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Seminar for High-level Governmental and Corporate Officials "Bauxite - Alumina - Aluminium: Analysis of Demand for Decisions on Industrial Development"

Budapest, Hungary, 3 - 12 May 1978

REPORT

id. 78-5385

Explanatory notes

References to dollars ($) are to United States dollars, unless otherwise stated.

One dollar is 100 cents (¢) = 1000 mills.

A slash between dates (e.g., 1970/71) indicates a financial year.

Use of a hyphen between dates (e.g., 1960-1965) indicates the full period involved, including the beginning and end years.

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions.

References to "tons" are to metric tons.

The following abbreviations of organizations are used in this report:

IBA	International Bauxite Association
CMEA	Council for Mutual Economic Assistance
EEC	European Economic Community
LME	London Metal Exchange
Alcoa	Aluminium Company of America (United States)

The following technical and specialized abbreviations are used:

COT	certain other transactions
DWT	dead-weight tonnage
LNG	liquefied natural gas
COA	contract of affreightment
kWh	kilowatt hour
kA	kiloampere

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INTRODUCTION

The Seminar for High-level Governmental and Corporate Officials "Bauxite-Alumina-Aluminium: Analysis of Demand for Decisions on Industrial Development" was held from 3 to 12 May 1978 at Budapest. It was sponsored by UNIDO and the Hungarian Chamber of Commerce within the framework of the Joint UNIDO/Hungary Programme for Co-operation in the Aluminium Industry, which was established in 1976 to assist developing countries in various aspects of aluminium industry development.

Aluminium is the most important non-ferrous metal, ranking second in metal production after iron and steel. In 1976, 13.1 million tons of primary aluminium was produced. The share of developing countries in this figure is only about 7 per cent, although these countries produce about 50 per cent of the world's bauxite and about 20 per cent of the alumina. They are also reported to have over 65 per cent of the world's bauxite reserves together with significant hydroelectric potential (in Africa, Latin America and South-East Asia) and "associated" gas flared (in many oil-producing countries). Thus the development of local aluminium production would be advantageous for the developing world.

The Lima Declaration and Plan of Action on Industrial Development and Co-operation, adopted at the Second General Conference of UNIDO in March 1975, recommended *inter alia* that developing countries should devote particular attention to the development of basic industries and should reach a share of 25 per cent in total world industrial production by the year 2000. In the aluminium industry, this target does not seem unattainable. UNIDO is helping developing countries to realize this objective through technical assistance projects, mainly the provision of experts and training to individual countries, or through programmes such as the Workshop on Case Studies of Aluminium Smelter Construction in Developing Countries, held in Vienna from 27-29 June 1977, and the present Seminar. Group training for geologists, chemical engineers and alumina technologists in the prospecting, analysis and testing of bauxite is planned for 1979.

Aluminium consumption is expected to grow during the next decades. Therefore, bauxite, alumina and aluminium production will have to be expanded, and a number of mines and plants will have to be established to meet the projected demand. Developing countries will be increasingly faced with planning decisions in order to ensure growth in the aluminium industry. It is also probable that UNIDO will have to extend its technical assistance in this field.

The main purpose of the present Seminar was to review, for decision makers in developing countries, selected topics related mainly to the economic and commercial aspects of developing the aluminium industry. The broad objectives were:

(a) To highlight the main factors affecting decision making on aluminium industry development;

(b) To provide current, essential information on pertinent technological and market aspects;

(c) To help identify areas in which technical assistance is needed.

The main topics reviewed were:

(a) Aluminium industry development and alternatives to be decided on at each stage;

(b) The choice between bauxite and non-bauxitic ores as raw materials, and the prospects for Bayer and alternative processes for alumina production;

(c) The transport of bauxite, alumina and aluminium;

(d) Trade of bauxite and aluminium;

(e) Problems of the metal market:

(i) Ideas on medium- and long-range forecasting;

(ii) The aluminium metal trade;

(iii) Analysis of the structure of the demand for metal;

(f) Problems with and implementation of agreements between developing countries and foreign partners to promote aluminium industry development.

CONCLUSIONS AND RECOMMENDATIONS

The general opinion was that the Seminar had been useful, though more countries could have been represented. It was especially appreciated that the lectures given had covered mainly the commercial side and not technology, which was generally well known. The plant visits were considered particularly valuable.

The participants felt that similar seminars should be held at regular intervals, for instance every year, preferably in developing countries. Speakers from developing countries should be invited to share their experience. Representatives from transnational corporations, financing institutions and research organizations would also be welcome.

The Seminar made the following recommendations for consideration by UNIDO:

Technical assistance activities

1. In addition to sponsoring feasibility studies for aluminium industry development, UNIDO should assist developing countries in evaluating existing studies and in negotiating with outside investors.

2. UNIDO should place more emphasis on finding ways in which developing countries can co-operate among themselves in aluminium industry development.

3. UNIDO should sponsor participants from developing countries at meetings, seminars and workshops on the aluminium industry organized by other institutions.

4. In preparation for new aluminium industries, training should be provided in all aspects, including management, quality control, effects on the environment and plant maintenance. In-plant practice is also essential.

Meetings

5. UNIDO should organize regular seminars on the aluminium industry, preferably in developing countries and with more speakers from these countries. Emphasis should be given to the problems of new aluminium industries, such as penetration of the export market and ways of developing human resources. Training seminars on agreements between Governments, investors and foreign partners are also recommended.

6. Separate meetings should be held on expanding the production of aluminium semis and finished goods in developing countries.

7. Other meetings should deal with problems of supply of auxiliary materials, such as caustic soda, petroleum coke, carbon cathodes and fluorides.

Information

8. UNIDO should collect information on aluminium industry development which could be made available to developing countries on request.

9. Developing countries should also be kept informed of trends in the bauxite-alumina-aluminium industry, and information on the available literature should be provided.

I. ORGANIZATION OF THE SEMINAR

The Seminar was attended by 19 high-level government and corporate officials from developing countries having a potential for the establishment or development of bauxite mines, alumina production, aluminium smelter capacity and aluminium semis plants. The countries represented, including those of lecturers and observers, were: Algeria, Argentina, Australia, Dominican Republic, Egypt, Ghana, Guyana, Hungary, India, Indonesia, Iraq, Jamaica, Malaysia, Mali, Suriname, Switzerland, United Kingdom of Great Britain and Northern Ireland and United States of America.

The Seminar was directed by the Acting Head of the Metallurgical Industries Section, UNIDO. Its agenda was as follows:

Introduction of participants

Official opening

Finalization of the agenda

Presentation of lectures

Discussion of each of the lectures

Visits to bauxite mines, plants and institutions of the Hungarian Aluminium Corporation

Discussions on conclusions and recommendations, including those concerning UNIDO technical assistance in the aluminium industry in developing countries

A list of the documents prepared for the Seminar is given in the annex.

The following plants, mines and institutions were visited:

Research Institute of Non-Ferrous Metals

Fejér County Bauxite Mines

INOTA Aluminium Smelter

Light Metal Works, Székesfehérvár

Almásfüzitő Alumina Plant

Headquarters of the Hungarian Aluminium Corporation

II. SUMMARIES OF LECTURES AND DISCUSSIONS

Eight lectures were delivered at the Seminar, each followed by discussion. The participants were given the texts of the lectures as working papers at the beginning of the Seminar.

Bauxite, alumina, aluminium: Main factors affecting decision making on their industrial development

A lecture on factors affecting decision making in the industrial development of bauxite, alumina and aluminium (document ID/WG.273/8) was given by E.T. Balázs and I. Molnár, Deputy Directors General of the Hungarian Aluminium Corporation, Budapest. It dealt with bauxite mining, alumina production, aluminium smelting, aluminium processing and investment incentives. The infrastructure required for an alumina plant was outlined, and the main factors determining the rate of efficiency of aluminium smelting were covered.

Lecture

Known bauxite reserves could ensure the supply of aluminium production for the next 75 years. The many additional sources of aluminium that may be considered in the long run include high-silica bauxites, various alumina-silicates, shales and fly ash. The sharp rise in energy prices has given further impetus to expansion of aluminium production because aluminium is light and thus economical to transport.

The Bayer process for alumina production and the Hall-Heroult process for electrolysis of alumina are by far the most frequently applied methods; new methods (subhalogenizing, carbothermic) have not proved competitive. The total energy consumption of the recently developed Alcoa process will not be significantly less than the lowest figure achieved on an industrial scale by the Hall-Heroult process. After 15 years of research Alcoa started up a plant two years ago with a capacity of 13,500 t/a; it is expected that at least five more years of research will be required before industrial application becomes possible. Therefore, for the coming decade the classic Hall-Heroult process is advised for new smelters. In the Union of Soviet Socialist Republics nepheline and alunites are used for industrial-scale production of alumina. Where bauxite is not available or is too costly but the conditions for aluminium smelting are otherwise favourable, alternative local raw materials may be sought for processing. The long-term trend is, however, towards Bayer alumina plants. The minimum quantity of mineable bauxite reserves needed for starting mining operations can be determined by simple economic calculations of returns and profitability. The quality of bauxite depends on the content of aluminium oxide and silica, the so-called silica module. Undesirable components are carbonates, iron, titanium, phosphorus, sulphur etc. Alumina basically occurs in the mineralogical form of trihydrate (gibbsite) or monohydrates (boehmite and diaspore). Of the iron oxides, goethite is the least welcome.

