OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

16242

TECHNOLOGICAL ALTERNATIVES IN THE NON-FERROUS METALS INDUSTRIES

György BOBOS
UNIDO consultant
March 1987

647

CONTENTS

A. INTROCUTION

One of the main recommendations of the First Expert Group Meeting on the Non-ferrous Metals Industries, held in Vienna, 18-21 March 1985 (1), was to conduct studies relating to the selection of technologies in the aluminium, copper, nickel, zinc, lead and tin industries that would be more suitable for developing countries, with the aim of promoting a more integrated and self-reliant development in these countries.

Among the recommendations of the meeting of Latin American experts in non-ferrous metals industries held in Caracas, 23-26 February 1987 (2), one can also read a suggestion concerning the design of small and medium-size plants, these matching better to the requirements of the markets, the availability of natural resources and the financial resources of the countries in the region.

The above mentioned studies should be based mainly on the investigations that have been carried out up to now, giving special attention to the research that has been done on reducing the size of the plants.

On this basis the drafter was requested by the UNIDO secretariat to prepare a study "Technological Alternatives in the Non-Ferrous Metals Industries" with the following terms of reference:

To formulate a discussion paper for the first Global Preparatory Meeting on the Non-ferrous Metals, that will present the main technological characteristics and alternatives in developing countries; the main technical measures to increase their technological productivity; and policies to increase the use of national resources and reduce the impact of economies of scale in developing countries.

The structure of the present study corresponds to the terms of reference indicated by the UNIDO secretariat. As suggested a careful analysis of the previous studies was undertaken with particular attention to those prepared through the activities of the System of Consultations Division (3) and of the Metallurgical Industries Section (4).

According to the terms of reference the main objective of the exercise is to determine the possibilities of developing new technological alternatives that are more adequate for developing countries, indicating the main advantages and disadvantages of the possible technological operation. For the purpose a review of the main technological routes being used in the non-ferrous metals industry was undertaken and a tentative assessment was made about the possibility of their application in developing countries. Similarily, on the basis of published information of research programmes being carried out in the field of non-ferrous metals industry technologies, in some cases indications will be given about the possibility of application of their expected results in developing countries.

Obviously the presented views should be considered with justified caution, which is the immediate consequence of the nature of the task to be performed, but also due to the fact that the presented analysis of the technological possibilities and options is a desk study, based mainly on the contribtion of UNIDO consultatns on a modest bibliographic research and on the experience in aluminium industry of the drafter (5). Therefore it might be expected that during the process of preparation of the consultation meeting, through the contribution of colllegues, experts in different branches of the non-ferrous metals industries to be reviewed at the consultation (Al, Cu, Pb, Zn, Ni, Sn) the number of technological alternatives more adequate for developing countries might be considerably increased and the conclusions of the present study consequently amended.

B. FRAMEWORK OF THE STUDY

1. The non-ferrous metals industries

Most of the integrated non-ferrous metals companies, in addition to the mining-, ore dressing- and extractive metallurgy operations are also transforming the metal into semis and castings. Some of them, mainly the aluminium companies are also converting the metal into different finished products (beverage cans, radiators for home heating, cables, window frames, etc.) To in crease share in the downstream fabrication business seems to be a generally adopted policy of the majority of the primary producers. When considering the technological alternatives in the non-ferrous metals industries, more adequate for developing countries, the problems related to the conversion of the metal have to be very carefully considered because, in most cases, the metal is reaching the end user through this process. Therefore, indications wil be given whenever possible concerning the viable size of conversion processes and the quality and quantity of semis requested for these technologies. Nevertheless, in order to maintain the present study within coherent substantive limits, under non-ferrous metals industries mining, ore dressing, metal and semis production will be understood.

2. Selection of technologies

Most of the processes and devicer being used for the extraction of aluminium from bauxite correspond to a medium level of technological sophistication. There are relatively few exceptions, e.g. the automatic regulation of some technological processes, the production of composite-materials, the development and fabrication of high-duty alloys (6). The situation is similar in the case of heavy non-ferrous metals under consideration (7), the fundamental technology is available from a variety of sources, and almost no cases are known in which a developing country was unable to purchase the required technology provided the country had adquate financing. Exceptions might occur with regard to relatively recent technological innovations, possibly under testing or concerning new very specific products. Generally speaking one could say that the market of the standard non-ferrous metals industries technologies is rather a buyer's market.

