnace is placed under an exhaust hood.	non-standard unit HPR	$ 21000
20.	Igniting kilns with kanthal heating elements	220 V; 3 kW kiln with temperature control, max. operating temperature 950 °C. Inside dimensions: 110x170x300 mm	PRC	3 pcs $ 4000
21.	Reactivity tester	to determine the corrosion of carbon specimens in various atmospheres. Furnace with thermal control up to max. 950 °C (± 10 °C), quartz-tube reaction zone, gas-flow system. The type of furnace is Heraeus ROK/R10/60, 2 kW	GFR and HPR	$ 7900
22.	Cutter head	for cutting samples (dia. 50x200 mm length) of pre-baked anodes	Switzerland	$ 2500

a.	b.	c.	d.	e.
23.	Determination of compression strength of carbon pieces	10 t tensile test machine with recorder, accuracy 100 N, thrust, piece, hydraulic operation	PRC	$ 12500
24.	Specific resistance meter for specimen	for measurement of resistance of cylindric specimens dia 40 mm and 110 mm length, digital display, measuring range 50-150 ohm.m	non-standard unit HPR	$ 2000
25.	"Carbotest"	digital display direct resistance meter for the grading of cathode carbons, measuring range 15-120 ohm.m	non-standard unit HPR	$ 1000
26.	Analytical balance with pneumatic brake	2 pcs, measuring limit 100 g, accuracy ± 0.001 g	PRC	total $ 2500
27.	Derivatograph	Automatic heating system, programmable up to 1100 °C with different atmospheres. Suitable for the recorded determination of the thermal changes of materials	HPR	$ 21000
28.	Viscosimeter	for the determination of viscosity of binding materials in the range of 80-200 °C Seibold (Austrian) system Contraves-MS-RT-B/D	Austria	about $ 37500

a.	b.	c.	d.	e.
29.	Determination of sulfur by combustion	gas-heated, quartz tube, combustion in O_2-atmosphere	non-standard unit HPR	$ 750
30.	Ultrathermostats	to control a heat-bath with an accuracy of ± 0.01 °C in the measuring range of 15-200 °C	HPR	3 pcs $ 5000
31.	Device for the determination of KS and R+B softening points	for testing the softening point of binding materials in the range of 50-120 °C	HPR	2 pcs $ 450
32.	"Elementar" analyzer (for C and H determ.)	Dennstaedt-system, furnace	HPR	$ 1250
33.	Vacuum-pumps	3 units for vacuum down to min. 13 Pa	HPR	about $ 1000
34.	Extracting set with 6 testing points	for the determination of soluble components of binding materials	HPR	$ 750
35.	Computer, data storage and processor, Type Commodore 64		GFR	$ 2500

POSSIBILITIES OF COOPERATION IN THE FIELD OF WHITE BAUXITES

White bauxite is aboundant in the People's Republic of China. It can be ascertained locally that such bauxites should have the following characteristics:

Fe_2O_3 < 0.5 %
SiO_2 < 2.0 %

The market requires, however, an even better quality according to which the following parameters should also be followed:

$Na_2O + K_2O$ < 0.1 %
CaO + MgO < 0.5 %
density > 3.1 kg/dm^3

In order to achieve these parameters chemical purification and calcination are needed.

ALUTERV-FKI is ready to cooperate in this field in

a) elaborating the technology
b) setting up the beneficiation plant unit
c) setting up the high temperature calciner
d) marketing the product thus produced

To achive the above mentioned aims UNIDO assistance would be welcome.

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