The cost of bauxite depends mainly on the mining operation. Open-pit mining is considered viable if the overburden is less than 5 m^3 per ton of ore; in a mechanized operation it may increase to 10 m^3. Manpower requirements under tropical conditions are 3-4 man-hours per ton using manual labour, decreasing to 0.3-0.6 man-hours per ton in some large-scale, fully mechanized operations. In underground mining the figures would be 4 man-hours per ton, or 1.5 man-hours for mechanized operations. Ore layers less than 2 m thick are generally disregarded for mining. The presence of water, gas and coal may cause difficulties.

Economic-scale operations may run from 5,000 to 10,000 t/a for surface deposits to at least 300,000 t/a for highly mechanized underground mining.

Investment costs depend on the type of mining operation, the treatment of bauxite at the mine, the scale of the operation, the infrastructure required etc. In open-pit mining they run from $8 to $80 per annual ton of processible ore, and in underground mining from $70 to $150. Production costs may include fuel, electricity, explosives, labour and overhead, depreciation etc. In open-pit mining they amount to $2-$3.5/ton; in Hungary underground mining of bauxites varies between $16 and $25/ton.

In general it is more economic to transport alumina than bauxite. Although water transportation is considered convenient, investments of up to $50 million may be required in order to load ore for ocean shipping. Difficult access to deposits and inadequate transportation infrastructure may cause the best-quality deposits to be left idle for a considerable time.

In marketing bauxite, the new guiding price of the International Bauxite Association (IBA) of $24/ton c.i.f. United States port provides some orientation, but prices as low as $12/ton f.o.b. are known.

Alumina production capacity may be estimated at around 31.5 million tons at present, with 93-94 per cent serving for aluminium smelting and 6-7 per cent for production of white corundum, refractory materials etc. The regional distribution pattern of alumina production capacities cannot be correlated with the location of reserves and mining of bauxite. The average production capacity of the approximately 80 operational alumina plants is 390,000 t/a. Some of these plants have an annual capacity of over 2.3 million tons. The average production capacity for 1985 is expected to reach 470,000 t.

The siting of alumina plants is determined by the size and location of bauxite mines, sea ports, infrastructure, water supply, disposal of red mud, soil conditions and location of the alumina market.

A main factor in determining the economic efficiency of alumina production is the "available alumina", that is, the amount that can be expected to be recovered. An increase of productivity in production lines and overall capacity by 50 per cent would mean a decrease of specific investment costs by 15-20 per cent.

Research and development work has resulted in the application of continuous processes in important phases of production, conversion to wet grinding, multi-stage flashing, introduction of falling film evaporators etc.

The space requirements for an up-to-date alumina plant with a capacity of 600,000 t/a are estimated at 80-100 hectares (ha) of land; the requirements for red-mud ponds may be 2-4 times greater.

Alumina production is highly capital-intensive. Investment costs are estimated at \$550-\$650 for each ton per year of capacity (1978 figures). Their distribution is typically as follows: 35 per cent for construction and erection, 45 per cent for machinery and equipment and 20 per cent for other. The capital requirements are: investment costs 75-80 per cent, working capital 5-6 per cent and financing costs 15-20 per cent.

Manpower requirements are largely independent of size within the normal range of capacities. A 600,000 t/a alumina plant employs 700-800 people. Alumina production does not have great flexibility in manpower/capital substitution.

The following figures give an indication of the amounts of raw materials and energy consumed per ton of alumina produced: bauxite (dry weight)

2-2.5 t; caustic soda 0.07-0.17 t; fuel oil (for steam production and calcination) 0.23-0.33 t; and electric power 300-350 kWh.

For aluminium production of 100,000 t/a, the annual inputs are: alumina 193,000-196,000 t; petroleum coke 44,000-47,000 t; tar pitch 11,000-12,000 t; fluorides 2,500-3,000 t; electric power 1.5-1.6 thousand million kWh. In the past it was common that aluminium smelters paid insignificant unit prices for hydropower: even today unit prices of 2-3 mill/kWh exist, but prices are expected to be at least 3-6 times higher after existing contracts expire. In 1976/77 new unit prices of at least 15 mill/kWh were calculated. The cost item of $220-$240 for energy per ton of aluminium based on a unit price of 15 mils is expected to at least double in the next 10 years.

Hydropower remains competitive if the investment cost per unit of capacity is not more than 15-20 per cent higher than that of the high-capacity nuclear power stations being established in developed countries.

It is advisable to secure a stable supply of alumina for the smelter by concluding long-term contracts for at least 75 to 80 per cent of the required material. Smelter size has been increased in recent years, and pots have been developed to operate with currents of 160-230 kA, each pot producing at the rate of 400-550 t/a. The number of pots in series varies between 120 and 240, each line thus having a capacity of 50,000-130,000 t/a of aluminium. In general at least two pot lines of 50,000-75,000 t/a capacity should be built to achieve economic plant size.

Environmental pollution may cause problems, even with acceptable methods of collection and cleaning of emissions, when more than 250,000-300,000 t/a of aluminium is being produced in one area. The maximum fluorine emission permitted in developed countries is 0.5-2 kg per ton of aluminium; similar regulations are expected to be laid down world-wide. Effective environmental protection can be achieved by using proper cell construction and operating technology, which ensure proper gas collection through hooding (dry-gas cleaning is favoured).

Söderberg anodes are divided into two types: horizontal-stud and vertical-stud anodes. It is difficult to apply horizontal studs at high amperages (above 100 kA). The vertical-stud anodes can only be partly closed and the efficiency of local, cell-gas exhaustion is 60-80 per cent. Although a third of the world's aluminium is produced using vertical-stud Söderberg anodes, the central-break-type, prebaked anode pots are considered the most up-to-date.

The infrastructure required for a smelter is similar to that of an alumina plant. A smelter with a capacity of 100,000 t/a requires 30-40 ha. The nearest settlement should not be closer than 500 m.

According to recent reports, investment costs including infrastructure are $2,000-$3,000/t for the smelter alone, depending on the location and existing infrastructure. The Spector report 1/ recorded investment costs, per ton per annum, of $1,550 in the United States, $1,540 in Venezuela and $2,250 in the Middle East.

Manpower is relatively low in relation to overall investment. A 100,000 t/a smelter requires 600-1,000 people; turnover should be low since a wide range of skills is needed. Production costs are made up mainly of electric power (20-25 per cent), alumina (25-30 per cent) and capital charges (25-30 per cent).

Aluminium should be produced near the market. Regarding the various operations, rolling should be established with a production capacity of not less than 80,000-100,000 t/a. Nonetheless, facilities with smaller capacities and a limited assortment may be economically established in developing countries. A casting and rolling shop with an annual capacity of 25,000-30,000 t may be economically viable already. An extruding operation with a capacity of 2,000-5,000 t/a is now considered economic. An anodizing unit that can be extended by stages of 2,000-3,000 t/a may also be practical. Rod, wire and power transmission cable can be produced economically using continuous casting processes at a capacity of 15,000-25,000 t/a of semi-fabricates, and it may already be viable to produce aluminium transmission cables at a capacity of 5,000-10,000 t/a.

There are various incentives for industrial development and measures to stimulate consumption that a Government can introduce. Examples of incentives granted to projects with mixed and private ownership are tax breaks, financing support and assistance in attracting foreign capital. In each case a detailed study and analysis of natural, human, economic and political factors has to be made in order to ascertain the techno-economic viability of the project.

1/ Stewart R. Spector, The Spector Report (New York, Oppenheimer, 1978).

Discussion

The minimum alumina content and the maximum silica content of first-class bauxite were questioned. It was considered that 40 per cent was the minimum alumina content if the proportion of silica was very low. But to ensure economic processing, 45 per cent was a better guiding figure.

The definition of "available alumina" was treated. The value of available alumina always reflected the level of technology. It should be determined on the basis of empirical testing and related to a specific technology. It reflected, besides losses of alumina bound to silica, alumina locked in mineral crystal structures, such as in goethite.

The effect of plant scale on the specific investment costs for aluminium smelters was said to be relatively small. The specific investment costs for a 150,000 t/a smelter would be 8-10 per cent above those for a 100,000 t/a smelter.

The decision about which process to use for mixed-type bauxite should be taken with care. If the boehmite content was more than 5 per cent, high-temperature technology was usually recommended. If the bauxite contained 5 per cent boehmite with small quantities of aluminous goethite, low-temperature processing could be selected, but if the goethite was highly aluminous, high-temperature processing might be advisable. Maximum figures could not be given because the selection of a process had to be based on technological testing and techno-economic calculations adopting actual cost factors.

The definition of bauxite was asked. It was explained that bauxite was a sedimentary rock and was one of the ores used in alumina production. Processed bauxite contained on an average more than 45 per cent alumina, but that proportion was deceptive since some countries were processing ores with a much lower alumina content (above 30 per cent only) when the active silica content was low and open-pit mining was possible.

As the lecture had favoured the prebaked anode process, one participant referred to the special skills necessary for handling that process, especially in producing the prebaked anodes, and said that developing countries might not be able to master it readily. Algeria was therefore establishing a plant based on the Söderberg process.

Regarding environmental protection and working conditions within the pot-room, the prebaked anode process and, recently, the cental-break type had been considered the best solution. Vertical-stud Söderberg anodes might, it was warned, cause difficulties for the workers. It was agreed, however, that recent improvements in the Söderberg process[2] have helped to compensate for some of its disadvantages; for instance, pollution had been decreased through effective hooding and power consumption had been reduced.

It was considered important to establish means of fixing alumina prices so that smelters in developing countries could be competitive on the world market. This question had been discussed by various groups of companies for years.