The knowledge required for efficient mineral processing, however, is not only a matter of obtaining the equipment needed to carry out particular operations. Such equipment, and instructions for its use, can be obtained, but many developing countries lack the "know-how" which comes from actual experience. This know-how is often internalized within TNCs, and hence is difficult to obtain unless a TNC is a partner in the processing venture. Lack of management experience, lack of knowledge of industrial operations, and lack of group know-how built up over time in an ongoing organization are likely to be more of a constraint on the ability of developing countries to process their raw materials than is the lack of merely theoretical knowledge (7). This is one of the reasons of the forming of joint ventures between state-owned companies in developing countries and TNCs, and the establishment of management; service and coproduction contracts between copper companies operating in developing countries and TNCs during the last decades (8).

The majority of the main pieces of equipment, used in these industries, can be produced in any country having a relatively developed mechanical industry; R and D activities concerning this equipment are being carried out in most of the developed countries. Regarding the practical industrial realization of R and D results, concerning new technological processes and new types of equipment, the big companies have the best possibilities. They only have the necessary means to create and introduce major innovations on an industrial scale; operate parallelly, if appropriate, in several fields of important R and D activities. This is particularly true concerning the alumina and aluminium production, if one has in mind the size of the up-to-date industrial units. Therefore, without any doubt, the big six TNCs, ALCAN, ALCOA, KAISER, REYNOLDS, ALUSUISSE and PECHINEY have, for the time being, the technological leadership in the aluminium industry. It should be, nevertheless, noted that there are several other companies operating in various countries, e.g. France, FRG, Italy, Japan, USA, USSR, not directly connected with the TNCs, having a technological knowledge close to that of these TNCs, either concerning the majority of the operations in the non-ferrous metals industries or regarding a part of them. These companies can be considered as possible sources of non-ferrous metals industry technology. It should also be noted that technology for these industries can be purchased via the major industrial consultants.

It is worth mentioning, that at the Regional Expert Group Meeting in Latin America on strategies and policies for further processing of non-ferrous metals (Caracas, February 1987) (2), countries in the region having experience in the mining metallurgical sector were invited to provide engineering and consultancy services to countries having the intention to get engaged in the activities of the non-ferrous metals industries. This possiblity and the technological development in several fields of the non-ferrous metallurgy in the socialist countries (8) have given the opportunity to producers in developing countries to start up, in selected cases, production without TNC controlled technology.

Actually there is no universally adopted methodology which would allow for choosing among technological alternatives, which is the most suitable in any given set of circumstances.

It might not be the objective of the present study to try to define relevant criteria, nevertheless it seems to be of purpose to explain some considerations on the constantly recurring question of "appropriate technology". (9)

According to Mr. Biritz, a technology is adequate when it satisfies four conditions, which are:

- purely technological constraints and parameters,
- limitations posed by the ability and know-how of the personnel to practice the technology,
- conformity to the economic requirements under which it has to operate,
- conformity to the prevailing socio-political environment.

Mr. Biritz defines also subparameters to the above indiciated parameters establishing correlation among process technology; product, its application; raw materials; economic benefits; manpower; socio-political constraints.

An attempt will be made in order to be more specific on these basic issues when dealing with the technological processes being used in the non-ferrous metals industries.

3. Economies of scale

It is obvious, that the availability of production input (e.g. energy, skilled labour, capital) in developing countries is very different from the relevant conditions in developed countries. Therefore the technological options considered as being the best for developed countries might not be the most advantageous for a developing country. This might be particularly the case when analysing the problem of economies of scale.

For process industries, when selecting technologies, the only variation to be considered is the size of the plant. It does appear (7), however, that there are certain basic efficiencies in the standard mineral processing technologies, and that the choice of a plant size below these minima will likely lead to higher unit costs. In the case of many Third World countries, this factor is reinforced by requirements for large amount of infrastructure development ot support any processing industry at all, and by the real economies of scale in certain infrastructure facilities (e.g. hydroelectric power plants).