On the subject of continuous casting, the installation of a Properzi cast-roller using molten metal from the pots was considered advantageous. Some plants were also operating continuous casting processes starting from molten metal rather than ingot.

For vertical-stud Söderberg pots, floury-type alumina was preferred since it better secured the covering of the gas-collecting part of the furnace. When mixed-type alumina was used, the results could not be controlled because of changes in the heat balance. With central-break, prebaked anode cells, sandy-type alumina had to be used, resulting also in easier transportation, feeding and portioning. Fluorine was more readily absorbed with the sandy type when dry scrubbing was used.

The success of an operation also depended on breaking and feeding technology. Intervals from as short as 10 minutes (in the United States) to as long as five hours (in Europe) were reported. There were fewer problems with shorter intervals.

2/ The following information was provided by Sumitomo Aluminium Smelting Company, Ltd, Japan, on inquiry by UNIDO: In Sumitomo's technology about 95 per cent of generated gas is collected at the pot and sent to the primary system for removal of dust, fluoride and other harmful materials. External emissions are thus reduced to about 0.9 kg of total fluoride per ton of aluminium produced without overhead scrubber and to 0.2-0.3 kg with overhead scrubber. A major characteristic of anode technology is low tar-fume emission, brought about by introduction of a special anode paste. Generation of tarry matter from the anode top is reduced so much that the average tar-fume concentration is only about 0.15 mg/m^3 in the air of the pot-room. Energy consumption for the Söderberg pots is 14,000 kWh/t of aluminium, with a current efficiency of more than 90 per cent. Cell life can be extended, on an average, to more than seven years.

Additional information was sought about the statement that smelters of less than 100,000 t/a capacity were unprofitable. When establishing a smelter, it was explained, a minimum capacity had to be set in order to provide load on the minimum reasonable anode plant. The common conclusion was that aluminium production of about 80,000 t/a was reasonable based on up-to-date technology. That led to the establishment of a smelter of about 100,000 t/a with two pot lines of 150-170 kA each.

It was agreed that the Alcoa smelting process offered some advantages, such as the possibility of using non-consumable anodes and an increased output by unit volume of equipment. Capital costs could thus be reduced. The disadvantage was that the process required petroleum coke as reducing agent, for the stage of aluminium-chloride production. Nonetheless, if the technology could be developed so that low-grade bauxites or chlorinated clays could be used, the Alcoa process would be an attractive alternative.

In response to questions about the requirements for environmental protection, a publication of the United Nations Environment Programme (UNEP) on "Environmental aspects in the aluminium industry- an overview", issued in May 1977, was referred to. In general, the cost for environmental control equipment was estimated at 6-7 per cent of the total investment for a smelter. The cost might be less in developing countries, depending on the location of the plant. The human factor had to be taken into account and the level of pollution that could be tolerated by workers. In seeking solutions, the overall economic conditions of a country would have to be balanced against the environmental aspects.

Bauxite and alumina production: Brief history, review of the present situation and prognosis

A lecture on bauxite and alumina production (reproduced in ID/WG.273/9) was given by J. Zámbó, Director, ALUTERV-FKI (Research and Development Centre of the Hungarian Aluminium Corporation), Budapest. It covered world bauxite reserves suitable for processing by the Bayer method. Information on raw materials other than bauxite that could be used in aluminium production, such as clays, alunite and nepheline, was given and the various technologies of alumina production were outlined. In addition, a techno-economic evaluation comparing the various alternatives for alumina production was provided.

Lecture

Assuming that the Hall-Heroult process will be used for making aluminium in 2000, the world-wide annual demand for alumina will have reached 140-200 million tons by that year. The industrial application of the new processes for aluminium production will not take place before the turn of the century, and the bulk of metal production in the year 2000 will most likely be done by electrolysing alumina. At present, more than 90 per cent of alumina is produced from bauxite. Abundant high-grade bauxite is available world-wide; bauxite reserves therefore do not set any limits to the development of the alumina industry.

Aluminium makes up 8.13 per cent of the earth's crust, being the most frequently occurring metallic element. In alumina production, the following raw materials are important aside from bauxite: bauxitic clays (and laterites); kaolinic clays; dawsonitic argillaceous slates; alunitic volcanic tuff; anorthosite; nepheline syenite urtite; leucite syenite, leucitite; and metamorphosed schists. The combustion products of different coals (ash, flue ash or by-product concentrates rich in aluminium oxide) may also be used for alumina production. These are referred to as non-bauxite raw materials to distinguish them from bauxites containing free aluminium oxides and hydroxides. High-silica bauxites, however, are also included in this group.

There is no shortage of aluminiferous raw materials. Nonetheless, the geographical distribution of bauxite is very uneven, which may cause shortages in some countries. As a result more research is being done on applying methods other than the Bayer process.

In alumina production, the Bayer process is the most frequently used. A weak point of this process is that the reactive SiO content of bauxite causes losses of caustic soda and aluminium oxide owing to the unavoidable formation of sodium aluminium silicate. Another limitation is the comparatively low precipitation efficiency, which has not yet been raised above 55 per cent. The storage and utilization of red mud cause another problem.

Pyrogen sintering technology is favoured for high-silica bauxites and for the complex utilization of raw materials such as nepheline.

Combined processes are broken down into parallel-combined and series-combined technologies. The parallel-combined method can be used to advantage if the bauxite processed can be separated into two kinds of ores containing different percentages of silica. The aim of the series technology is to decrease heat demand during sintering, requiring relatively high power inputs.

The technology for complex processing of nepheline concentrates was worked out 25 years ago in the Union of Soviet Socialist Republics, for production of alumina, soda, potassium salt and cement. Data from the Union of Soviet Socialist Republics indicate that the cost of complex processing of nepheline ores is 10-15 per cent less than that of producing the end-products separately. In producing 1 t of alumina by processing Kola nepheline, 0.78 t of calcined soda, 0.3 t of potassium salt and 10 t of portland cement are obtained. Therefore, the limitation in application of the process is partly due to the large amount of cement it yields.

Large alunite deposits occur all over the world. Recently there has been interest in their possible use in alumina production and in the chemical industry. Vanadium pentoxide and gallium are gained as by-products of alunite processing. Potassium sulfate, soda salt and caustic soda are also recovered.

Aluminous ores with high silica content can be processed to yield alumina and cement via calcium aluminate. An industrial-scale plant for the production of 100,000 t/a of alumina and 1,000,000 t/a of cement is under construction in Poland, and preparatory work is being done in Hungary on the establishment of a plant to produce 50,000 t/a of alumina and 500,000 t/a of cement.

Acid treatment of non-bauxitic ores can be applied to almost all aluminous silicates. There are various shortcomings, however, such as high power consumption and the necessity for corrosion-resistant equipment and for pre-treatment of the raw material. In spite of extensive investigations at the pilot-plant level, no progress in resolving these problems has been reported.

The lecturer's conclusion was that alumina could be produced most efficiently from high-grade bauxites using the Bayer technology. Problems remain in the further intensification of the technology, the processing of high-silica bauxites and the use of red mud.

Since the economy of alumina production depends on several factors and varies from country to country, no method can be generally recommended. Decisions on the choice of technology should be taken on the basis of individual investigations and local conditions.

Discussion

The plans of Hungary to establish a unit producing 500,000 t/a of cement and 50,000 t/a of alumina were discussed. To be competitive, the price of the cement produced in the combined process would have to be about the same as that of traditional cement.

Alunite was described as a complex raw material used also in the production of sodium, potassium and sulfuric acid. Since sulfuric acid could not be consumed in large volumes as a chemical, a fertilizer plant was normally established along with an alumina plant. Processing of alunite and nepheline was limited because it was tied to market demand for potassium, cement and sulfuric acid.

It was stressed that table 6 of the text of the lecture provided index figures only, using 100 for the Bayer process. As those figures were taken from various sources and were based partly on laboratory-scale investigations, any absolute figures used in place of the index figures could not be expected to tally completely. But it was appropriate to assess the present situation and prospects. Detailed data for alunite or nepheline were not included because they were not available, but information from the Union of Soviet Socialist Republics indicated that those raw materials were cheaper.

Questions were asked about advances in the application of the new technologies. It had been reported, for instance, that Poland was establishing a plant for the production of 100,000 t/a of alumina and 1,000,000 t of cement, which would come into operation in 1979. Most of the technical problems had been solved. Nonetheless, as the process essentially yielded cement and alumina as by-products, it could not be regarded as competitive with the Bayer process.

It was mentioned that in the Union of Soviet Socialist Republics only nephelines containing more than 19 per cent potassium oxide were processed because large, high-grade nepheline deposits were available there. Lower-grade nepheline could be processed with lower efficiency. Reference was made to studies being carried out in the United States by Alcoa on treating ashes to produce alumina, which had been done successfully by the acid process.

A question was asked about the threshold values for bauxite-quality indices beyond which other processes would become competitive. Three potential competitors would be nepheline processing, alunite processing and acid treatment. As large-scale acid processing had not yet been carried out, only theoretical calculations could be made, which indicated about 20-40 per cent higher costs using that process. The price of bauxite was at present still low enough to secure the long-term competitiveness of the Bayer technology.

Information was also sought on the Pedersen method for processing lateritic ores with low alumina content, high iron content and (usually) low silica content. It was reported that the process had been improved and successfully applied in the Union of Soviet Socialist Republics. In the first stage, iron and calcium aluminate were produced. Alumina could be extracted by the Bayer process, and then a modified Pedersen process was applied for red mud, using limestone. Economically, the process would probably be viable under the following conditions: absence of iron ore; abundance of laterite with high iron content; availability of good-quality limestone; and sufficient demand for cement in the particular country or region.