The apparent advantages in constructing an optimium-size plant are often, however, not realized in developing countries. Among the specific difficulties which often arise in such projects are the following:

(a) large plants often experience longer construction times, higher costs and greater difficulties in arranging utilities, ancillary facilities and infrastructure than small plants;

(b) large plants tend to experience more technical operating problems than small plants, maintenance may be more problematic, and technological rigidities are more likely to occur; and

(c) operating rates tend to be lower in large plants than in smaller units, thus increasing average fixed costs.

Regarding the minimum economic plant size the following figures were e.g. published (10):

TABLE 1: MINIMUM ECONOMIC PLANT SIZE

(Thousands of tons per annum)

Type of plant	Minimum economic size
Alumina refinery	400
Aluminium smelter	60-80
Copper smelter	100
Copper refinery (primary)	60
Steel mill (integrated)	1,000
Steel mill (DR/EF)	100
Tin smelter	15
Lead smelter and refinery	30
Zinc smelter	30
Nickel smelter (sulphide)	25
Nickel refinery	25
Ferro-nickel plant (oxide)	10-15

Sources: World Bank, United Nations Centre for Natural Resources, Energy and Transport.

Note: Considerable economies of scale (up to 20% per unit of product) can still be achieved at larger capacities (e.g., up to 5 million t/a for integrated steel mills, up to 1 million t/a for alumina refinery).

The rapid technological change occuring in some mineral processing industries also has implications for developing countries' ability to establish processing facilities. On the one hand, certain developments, such as the use of direct-reduction/electric arc furnace technology for steelmaking or the production of aluminium sheets and strips by continuous casting permit the construction of plants on a much smaller scale than was previously thought economical, opening the way for processing for the domestic market in many countries.

On the other hand, new developments such as continuous casting in copper have the effect of making it more difficult for producers located at considerable distances from major markets to compete effectively (7).

Attention is also drawn to the fact that in the cost of the metal reaching the consumer there are three important inputs the price of which are mainly determined by the location of the industrial objects. These are the quality of the ore, the price of the energy used in the process and finally the transportation costs involved in the transformation of the ore into metal and its delivery to the customer.

The individual or consolidated influence of these items on the profile of the operations might be stronger then that of the size of the plant, obviously within reasonable limits. In some cases favourable conditions regarding the above mentioned important inputs might compensate slight differences in the technological level of the plants. This might be one of the reasons of the relatively good results achieved by some smaller companies on the aluminium market or explain the impressive performance of some medium-size copper companies in Latin America.

In Table 2 under copper metallic copper of different quality and the metal content of sold concentrates are understood (11). From the 234,000 t of metal produced in 1983 ENAMI's share was about 120,000 t. ENAMI is a state owned company, its responsibility is to smelt and refine the copper containing materials obtained by the medium and small enterprises and by individual miners.

TABLE 2: COPPER PRODUCTION IN CHILE
(1000 tons)

		1979	1980	1981	1982	1983
1	Total production	1,062.7	1,967.9	1,081.1	1,242.2	1,257.1
2	Production of small and medium companies	152.5	163.4	187.5	203,8	234
3	2/1 %	14.4	15.3	17.3	16.4	18.6
4	Total number of employees	46,739	46,638	46,464	39,463	n.a.
5	Employees in the medium and small companies	15,940	16,491	17,158	12,706	n.a.
6	5/4 %	34.1	35.4	36.9	32.2	-

Three medium size companies produced in Chile more than 100,000 t of copper in 1983.

According to the available information (12) the situation of the medium size companies is quite satisfactory, they are fully integrated, producing and exporting their metal. These companies are using up-to-date and efficient technology and are participating in the realization of the programme of development of the copper production in the country.

The operations of the small-mining, should they sell concentrates or ore, are strongly influenced by the overall situation of the copper market, namely the price of the metal. On the basis of the information drawn in Table 1 and Table 2, the following observations can be made:

- The productivity in the small- and medium- size enterprises group is much inferior than that in the big plants, namely in these belonging to CODELCO-Chile. Very probably, the main reason of this situation is the technology being used in a great number of small mining operations.

- The production in 1985 of each of the well succeeding medium-size companies is much less than the minimum economic plant size included in Table 1.