As regards the purity of aluminium processed from nepheline and alunite, the problems would be the same as in the Bayer process and the combined processes. Almost no information was available on acid treatment.

History and analysis of the bauxite and alumina market, with case study of Hungarian experience

A lecture on the bauxite and alumina market (see ID/WG.273/6) was given by P. Relle, Commercial Director, MINERALIMPEX (Hungarian Trading Company for Oils and Mining Products), Hungary. It covered companies participating in bauxite and alumina trade, price issues of the trade and policy considerations concerning long-term and spot transactions. The lecturer commented on alumina price clauses in detail from a trader's point of view.

Lecture

World bauxite production, which was 47 million tons in 1968, had increased to more than 80 million by 1977. Both figures cover about 1.5 million tons of non-bauxitic ores such as alunite and nepheline. Such substitutes are not expected to have any serious impact on production figures for the next 10-15 years.

The main regions exporting bauxite are Africa, Australia and Latin America. Asia (mainly Japan), North America and Western Europe are importers. Most of the proven bauxite reserves (60-80 per cent) are located in developing countries, which have become increasingly desirous of having downstream operations established in their territories, a circumstance that has in some cases also served the interests of the transnational corporations mining bauxite in these countries. As a result of such operations, developing countries, which in 1960 accounted for less than 10 per cent of bauxite refining, now refine about one third of the world's bauxite. Their economic situation, however, has not improved commensurately.

Bauxite-producing countries formed the IBA in order to be able to influence prices and strengthen their national interests; IBA members hold most of the global bauxite reserves. Governments in some developing countries have taken measures both to develop new downstream operations and also to secure national ownership in order to add to foreign exchange income. They have also increased taxes. In Jamaica the tax is about $18/t (compared with $2 in the early 1970s), opening the way for agreements on downstream operations. All other IBA members (except Australia, Ghana and Yugoslavia) have also increased their taxes in varying degrees. Guinea, Guyana and Jamaica are about to introduce measures attaching their bauxite shipments to employment in their newly established national shipping companies.

National aluminium industries have been established in a number of countries where no bauxite is mined but cheap energy is available. Under the Hungarian/Union of Soviet Socialist Republics agreement on alumina and aluminium, signed in 1962, Hungarian bauxite is refined to alumina close to the mines, and the alumina is shipped to a Soviet smelter for processing to aluminium, to be returned to Hungary in the form of ingots or billets. Export of Hungarian alumina will reach a peak of 330,000 t in 1980; it will remain on this level until 1985. In spite of the distance (3,000 km) that the alumina must be transported it is cheaper for Hungary to produce aluminium in this way than to import energy. A similar agreement exists between Hungary and Poland.

Firms participating in bauxite and alumina trade may be divided into three groups: transnational corporations, producers not belonging to transnational corporations and trading companies. Transnational corporations are distinguished by their verticality and global character. About two thirds of the world's bauxite and alumina trade is shared by six transnational corporations. In 1968 these corporations accounted for about 80 per cent of alumina refining, but their share was down to 67% by 1977. This decrease was the result of nationalization (such as in Guinea and Guyana); the establishment of new state-owned enterprises (e.g. in Bharat, India and Seydişehir, Turkey); and a significant increase in the capacity of companies operating independently of the large corporations.

Although the vertical integration of the transnationals is complete, that of other producers still needs to be strengthened. Many of these smaller companies are partly or totally state-owned.

Trading companies predominate in a number of countries where production and trading activities are traditionally kept separate, such as in countries of the Council for Mutual Economic Assistance (CMEA). Another reason for the existence of such companies is that some producers like to avoid risks and often do not have experience in trading. During the past few years, producers have gradually recognized the existence of traders in the bauxite-alumina-aluminium market. This trend goes hand-in-hand with the increased amount of alumina being traded on the open market, which is nearing 20 per cent of the alumina produced. The share of trading firms in the market has also been favoured by up-to-date functions of swap activities, which are classified as activities in time and activities in space.

The use of reasonable price clauses has always been advocated in Hungary. Most price formulae are based on three criteria of quality: moisture, aluminium-oxide content and silicium-dioxide content. Bauxites containing 45 per cent of available Al_2O_3 should be the IBA base at present, with a floor price of about $24/t landed in Canada and the United States.

The most frequently used pricing methods in the alumina trade are: contracts with fixed prices; the linking of alumina prices to the price of aluminium ingots; and escalation clauses applying linkage to more factors. The last method cannot be avoided in some areas of international business, but it is not necessarily applicable to the alumina trade.

Because of the importance of long-term as opposed to spot transactions, investment costs and the proper timing of investments are main factors in deciding on rationales. In most branches of the economy a continuous supply can be secured only by long-term contracts, and it is expected that reliance on such contracts will be the rule in future even more than it is today.

The future of spot transactions is more unpredictable. Demand for aluminium generally increases at roughly double the rate of yearly growth of GNP. Nonetheless inflation has in recent years limited the number of new investors in the aluminium industry, which may lead to a shortage of primary aluminium in future. Only good forecasting of the bauxite and alumina markets can indicate whether favourable spot transactions can be made.

Discussion

One participant was of the opinion that developing countries usually had to accept the price structures offered by big companies. Investigations by independent experts had revealed substantial differences between base price and primary aluminium production costs.

It was agreed that there was probably no good and just price clause. Most clauses were based on the American Metal Market or the Metal Bulletin, using the Canadian world price. Many would be established according to the quotations for "certain other transactions" (COT) in the Metal Bulletin, since they gave a better market picture. This was, however, limiting because of the relatively few transactions made under COT. European transactions were usually based on the Canadian price. It was explained that under the Hungary/Union of Soviet Socialist Republics agreement, alumina was exported from Hungary to the Union of Soviet Socialist Republics and aluminium imported from the Union of Soviet Socialist Republics at the CMEA market price. In general, however, the aluminium price clause was considered to be a question of bargaining.

It was stated that, whereas profits were made at the expense of the raw materials supplier in the past, they should be made in the primary raw materials domain as well.

Investment cost was an important factor, but it was not directly related to prices. On the other hand, market prices plus actual cost factors would determine return on investment.

It was pointed out that when the alumina price was linked to the aluminium price, energy costs of over 30 per cent were already included in the latter. Therefore no additional escalations owing to energy (fuel-oil) cost rises should be included in the price clause. It was agreed that the world price of metal had not increased in line with energy cost increases.

Basically, countries establishing an aluminium industry needed information on two points: (a) the market price (assessment of which would require special expertise including market research, forecasting and review of the current position), and (b) the costs of producing the metal locally. Even if production costs should turn out to be relatively high, government losses could be balanced by the positive socio-economic impact on overall industrialization. Moreover, downstream operations could yield profits. It was therefore generally considered that available resources should be utilized.

Prices should not be derived solely from the costs of the particular operation but from the actual market situation. Small plants might be at a disadvantage because the market was governed largely by transnationals. It was predicted, however, that the future aluminium market would be good and that the markets for bauxite and alumina would improve.

The world market for aluminium metal and semi-finished products: Quality aspects, and conditions influencing and problems related to demand

A lecture on the world market for aluminium products (see ID/WG.273/3) was given by A. Mersich, Commercial Director, METALIMPEX (Hungarian Trading Company for Steel and Metals), Budapest.

Lecture

The yearly growth rate in aluminium production is 5-7 per cent. In 1976, virgin aluminium was produced in 40 countries, as compared with only 30 countries with production facilities 10 years ago. Some 13,082,900 t of virgin aluminium was produced in 1976, although actual smelter capacity was 15.6 million tons. Aluminium smelting was based more on the availability of energy and the proximity of markets than on the abundance of nearby ores.

Aluminium is frequently transported from one continent to another, e.g. Hungarian aluminium is sent to Japan in containers on the Trans-Siberian route at a cost of $80/t, and by ship from the Federal Republic of Germany to China at $50-$60/t. Transport costs make up roughly 5-7 per cent of the value of aluminium. Government import policies sometimes pose obstacles.

The European Economic Community (EEC) exacts an import duty from non-members of 7 per cent on raw aluminium. In the United States the import duty on virgin aluminium is 1 cent per pound for most-favoured nations and 4 cents for others. Import duties are often combined with import quotas.

Considering that the value of the virgin metal is $1,000-$1,100/t, recycling is imperative. Great care must be taken to separate and store the scrap properly. In 1976, 3.1 million tons of aluminium was recycled (not counting countries with centrally planned economies). The share of recycled aluminium was about 30 per cent of primary metal output in countries such as the Federal Republic of Germany, France, Italy, Japan, the United Kingdom and the United States.

World consumption of primary aluminium in 1976 was 13,862,000 t. Aluminium demand has tended to be strong in comparison with that of the other leading metals. The same trend is reflected in the price of metals. There are two price quotations for aluminium: the world export price of Alcan Aluminium Ltd, Canada, for 99.5 per cent virgin ingots quoted in cents (¢) per pound for all main world ports (excluding Canada, the United Kingdom, the United States and South America). On 1 March 1976 the quotation was 43 ¢/lb; on 1 April 1977 it had increased to 51 ¢/lb. The other quotation can be found in the Metal Bulletin under the heading COT. This quotation usually fluctuates below the "official" quotation of Alcan. The average quotation in 1977 was $982-$999/t. COT aluminium prices showed extreme variations, and copper and zinc did even worse. Aluminium has apparently recovered from the recession of 1975 and, excluding the possibility of a general recession, which is not expected, a steady increase in consumption can be projected. Given a low expansion rate of 3 per cent in the countries of the Organisation for Economic Co-operation and Development (OECD), an average growth rate for aluminium consumption of 5 per cent is probable. Since new investments in aluminium smelters have generally declined during the last years, a relative shortage of aluminium will occur around 1980. Moreover, a further but relatively modest rise in prices is likely.

World aluminium smelter capacity was estimated at 15,800,000 t in 1977. The six transnational aluminium companies had a share of 6,883,000 t, and 5,276,000 t was state-owned.

The free-market turnover is presently estimated at 500,000-600,000 t/a. The biggest single buyer in this market is China. Speculation in the aluminium trade has grown recently because international merchant companies are taking over more and more of the metal on the free market. Extensive swap operations have also been reported. A separate market is developing for customs-cleared aluminium ingots in the EEC countries.

Opportunities for trading aluminium on the London Metal Exchange (LME) have increased lately, and the LME has a subcommission dealing with this subject. The main features of the LME are:

(a) Prices are quoted twice daily;

(b) The LME quotation is generally recognized as the price of the metal not only in ingot form but also from the stage of ores and concentrates to that of semi-finished and finished products;

(c) It is general practice to agree on an "unknown" price;

(d) Contracts can be concluded from prompt to 90 days forward, without the risk that price movements will affect the contracts in the period covered.

Competition is keen in the sale of aluminium semis. Statistics relating to this subject are complex; there are no price quotations at all for the higher qualities and specialities yielding the best returns. Semis can often be produced economically in small shops with little investment. Many countries have protective duties on semis. In Austria the duty on imports from countries outside the EEC or European Free Trade Association (EFTA) is 17 per cent for sheets and extrusions and 27 per cent for foils. In the lecturer's opinion, administrative measures such as import contingents, individual licensing and preferential duties impede the export of semis to potential markets.

In packaging and forwarding semis, damage to the metal can easily occur, and great care should therefore be taken in this regard.

Discussion

The discussion centred on the possibility of aluminium being quoted on the LME. If that materialized, caution was advised because of the possibility that some of the big producers might eventually manipulate the market; this had happened with copper in 1962/63 and with zinc in 1974/75, when the free-market price had been more than double the producer's price. No projections could be made regarding producer price as such. It was considered that the free market would have a better guide in the LME, and that the producers would be offered better financing because metal could always be sold to the LME.

The modus operandi of the LME was explained in detail. There were 25-30 brokers in the ring to negotiate, and buying and selling was usually done in units of 25 t, from prompt to 90 days forward. The price commission quoted two prices: a settlement (prompt) price and a 90 days (future) price. The legal partner was the broker rather than the end owner. Long-term contracts were worked out by employing the average and taking account of fluctuations.

It was reported that the annual reports (called "10-K" reports) filed by American aluminium companies with the United States Securities and Exchange Commission could be obtained from Washington, D.C.

Transnationals accounted for 90 per cent of the production and sales of alumina in market economies and 67 per cent of the aluminium. The alumina market is a buyers' market, shared by six transnationals and several state-owned smelters.

The quotations of EEC customs-cleared aluminium were considered interesting, but EEC transactions were regarded as too small to influence the market. Although forgings were not used in large quantities, they were of interest because of their imports and prices. Precision forging, done in order to save on waste materials, was gaining momentum.

It was felt that the prices in the Metal Bulletin for semis were higher than could be obtained. For high-grade semis, quotations were difficult to get.

On the subject of duties, the example of Hungary was cited. It was reported that the import duty on imported aluminium semis was 10 per cent. Substitution of aluminium for other products had been started in the 1930s and carried as far as possible. In 1976 Hungary had produced some 184,000 t of aluminium semis and 50,000-60,000 t of copper semis, of which 20,000 t of aluminium and 16,000 t of copper had been used for electrification.

Aluminium semis and finished products: Recent trends in end-uses, the pattern of developing markets and possibilities of substituting aluminium

A lecture on aluminium semis and finished products (see ID/WG.273/4) was given by R.W. Boos, Director, PROGNOS AG, Basel, Switzerland.

Lecture

In 1965 packaging in the United States accounted for 9 per cent of aluminium consumption; this figure doubled in the next 10 years. Some 60-70 per cent of aluminium in the United States and Europe is consumed by the transport, construction, packaging and electrical engineering sectors.

Major products in the transport sector, partly or totally made of aluminium, are passenger cars, trucks, buses, caravans, military vehicles, aircraft, ships and rail vehicles. In addition, three automobile companies (Peugeot, Renault and Volvo) have jointly developed an all-aluminium engine with apparently satisfactory results.

A new application for aluminium has emerged as a result of the growing number of tankers carrying liquefied natural gas (LNG). For a tanker intended to transport 125,000 m^3 of natural gas, some 10,000 t of aluminium sheet is required.

With consumption growing at an average (unweighted) annual rate of 8.2 per cent, the transport industry is at the head of the list of major consumption sectors. This high rate of growth is accounted for mainly by die-cast aluminium constructions (chassis, engine parts in passenger cars and trucks, axle bed bolsters of rail vehicles, motor-bicycle frames). An increase is also expected, however, in the demand for profiles (truck and railway-coach superstructures), rolled products (truck cabs, sheets for LNG tankers and parts of bodies of passenger cars) and forged products (rims for road vehicles and motor bicycles).

The construction sector uses the following aluminium products: doors, windows, facing elements, roof covering, exterior panelling, fittings, sun-shades, heating and ventilation equipment. The best opportunities for aluminium application are found in the construction of institution buildings.

Aluminium products have strong competition. They can be replaced not only by pure synthetic materials but also by aluminium/synthetic compounds, which have more potential for development than compounds of aluminium and wood.

Packaging is one of the major application areas for aluminium in nearly all industrialized countries. Its share fluctuates between 5.2 per cent in Japan and 22.8 per cent in the Netherlands. Although opinions vary, aluminium cans will probably have more success as beverage than as food containers. Extrusion-moulded packaging materials have considerable force in the market. Aluminium foils are also important but their growth in the past has not been overwhelmingly large (around 2 per cent per annum).

The increase in aluminium consumption in electrical engineering has been rather modest in highly industrialized countries. Nonetheless, it can be assumed that aluminium, having replaced copper in open-air transmission lines, will also soon replace it as the conductor in cables. As a coating material, however, aluminium will probably be replaced by plastics.

Aluminium consumption grows about one and a half times as fast as GNP. In future, it is expected to outgrow production capacities. An average annual growth rate of approximately 5-6 per cent should prevail in the years up to 1990. The aluminium market in the developed countries of the West will expand but will be subject to relatively frequent fluctuations, while in the developing countries a relatively stronger, more constant increase in demand will occur.

By comparison, during the period 1974-1990 the average annual growth rate in consumption in, for example, the Federal Republic of Germany is expected to be 4.5 per cent and in the United States, 5.8 per cent.

As an example of a developing country with a high rate of growth, Iran may be cited. GNP has increased annually by 8.6 per cent on an average, and this rate is expected to reach 10-11 per cent by 1990. Total aluminium consumption is now around 20,000 t. By 1990 it should be about 280,000 t, which would correspond to a growth rate of 17.9 per cent.

By comparison, during the period 1974-1990 the average annual growth rate in consumption in, for example, the Federal Republic of Germany is expected to be 3.5 per cent and in the United States, 5.8 per cent.

Discussion

Some participants regretted that the lecture had concentrated mainly on Western European figures, but they agreed that the text could serve as a general guide for developing countries in making detailed studies of specific areas.

Many developing countries would have to export most of the metal they might produce. Thus, two aspects were important in considering the feasibility of building a smelter: the general possibility of exporting and the chances of maximizing returns for the industry by exporting particular types of products.

Domestic consumption of aluminium could be stimulated but this took time. Even if, for example, Guyana were able to increase consumption to 7.2 kg per capita, only some 50,000 t/a would be consumed, probably too little to justify the establishment of a modern smelter. It was considered advisable to establish secondary facilities, such as rolling, in order to satisfy demand and stimulate consumption.

The subject of penetration of markets by developing countries was raised. Success depended largely on the market strategy by a company. Consumers' needs had to be considered; with special products penetration was almost always possible. Knowledge of technology and of the market were requisites for successful negotiation and market penetration.

Figures were given for aluminium consumption in Hungary. For the 146,000 t of finished goods in 1976, the end-use pattern had been similar to the one given in the paper except that in transport the figure had been 10 per cent and in electrification 30 per cent. Thirty per cent of all finished goods was exported. Per capita aluminium consumption in Hungary was rather high, especially in relation to GNP figures. Hungary was an example of a centrally planned economy in which the Government could, by the policies it laid down,create a market for a particular item, in that case aluminium.

It was felt that the chances for using aluminium for packaging in the fishing industry were good. As regards electrical engineering, while developed countries were changing to aluminium wire, developing countries just starting to electrify should employ aluminium from the beginning.

It was stressed that demand in developed countries differed greatly from demand in developing countries which, in its early stages, was governed primarily by the need for cooking pots and roofing. In this connection, a participant described a survey he had conducted on the market for aluminium in tropical countries. Most of the items with market potential were intended to meet fundamental needs: cooking utensils, house roofing, sprinklers for irrigation, and roofing in sheds where cattle, chicken etc. were fed and protected from sun.