Without having the intention to ddraw any general conclusion from the quoted date, one can say that even in mining and extrative metallurgy sectors of the non-ferrous metals industries, in very selected cases, medium-size enterprises might be competitive with capacities not reaching the generally accepted minimum economic plant size. Obviously one should be extremely cautous when assessing the viability of this type of enterprises, in the majority of cases economies of scale will be decisive.

4. Possibilities for increasing the use of natural resources in developing countries

Ways and means to increase in developing countries the use of natural resources should only exceptionally be sought through the establishment of mining or extractive metallurgy objects with capacities not reaching the generally accepted minimum economic plant size. This might be successful only in very favourable cases. Downward and horizontal integration of the non-ferrous metals industries, - as it will be indicated in Part C of the report - organization of the production of finished metal goods might, in frequent cases, lead to a more profitable use of natural resources, promote a balanced development of the economy of the country and request investment decisions compatible with the possibilities of the country.

Already at the Vienna Expert Group Meeting on the Restructering of the Non-Ferrous Metals Industries in March 1985 (1) the importance of the interaction of these industries with other related industrial sectors, capital goods, iron and steel, construction, etc. was pointed out. The need for analysing the possibilities for a greater degree of processing of the non-ferrous metals in the developing countries was also emphasized. The meaning of these statments became clearer in the light of the deliberations of the regional expert group meeting in Caracas, February 1987. (2) The conclusions and reecommendations of this meeting among others state:

- Strengthening the relationship between mining and industrial processing should be considered by the region of high priority;

- When developing technologies suitable to the size of the market in the region, special attention should be payed to the technological development of the production of semis and finished products;

- Market conditions of the non-ferrous metals in developed countries should be reviewed in order to increase the demand and identify possible new applications for these metals.

These statements define the framework in which the non-ferrous metals industries should practically operate. It is different from the classical mining-extractive metallurgy approach and might be the basis, for several countries of a more efficient broader technological policy. It is basically an end-consumer orientation which can very probably lead to the identification and possibly best utilization of all possibilities of national and internation development for the non-ferrous metalls industries.

TABEL 3: R+D ACTIVITIES OF INSTITUTIONS IN LATIN AMERICA IN THE FIELD OF NON-FERROUS METALLURGY

Country	Name of the institution	Resources in million US$, 1985	Activities	Professional staff
Argentina	INTI	0.5	Extraction of Ni and Co	14
Brazil	CEPED	13.0	Co extraction; obtention of precious metals; Ni sulphate plant	160
Brazil	CTP	0.5	Environmental control in the Cu and Ni industries	10
Brazil	IPT de	0.04	Extraction of Cu from complex oxidized ores	2,600
Chile	CIMM	2.0	Cu ore dressing and metallurgy; cold processing methods for "small mines" separation of molubdenum and arsenic. Recovery of rutile from copper tails.	300
Chile	INTEC	1.0	Heap leaching Cu-oxides, of Au and Ag. Tailing recovery Cu, Au, Co, W, etc.	72
Chile	INA/CAP	8.5	Training on process control and autorisation in the copper industry	121
Chile	Universidad de Tarapaca	0.05	Non destructive testing, standardization and quality control of metal products	52
Colombia	CIDI	0.12	Recovery of Zn in a siderurgical plant	15
Columbia	Servicio Nacional de Aprendizaje	120.0	Short course on aluminium alloys; short courses on copper alloys	8,204
Costa Rica	Instituto Technologico	0.04	Extraction of aluminium minerals. Recycling and refining of aluminium alloys	8
Ecuador	Politecnica de Littoral	0.06	Aluminium alloying scrap-recycling and refining.Pure Ni deforming Zn and Cu alloys	7
Peru	INGENMET	1.708	Exploration and evaluation of deposits (Cu, Pb, Zn, Ag); (Sn, W, Au). Problems of underground mining, beneficiation of ores	

There is still much to do in order to pay the necessary attention in some countries to technological development of the production of semis and finished products. Table 3 reflects some information about the R+D activities of selected Latin America institutions in the field of non-ferrous metallurgy (13).