It was pointed out that cooking utensils of aluminium did not use as much fuel as cast-iron products. They could therefore help to slow down depletion of wood supplies and the resultant soil erosion in developing countries. Furthermore, using aluminium instead of thatch for house roofing in tropical Africa could help reduce disease by removing a living and breeding area for insects. In the United States, aluminium roofing was used for farm buildings to reflect heat from the sun. As a result, milk, egg and meat production had increased substantially. It was explained that, while galvanized iron was cheaper, it had to be replaced after 10 years or so.

The use of sprinkle instead of open-ditch irrigation reduced workers' exposure to parasites. It also prevented the soil from slipping and saved water, especially on slopes.

The biggest problem in building an aluminium industry in developing countries was thought to be cost, and a government subsidy would usually be necessary, for instance in housing or in making investments to improve farm production.

Long-term arrangements between developing countries and consumers of bauxite, alumina and aluminium

The lecture (see ID/WG.273/7) was prepared by S. Moment, Consultant, Portland, Oregon, United States. It covered the various kinds of arrangements, long-term and other, that developing countries may enter into in order to secure investments and to guarantee a supply of bauxite, alumina or primary aluminium to consumers. It investigated principal corporate, financial and co-operative ties between producing countries and consumers of bauxite and alumina with regard to the following countries: Australia, Brazil, the Dominican Republic, Guinea, Guyana, Haiti, India, Indonesia, Jamaica, Malaysia, Sierra Leone and Suriname. Ties between aluminium smelters were reviewed for Algeria, Argentina, Bahrain, Egypt, Ghana, Iran, Iraq, Japan, the Libyan Arab Jamahiriya, New Zealand, Saudi Arabia, the United Arab Emirates (Dubai) the United States and Venezuela.

Lecture

A change has occurred in the climate for international investments in projects to produce basic materials for export. Both developed and developing countries are demanding greater revenues, higher taxes and higher prices for their exports. They prefer to employ their own citizens rather than expatriates, and they want to process their raw materials to more advanced stages. Some want participation in or complete ownership of enterprises.

Because securing investments and receiving adequate returns have become to uncertain, investment is no longer expanding as it did in the 1950s and 1960s. Therefore, a close assessment of the current situation and future prospects is in order.

World demand for primary aluminium is expected to increase from 14 million tons in 1973 to about 54 million tons in 2000. According to World Bank projections, in 1985 155 million tons of bauxite, 47 million tons of alumina and 23 million tons of aluminium will be produced. These projections assume that the developed economies will continue to supply 40 per cent of the bauxite, 76 per cent of the alumina and 83 per cent of the aluminium.

Developing countries can be expected to have the largest rates of growth in demand for aluminium because of their present low level of consumption. In total tonnage, developed countries will have the largest growth in demand because of the present strength of their markets.

For the developing countries to produce the output of bauxite, alumina and aluminium projected by the World Bank, $25 thousand million(at the 1975 level) will have to be invested between 1976 and 1985. For individual projects, the capital cost of capacity would be $85/t of bauxite, excluding infrastructure; $750/t of alumina in an unintegrated plant; and $2,800/t of aluminium in an unintegrated plant.

The principal sources of capital for bauxite and alumina projects are the leading private aluminium corporations, the Union of Soviet Socialist Republics and some of the oil-producing countries in the Middle East.

Two market groups are usually considered separately: open-market economies and centrally planned economies. Centrally planned economies engage in considerable trade among themselves in bauxite, alumina and aluminium.

The Union of Soviet Socialist Republics has given financial and technical assistance for projects in Egypt, Guinea, India, Turkey and Yugoslavia, and it is expected that developing countries will continue to find the Union of Soviet Socialist Republics interested in providing technical help and supplying mining and other equipment in exchange for bauxite and alumina.

On the open market the six transnationals predominate since they control their own supplies of bauxite and alumina. They must have a steady supply of metal in order to support large investment in fabrication; they are obliged to provide dependable supplies of metal to extensive markets; they have long-term obligations for supply; and they are required by lenders to have assured bauxite and alumina resources.

In the lecturer's opinion, arrangements with the six transnationals are more advantagesous for developing countries than co-operation with smaller, unintegrated enterprises, which may bring higher production costs, lower profitability and less revenue for Governments to share. Moreover, smaller companies are less able to finance infrastructure such as railroads, town sites and social services for workers.

In world aluminium markets it is notable that the share of new entrants competing with the six transnationals is growing.

Owing mainly to the high cost of oil for power, the Japanese aluminium industry has become uneconomic and unprofitable. It is looking for new smelter capacity outside of Japan. Although the American aluminium industry is still profitable, by the early 1980s the United States will be increasingly reliant on imported aluminium. In developing countries the bauxite deposits are government-owned, and the State arranges contracts, leases or concessions with others for development, or develops the bauxite itself. Arrangements among countries and individual problems vary greatly. For instance for shipments of bauxite from Jamaica to the United States, the delivered price is reported to be about $30/t, compared with an estimated delivered price from Brazil of only $20/t. Commercial bauxite reserves in Jamaica, formerly estimated at 800 million tons, are now estimated at 1.5 thousand million tons and may be even 2 thousand million. Guyana and Suriname must find assured markets for aluminium so that they can enter into guaranteed long-term contracts that will enable them to pay for power.

In Brazil, development of some 2 thousand million tons of bauxite reserves is starting. The first project (Trombetas), in which $300 million has been invested, will produce bauxite mainly for export. The bauxite price as of 1977 is estimated at $10/t f.o.b. Trombetas, which would mean $19 delivered cost to Canada or the United States. Another major project, not only to export bauxite but also to supply the Belem Alunorte smelter, is being planned with the co-operation of a British company.

In New Zealand the hydroelectric plant was built by the Government primarily to serve the smelter. The price originally agreed to for power (in 1963) was 0.3 ¢/kWh, but this has been raised by the Government to about 1.5 ¢/kWh, about five times more. Expansion of capacity is thus doubtful. This brings up the issue of the long-term supply of power that concerns developing countries offering hydropower to attract smelters. The same issue affects Middle Eastern countries that offer power at a low price based on surplus gas resources. Conditions could change so that gas would become more valuable if used to produce petrochemicals or sold as liquefied gas for export than if put into power generation.

Governments enter into the following types of agreements concerning bauxite, alumina and aluminium:

(a) Projects owned by the host Government and carried out under bilateral government-to-government agreements. Examples are the agreements between Guinea and the Union of Soviet Socialist Republics and the agreement between Turkey and the Union of Soviet Socialist Republics;

(b) Projects partly owned by host Governments through arrangements with private companies or consortia, e.g. in Bahrain, Brazil and Venezuela;

(c) Projects wholly owned by private investors, such as those being implemented by Australia, the Dominican Republic, Haiti, Sierra Leone and Suriname;

(d) Smelter projects owned by private investors for which power plants have to be built to support the smelters. The most important agreements in this category are those in which Governments provide the power and own the generating facilities. Projects of this kind are being carried out in Argentina, Ghana, Iceland and New Zealand.

Of greatest concern to developing countries are the agreements of other Governments with which they may have to compete when trying to attract capital.

Regarding the principles incorporated in the various arrangments, an interim agreement on principles between parties is useful. Feasibility studies can cost millions of dollars and last a number of years; they are required by international financing agencies. After the principles are agreed on and feasibility studies are completed, the package concept may be adopted and agreement may be reached on the extent of government ownership and participation. An interesting example of a combination of several possibilities is in Guinea, where a mixed pattern of ownership policies has been followed. The duration (term of the agreement) and provisions for settling disputes are also of consequence. Other important stipulations concern organization, responsibilities and associated agreements; the fiscal regime (including conditions related to the payments the Government may receive and the limitations on such payments, such as share of profits, income taxes, royalties, duties etc.); and measures to support the fiscal regime (e.g. a most-favoured company clause). The question of domestic labour should also be taken care of, including the provision of training by the outside investors. Recent agreements have also provided for the protection of agriculture, other resources, workers or nearby populations from harmful effects of activities of the enterprise. Preferences for local supplies and services may also be included. Not uncommon are commitments towards related projects, such as feasibility studies by outside investors for additional projects. Moreover, account should be taken of force majeure provisions, waivers and contracts for power.

In his conclusions on guidelines for negotiating new agreements, the lecturer emphasized the following:

(a) Developing countries should frame their agreements to meet their needs for long-term stability;

(b) Individual projects now planned cost from a few hundred million dollars each to one or more thousand million. From now until 2000, the world-wide requirements in this industry are in the tens of thousand millions of dollars;

(c) Developing countries need outside investors and technology;

(d) Outside investors may come from centrally planned economies or from open-market economies aided by international financing agencies;

(e) Developing countries are competing among themselves but also with developed countries to attract new investment;

(f) Competition may also come from abundant non-bauxitic resources in the United States, which may be developed for producing alumina if developing countries impose conditions that make the cost of long-term supplies of bauxite too high;

(g) Investors require long-term conditions at the lowest possible cost, a dependable supply, recovery of their investment and a fair rate of return;

(h) While accepting the international trend towards total or partial ownership by Governments, investors will be attracted only if such ownership does not endanger the stability of supply; raise the cost of bauxite, alumina or aluminium; interfere with production by efficient methods to serve investors' markets; or jeopardize the recovery of a fair rate of return;

(i) An understanding is needed to assure recovery of the investment of outsiders and to give them a subsequent annual rate of return that is competitive with returns they could get from other long-term investments;

(j) To achieve this understanding, developing countries need full access to feasibility studies made by investors so that they can determine the terms to be negotiated for taxes, other government revenues etc. Such information may be requested by international agencies and reviewed by the developing countries' own advisers;

(k) If developing countries and outside investors could agree on return of investment, a fair rate thereafter and the method for adjusting the rate of return to changing conditions, suspicion against outside investors would be lessened and relations eased;

(l) If agreement can be reached on these basic questions it will be easier to negotiate terms relating to such other conditions as payments to the Government and exemptions from certain taxes or levies, prices, responsibilities, labour supply, training, priorities, environmental protection, use of locally available services, equipment and contracts for power.

Discussion

It was considered important to build up trust and confidence between the developing countries and outside investors. Developing countries were willing to enter into close co-operation with developed countries and transnationals which, however, would have to consider the principles and spirit of the new world economic order and that some reshaping had already taken place within that order.

It was noticed that the lecture had been based mainly on Jamaican bauxite. The lecturer was asked to supply information on world-wide developments in bauxite alumina and aluminium, including in CMEA countries, and to treat the question of reasonable pricing of bauxite and alumina, making price comparisons of the various bauxite qualities from different sources. It was agreed that UNIDO would look for means to sponsor such a study, which would then be made available to decision makers in developing countries.

Questions were raised about the United States law on ownership of resources on the subsurface of the soil. A distinction had to be made between government-owned and privately owned land, for which different laws existed. Government-owned land included off-shore marine land (320 km) and licence could be given under competitive bidding to private companies. On private lands the owner also owned any minerals underneath the land.

Participants were informed that there was no restriction on foreign ownership of United States mineral resources. Examples of joint ventures were cited; even exclusive ownership existed. The situation was different in other countries, such as Jamaica, where the owner might own the surface rights but the minerals belong to the Government.

On the question of reasonable pricing for bauxite, no specific answer could be given. While the IBA price reference of $24/t c.i.f. United States port was a good guiding figure, negotiated agreements were still the best solution.

It was expected that increases in aluminium prices would also increase the value of bauxite. If the price of the latter were to become higher than the cost of equivalent substitute material, other possibilities for alumina production would be sought.

Other sources of alumina were explored, it was asserted, mainly because of fear of a cut in the supply of bauxite. It was suggested that such research should concentrate equally on energy-saving measures in bauxite processing.

The point was made that, in feasibility studies for developing countries, financial feasibility should also be elaborated, including when investment would pay off, and that such information should be made available to potential outside investors.

Even if a developing country was not taxing a transnational company operating within its borders, the income of the country was being increased, it was stated, simply by having a local aluminium industry.

Short-, medium- and long-range trends in aluminium supply and demand

The lecture, which concentrated on the forecasting of aluminium demand (see ID/WG.273/5), was prepared by S.R. Spector, Vice-President, Institutional Research, Oppenheimer and Co., Inc., New York. The methodology of forecasting was demonstrated with model charts on the shipment of aluminium.

Lecture

A forecast has to be understood in the context of the macro-economic trend used in making the projection. In building a model of the aluminium industry, the following economic indicators are used as independent variables correlated to the shipment of aluminium to the economy: the index of industrial production; housing starts and mobile-home production, home improvement and expenditures for non-residential building; changes in customer inventory of aluminium products and inventory and backlog in the economy as a whole; competitive prices of materials competing with aluminium, again with appropriate lags.

The domestic shipment model has a correlation of 99.7 per cent and a standard error estimate of 2.3 per cent per quarter. Aluminium demand models of varying complexity are available for each of the industrial countries of the world.

The lecturer's medium-term forecast of aluminium demand in the Western economies referred to the years 1978-1982. During this period expansion of new primary smelter capacity is expected to increase no more than 4 per cent per annum, and aluminium consumption in the United States is expected to show an average growth rate of 5.3 per cent. Customer's stocks are considered to be at minimum working levels already and will have to be augmented by some 90,000 t towards the end of 1978. United States domestic shipments should grow as follows: in 1978, 14.5 per cent over the 1977 figure; in 1979, only 1-2 per cent; in 1980, 4.7 per cent; in 1981, as in 1980; in 1982, 8.2 per cent. Exports are likely to remain constant for the next two years, and supplier inventories are expected to grow progressively tighter.

Primary aluminium production in the United States in 1977 equalled 84.5 per cent of capacity. In 1978, 93.3 per cent of capacity is likely to be reached and in 1979, 94 per cent is possible. In 1980 and 1981 production should equal effective capacity, except for two Texas plants which will remain closed.

To meet future demand the United States will have to depend more on imported aluminium. Imports were 608,200 t in 1976 and 682,600 t in 1977. The forecast for 1978 is approximately 800,000 t. In 1980 imports may rise to 950,000 t, in 1981 pass 1 million and in 1982 amount to 1.2 million tons. Secondary aluminium recovery may rise to 22.7 per cent in 1982, compared with 21.7 per cent in 1977.

The world production of primary aluminium, by area, is given below:

World production of primary aluminium[a/]

Area	1977		1978 (estimates)	
	Volume (thousands of tons)	Average operational rate	Volume (thousands of tons)	Average operational rate
North America	5 093	88.6	5 468	95.5
Latin America	358	68.7	472	67.2
Europe	3 491	94.5	3 660	97.5
Africa	367	84.3	438	99.3
South Asia	379	66.6	408	67
East Asia	1 235	75.4	1 278	78
Oceania	393	100	401	100

a/ Excluding China, Eastern Europe and the Democratic People's Republic of Korea.

The general forecast of aluminium demand in markets outside the United States indicates that the rate of growth will peak in 1979 and slow down in 1980 and 1981 before accelerating again. The demand for primary aluminium in market economies was just under 11.3 million tons in 1977. Aluminium demand is made up of three elements: regional demand outside the United States; net United States import requirements necessary to balance the American market; and shipments to the Socialist countries. The net United States demand will tend to create a metal squeeze so that consumers in the major importing regions (Europe, Japan and the United States) will have to compete in the market for limited supplies. Shipments of aluminium to the Socialist countries are highly unpredictable. The projections assume a demand of 180,000-225,000 t through 1982 in China and Eastern Europe. As for supply, the components include primary aluminium production and imports of primary metal from Eastern European countries. Eastern European supplies of primary aluminium and fabrications are projected to rise from 317,000 t in 1977 to 400,000 t by 1982. Japanese smelters are proposing to inactivate 340,000 t of capacity. It is believed, however, that if the demand pattern develops as projected over the next two years, some additional capacity may be in operation by 1982.

An analysis of the various consumption patterns indicates that demand for aluminium grows as countries become more industrialized and as nations improve the standard of living of their people, since aluminium is a consumer-oriented commodity.

In future, developing countries will undoubtedly have a larger share in the aluminium industry as their abundant resources enable them to become major suppliers of raw material, energy and finished products. The potential demand for finished aluminium from these countries is enormous. In developing their resources, they must work out a partnership concept to satisfy both the private and public sectors.

Discussion

The structure of the model used for projecting aluminium demand in the domestic and export markets was explained in more detail. It was based mainly on estimates of the various industrial activities in the economy and took into account 36 variables, including housing, mobile-home production, home-improvement loans, customer inventories and the price of copper, lead, zinc, steel, plastics etc.

The statement by the lecturer that it was highly unlikely that the Government, in the case of a government-owned smelter, created the production pattern was debated. The example of the Union of Soviet Socialist Republics was mentioned, where the Government gave the incentives to develop the production pattern. According to the Indian participant, the Government in his country had been decisive in creating new products and new markets, while the private aluminium sector had taken no initiative in developing new products such as alloys. The Ghanaian participant stated that this experience was also true of Ghana.

Although it was generally agreed that a government smelter should make profits, it was conceded that in recession times such a smelter might have to suffer losses in order to maintain employment.

Hungary was mentioned as proof of the merits of the public sector in developing the aluminium market. From the time bauxite extraction had begun until 1945 there had been private companies, and 90 per cent of production had been exported as ore. Vertical integration had been built up after the Second World War, and government policies developed that had led to a marked increase in domestic consumption of aluminium.

It was recommended that, to meet aluminium demand, smelters be developed on a partnership basis with an existing company. Such partners should be offered an adequate return on investment.

Costs and other aspects of transporting bauxite and alumina

The lecture was prepared by G. Haclin, member of Brook Hunt and Associates Ltd (Mineral Consultants), United Kingdom, and J.P. Rowbotham, of H.P. Drewry and Co. Ltd (Shipping Consultants), United Kingdom, and delivered by J.F. Brandon, Chief Trading Executive, Amalgamated Metal Corporation, London. It is reproduced in ID/WG.273/10.

Lecture

In the period 1966-1976 total world combined shipments of bauxite and alumina increased by 80 per cent, from 23.4 million to 42.3 million tons. In bauxite, this represents a growth of 7.7 per cent per annum.

At a comparatively early date the aluminium industry initiated the transport of materials in bulk, usually as full shiploads. Use of larger, specialized vessels of the bulk-carrier type has been encouraged, stimulating investment in modern bulk-handling equipment at many ports. There has been a greater dependence on long-term bulk-shipping arrangements, freight contracts and period time-charter agreements. A large and growing proportion of all shipments of aluminium raw materials is carried out under long-term arrangements. Short-term chartering operations cater only for marginal transport requirements.