First of all, it seems that Table 3 contains only a small fraction of the R+D activities in non-ferrous metalls industry in the Latin American countries. Very probably R+D is being carried out in the facilities of the important state-owned or private companies operating in the region. Nevertheless, the information in Table 3 merits attention, the R+D activities are dealing with:

- prospection and mining of non-ferrous ores;
- beneficiation of non-ferrous ores;
- production of non-ferrous metals;
- production of alloys;
- extraction of precous metals and other useful components of the ore;
- automation, process and quality control;
- recylcing.

The projects reflected in Table 3 are well chosen and they could surely be included in a good technology programme for the region. Nevertheless more of them is dealing explicitly with downstream processing. Therefore, the expansion of the activities in this direction seems to be the most desireable.

In the context, it is worth mentioning that recently the major traditional copper and aluminium TNCs have strengthened forward integration. Phelps Dodge, Asarco, Inco and Noranda established or expanded fabricating subsidiaries.(8) In the USA, R+D activities concerning new innovative aluminia processes were slowed or stopped. Though projects regarding increasing efficiency in the Bayer and Hall-Heroult process are being continued, R+D programmes of the largest US producers were revised and emphasis was shifted from these processes to other namely downstream activities. (14) It seems to be highly advisable that R+D institutions operating in developing countries respond also promptly to the changes which happen on the markets of non-ferrous metals. Under the conditions presently prevailing world-wide in the non-ferrous metals industries in the following an attempt was made in order to describe the different main options of technological development which selected in different sectors of these industries according to the character of the activity under consideration:

a) Mining and extractive metallurgy

- identification of the processes;
- replacement of the obsolete equipment;
- recovery of additional useful components of the processed ore;
- establish production capacities not reaching the generally accepted minimum economic plant size only as the basis of reliable economic and market analysis and under exceptionally favourable national conditions;
- utilizing all possibilities for processing products (e.g. special aluminium, corundum, fused alumina, copper sulphate, etc.)

b) Production of semis and finished products

- selection production profile and size using all technological possibilities;
- under favourable market conditions establishment of production facilities without own natural resources, with subsequent - if appropriate - later upstream integration;
- promotion of the demand for non-ferrous metals, particularly via creation of advisory services for customers.

In Part C of the report, whenever possible, information will be given concerning the technological characteristics and alternatives regarding the production of the metals being on the agenda of the first consultation meeting with due consideration of practical applications; operations related to the elaboration of semis and finished products will be described only for aluminium and copper.

C. CHARACTERISTICS OF THE MAIN TECHNOLOGICAL PROCESS USED IN THE NON-FERROUS METALS INDUSTRIES

1. Aluminium

The extraction of bauxite, its refining into alumina as well as the production of the metal by electrolysis are well established technologies. Although a steady improvement of these processes is taking place, fundamental changes are not expected by the end of this century. Bauxite resources known at present will not be a limiting factor to further growth of the aluminium industry. The application of up-to-date methods of remote sensing might facilitate the identification of new ore deposits particularly in developing countries. Nevertheless the processing of low grade bauxites and non-bauxitic materials into aluminium might have local importance, because some countries may want to process their existing own raw material.

An energy-centric aspect is dominating both in aluminium production and consumption, determining the development trend. This and the better exploitation of capital goods - due to their increasing cost - is the promoter of the development of the Bayer and Hall-Herault processes. Apart from the climatic factor there is no technical limitation to use these processes anywhere in their present or developed form, provided the erected facilities can be run and maintained in a given country, because when designing the plant a reasonable choice of automation and mechanization was made and the personnel was exposed to an appropriate training.

Due to environmental protection coming more and more into the fore new aluminium smelters are of the pre-backed an ode type using sandy alumina. This is the reason that new plants are based on the production of this type of alumina and some older ones - if not producing sandy - are transformed to produce this variety of alumina. Developing countries have mostly trihydrate type bauxite, the production of sandy alumina causes no problem with such raw material.

The development in semi-products' fabrication looks to be more dynamic. Although the basic production methods are well known since decades, but the efficiency of these processes as well as the production of products with increased quality parameters lay steadily in the fore of recent development. Aluminium's success in the competition with other materials depends upon the steady improvement of the properties of its semi-products in order to meet better numerous end-use requirements. This objective and more economic production are the main development tendencies in this field. Therefore, when establishing fabrication facilities the proper design of the product mix is of paramount importance.

Size of units play an important role in the economy of production. The size of an aluminium plant grew from the previous 120,000-150,000 tpy to a line capacity of 300,000-500,000 tpy. Plant capacities reach or surpass hence often 1 million tpy. On the other end smelters are nowadays built with capacities of about 100,000 to 300,000 tpy, the actual capacity depending on the line capacity.

Sizing of semi-production lines is a complex question. There are certain semi-products the transport of which is only economic within a very limited area. Fortunately such semi-products can be produced in relatively small-size plants. This is typical for extruded products, where 1-3000 tpy production facilities might be economic. Rolled products on the other end are transportable even to long distances, but the size of their econcmic production is much larger. Cast-rolling units could be of smaller size, even 10,000 tpy units might be viable. Such production lines have to operate, however, in conjunction with a smelter and the spectrum of the semis production with this type of equipment is narrower than with usual rolling mills and the fabrication of some high-alloyed aluminium products is not possible. The size of economic rolling mills - which are independent from a smelter - is much larger, at least 40,000 tpy and the larger the cap activity, the better its economy. Cold rolling mills could be of a smaller size than the hot ones. It is ideal, however, to have both at the same place, otherwise an intermediate product has to be shipped to the cold mill, but it is also a common practice to set up cold mills [illegible]cessing coils.

Majority of the rolling mills are located in the center of consumption, suppplying with their products relatively large areas. Due to transportation reasons extrusion facilities are located nearer to the customers.

The location of finished product manufacturing facilities depends on the type of product and the technology used. Special marketing and promotion can be carried out for finished products having a predominant aluminium content. Wire and cable manufacturing, facilities producing kitchenware and other utensils, containers and certain aluminium products for the building industry could be typical ones. The setting up of such facilities depends - in the majority of cases - only from the market, domestic prices of the product and the chosen technology, while the local production of other types of fin ished products depends to a larger extent from the general development level of the area under consideration.

Prices per unit of volume are subject to great variations, even where the bulk of a concrete item consists of aluminium structures. Same applies also to small-size objects (e.g. artifacts) the production of which - in spite of the small series involved - may be throughout economical. It should be pointed out that with plainer items, in whose manufacture relatively few and simple operations are involved (e.g. holloware), as a rule only large-scale production may be a paying proposition. In contradiction, however, where wages are low and investment resources are poor, the manufacture of deep-drawn kitchenware may even in smaller series be economical.

Approximate optimum capacities for the large-scale manufacture of some selected finished items are dealt with in Table 4.

Capital expenditure is related to that of erecting a smelter. From a comparison of the corresponding figures it will be observed that specific investment costs for one tone of finished product may greatly vary with the type of product under review, and my be as much as 5 to 6 times that of the ingot (e.g. in case of kitchenware) or just a fraction thereof (e.g. in case of furniture frames, ladders or scaffoldings). One point, however, is especially significant: reasonable size capacities for this type of products can be found in the 500-5000 tpy range.

TABLE 4: ECONOMICALLY FEASIBLE MINIMUM SIZE OF FACILITIES AND THEIR INSTALLATION COSTS (smelting = 100)

Plant	Processed metal per cent	Investment costs per cent
Aluminium smelter	100	100
Finished product manufacture		
Kitchenware	0.1	0.6
Cans	2.25	7.2
Liquid gas bottles	2.0	3.6
Casks	0.4	1
Radiators	0.75	1.1
Lamp posts	1.22	1.8
Stranded wire, uninsulated conductor	4.4	0.9
Cables, insulated conductors	10	6
Containers and tanks	1.2	2
Collapsible tubes and aerosol bottles	5	6.5
Sandwich panels for the building industry	0.7	0.6
Portals, small buildings	1.0	0.4
Furniture frame, ladder, scaffolding	0.8	0.2

2. Copper

Most copper today is processed by mining, waste leaching and cementation, concentrating, smelting, and refining. Open-pit mining is more common than underground mining and overburden, or waste, contains some copper. Frequently the waste is leached to extract the copper, which may be recovered by passing the leach solution through a bed of scrap iron, precipitating metallic copper, and dissolving the iron; the last operation is called cementation.