While some aluminium companies own bulk vessels for ocean transport, others prefer to enter into a contract of affreightment (COA). Under present market conditions such a contract is a less costly method of transportation than vessel ownership or the other main option, the period charter. Even companies with proprietary fleets may supplement their transport capacity by time chartering tonnage for short or long periods. Vessels may also be chartered for single trips. The Japanese have a unique system in which aluminium companies enter into "cargo guarantees" with Japanese shipping lines, directly or through Japanese trading houses.

Regarding the bulk-shipping market and freight rates in bauxite and alumina trade, open-market freight rates are rarely stable. In comparing data on freight rates for three routes, a trend is evident that broadly mirrors the depressed market conditions which set in in early 1971 and persisted through mid-1972. After that freight rates moved steadily upwards until mid-1974. Since then they have fallen to extremely low levels owing to world recession. Single-voyage freight rates for bauxite were at their lowest in early 1972 and in 1975.

Between Australia and north-western Europe, rates were rising from a low of $3.65 to a high of $18.50 - a fivefold increase - for shipments between 45,000 and 65,000 t of bauxite. Spot freight rates for bauxite do not fully reflect differences in the length of the haul. The bulk carriers which have up to a 50,000 t capacity and are used, for example, between Guinea and the United States, allow for cheaper transport than is possible with vessels carrying a maximum of 20,000 t from traditional origins such as Suriname. More and more reliance has been placed on long-term arrangements rather than on spot chartering.

It is more satisfactory to base a comparison of shipping costs on an analysis of vessel costs than on actual freight rates. Differences in costs resulting from route lengths and ship-size preferences can then be explained in terms of the real, underlying costs of providing the shipping service.

Ocean freight and other shipping make up a large part of total raw material cost, increasing with longer hauls and decreasing with larger vessels. Australian shippers now employ 60,000 tonners almost exclusively on the long hauls to north-western Europe. Under 1976 conditions, the theoretical unit cost of transporting bauxite to north-western Europe would have been within the following ranges in cost per ton: from Suriname, $4.5-$6; from Guyana, $5.5-$7; from Jamaica, $4-$4.5; from Guinea, $3-$3.5; and from Australia, $10-$10.5.

The need for covered storage, the practice of blending bauxite and the low material throughputs of individual plants affect the size and frequency of shipments. The bauxite carrier is the most highly specialized type of vessel in the trade. Its sophisticated conveyor-fed, self-unloading devices reduce flexibility, and in practice any bulk vessel with or without cargo-handling equipment on board is suitable for transport of aluminium raw materials. All shipments above 20,000 t can conveniently be handled by bulk-carrier vessels, including ore carriers, open-bulk oil carriers and even ore-oil vessels. For anything smaller, a tweendeck cargo ship may be employed. Bulk vessels haul over 70 per cent of the total trade in aluminium raw materials. Smaller, mainly break-bulk vessels are still used extensively in certain trades, such as those crossing the Caribbean or the Mediterranean.

Alcoa's fleet includes two bulk oil carriers of 15,000 dead-weight tonnage (DWT) designed to carry bauxite on the outward voyage from Suriname and to return with fuel oil or caustic soda. These ships are in fact constructed like barges.

The main trend over the past 10 years has been the transition from small to medium-sized ships. Vessels of 100,000 DWT have also been introduced but they remain exceptional. In the next years, vessels of 40,000 DWT and upwards will probably become more frequent, and the maximum of vessels carrying bauxite will probably increase still more. Alumina will be shipped in larger lots although it is not envisaged that individual smelters will ever be able to receive and store much more than 50,000 t at a time.

All shipments of bauxite to North America and Japan pass through privately owned berths, mostly alongside alumina plants.

The efficiency of ports depends on the depth of the water, the average rate at which vessels can be loaded or discharged and the availability of adequate storage facilities. Most important is the materials-handling equipment; loading rates of up to 3,000 t/hr may be achieved by travelling (or slewing) shiploaders, but unloading normally takes much longer. Grabs or clam-shell units are the most common equipment at ports receiving bauxite and alumina shipments. Discharging by this method is not inherently slow (1,500 t/hr), but the problem of eliminating dusting is almost insurmountable. Environmental considerations have led from the application of dust curtains to sophisticated dust-free systems. For example, the recently completed installation at Bunbury, Western Australia, is completely sealed and serviced by a vacuum-cleaning system. With an operational rate of 2,000 t/hr, it is also one of the highest capacity freight-loading terminals for alumina ever built. Pneumatic unloaders (or loaders) have capacities of only 100-500 t/hr.

For land transport there are essentially six alternatives: road, railway, trunk conveyor, aerial ropeway, canal/barge and pipeline. The cost of transporting 5 million wet tons of bauxite (12 per cent moisture) 40 km by land in a straight line from mine to port would be as follows (in $/t): by railway, 2.22; by trunk conveyor, 1.66; by canal/barge, 3.12; by pipeline, -0.2 mm material size, 1.16; by pipeline, -2 mm material size, 2.44.

The dominant influence on the volume and pattern of trade in bauxite and alumina from now until 1986 will be the growth rate, which is predicted to decline to 4-4.5 per cent per annum in the 1980s. Other influences will be: the trend towards decentralizing the world aluminium industry by locating new smelters away from traditional areas; the increase in East-West trade; the dominance of Australia, despite increasing competition; and a continued rise in the underlying costs of transporting raw materials. Port and terminal improvements will make possible the use of larger vessels, with a greater share of the bauxite trade being handled by vessels in the 40,000-100,000 DWT range and of the alumina trade by vessels in the 20,000-50,000 DWT range.

For the next three years, producers of bauxite and alumina who must ship their materials great distances will continue to be favoured. In the longer term, increasing competition will provide the incentive for making all of the transport systems used by the industry more efficient.

Discussion

More information was requested on Afrobulk. It was explained that, in accordance with an agreement signed in 1963, Afrobulk chartered ships, on behalf of the Government of Guinea, to carry up to 50 per cent of the country's bauxite. It negotiated with each of the main partners.

In general, the cost of aluminium transport per kilometre and ton had to be worked out for a given route, since no standard cost existed. The Indian participant pointed out that the price was usually fixed before shipping took place. Appropriate vessels had to be secured, and optimum cargo or consignment size should be agreed on in the contract. An exchange of goods should be arranged so as to avoid empty ships. It was considered, however, that sending a cargo a distance of 14,000-19,000 km and allowing the vessel to return empty was practised only in exceptional circumstances.

Backhauling was mentioned as a means of influencing the bauxite and alumina.

The trunk-conveyor system was described. It had a large capacity similar to that of the belt-conveyor system. It was usually used for transporting coal over long distances to a power station. Most popular was the link-belt system in which the conveyor was supported by steel ropes holding its edges and mounted on stands. It would have to be covered to be used for the transportation of bauxite. It was felt that, even at longer distances (up to 200 km), the trunk conveyor would probably be the best solution. If other materials could be transported or if a project was to serve other purposes, the construction of a railway or heavy-duty road would be necessary; otherwise the system might not prove advantageous. In any case, in choosing a transport system, regional planning and requirements would have to be taken into account.

The national interest was another important factor. The example of Argentina was mentioned, where the Government had built a multipurpose port instead of the simpler port that would have satisfied the requirements of the aluminium company. In such cases the Government would usually cover the extra costs or, if it covered all costs, would charge the aluminium company certain fees.

The difference in freight rates between bauxite and alumina was questioned. The discrepancy, it was explained, resulted mainly from different handling costs, since the cost of loading and discharging bauxite was usually lower than that of alumina. Handling costs influenced the freight rate which, however, was also bound to distance and size of vessel.

Regarding transportation of alumina by pipeline, this was a possibility in theory but had never been done in practice. It could be expected that alumina thus transported would have a high iron content if iron pipe were used, and that disintegration of particles would occur, whereby the sandy character of the alumina would suffer. If a trunk conveyor were used, it would have to be covered. No other precautions were necessary.

As for water depths in ports, that was related to the draft of vessels. A 25,000 t vessel needed a depth of 9 m, a 100,000 t vessel needed 15 m.

Shipments of aluminium had to be carefully packaged because freight tariffs varied with the kind of metal. The tariff on primary aluminium ingots was different from that on sheets, for example. In the case of an annual freight agreement, the shipping line would consider only total tonnage and the major destinations. It was supposed, however, that each company knew more or less what products would be shipped.

An important factor was the cubic metres of cargo space used per ton of material. Cargoes were usually weighed by DWT survey which was considered the best method.

Annex

LIST OF DOCUMENTS PREPARED FOR THE SEMINAR

ID/WG.273/1	Provisional agenda
ID/WG.273/2/Rev.1	List of participants
ID/WG.273/3	World market of aluminium metal and semi-finished products: Quality aspects, conditions and problems with an impact on demand (internal and for export) A. Mersich
ID/WG.273/4	Aluminium semis and finished products - Recent trends in end-use patterns - The pattern of developing markets - Aspects of substitution by aluminium R.W. Boos
ID/WG.273/5	Short-, medium- and long-range trends in aluminium supply/demand S.R. Spector
ID/WG.273/6	History and analysis of marketing activities in the field of bauxite and alumina (case study of Hungarian experience) P. Relle
ID/WG.273/7	Long-term associations of developing countries with consumers of bauxite, alumina and aluminium S. Moment
ID/WG.273/8	Bauxite - alumina - aluminium: Main factors for decision-making on industrial development E. Balázs and I. Molnár
ID/WG.273/9	Bauxite and alumina production; historical retrospection; review of the present situation and prognosis J. Zámbó
ID/WG.273/10	Transport of bauxite and alumina - Volume, costs, technical background, future trends J.F. Brandon, G. Haclin and P. Rowbotham

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