The copper ore from the mine, often containing less than 1% copper, is transported to the concentrator where it is first crushed and then ground with water. The ground ore slurry enters flotation cells, where copper concentrates are collected as a froth. Following dewatering, they enter the smelter. In the smelter the sulfide minerals react with oxygen and fluxes to produce impure copper metal, SO_2, and slg. Smelting occurs in two steps.

In the reverberatory furnace, the copper concentrate is melted to produce matte, the mixed sulfides of copper and iron. Next, air is blown through the matte in the converters, producing impure copper plus a slag containing the iron. The impure copper is then cast into anodes and purified by plating onto pure copper in an electrolytic tankhouse.

Other hydrometallurgical processes include the direct leaching of ore followed by recovery of copper by cementation or electrowinning. Recently, however, hydrometallurgical treatment of concentrates in lieu of smelting is being developed in order to avoid the high cost of environmental control facilities required for new smelters. (28)

In order to decrease production, particularly energy costs the conventional copper sulphide flowsheet consisting of curshing, grinding, flotation, dewatering, smelting and refining underwent very significant changes since the mid seventies with the following main trend.

The escalation of size (26) in mining and milling equipment to bring about reductions in operating and maintenance costs (the so called economies of scale); intensification of chemical, pyrometallurgical processes by injection of oxygen, by which reactions were sped up and capacity of furnaces increased; replacement of expensive pyrometallurgical processes with high energy consumption by less expensive hydrometallurgical processes which promote chemical reactions at lower temperatures and with amore thorough treatment of materials.

In mining, technological improvements range from improved and more efficient explosives to more accurate and greater mobility drills. In mine ore handling systems, improvements have ranged from in-pit movable crushers to development of fleets of giant trucks and change to large tonnage transportation (away from trains and trucks) and huge conveyors.

Comminution operations account for over 50% of overall milling (crushing-grinding-classification-concentration-dewatering) costs. Classification operations generally include intermediate comminution operations after removal of material already reduced to a specified size.

In this respect, in the last two decades a fundamental change in classification technology has been taking place almost universally by replacing rake and bowl classifier technology with hydrocylones. The tremendous advantages of hydrocylones are their effective classification and separation of fines, low consumption of spare parts, very small size of equipment, permitting to double grinding capacity under the same roof, and their easy adaptation to automatic controls of the grinding circuit.

Autogenous grinding is the grinding of ore by itself rather than by special metallic or nonmetallic grinding bodies distinct from the ore. However, autogenous grinding is not always successful for crushing and grinding big chunks of rocks by itself, due to a deficiency in the rock media, or when frequent changes in quality of media occur. In this case in order to assure smooth operation, large steel grinding balls are added in quantities between 2% and 10% of the total volume. Currently, most of such semi-autogenous mills carry less than 5% by volume of such steel balls, while the traditional ball mills use a 45% by volume ball charge. In most porphyry copper operations today, which treat such large tonnages as between 20,000 and 150,000 tons per day, semi-autogenous mills in fact replace secondary and tertiary crushing and the rod mill grinding stage.

In the area of concentration, technologically new system for replacement of traditional flotation cells was developed in these last years in Canada. This is the so called column flotation. The idea offers a number of advantages in the separation of different minerals, particularly in the copper industry and in the area of byproduct molybdenum recovery.

The principal characteristic of this column is that it has no recovering parts and solids are kept in suspension by rising bubbles alone.

Hydrometallurgy, in particular the leaching technology proved to be a safe, efficient and cost effective method for a number of metals, which include copper, gold and uranium. These chemical processes can be carried out in a number of ways, starting with in situ leaching, when fragemented and fractured materials is not excavated, or by the heap leaching method when the broken rock is dumped on specially prepared pads and sprinkled with leach liquors which are conveniently recirculated. Leaching can be carried out also at atmospheric pressure or in closed vessels at elevated temperature and pressure. It can be purely chemical, using acid, caustic soda or cyanide, or biological using partiuclar strains of bacteria. The bacteria do not actually leach the materials but rather render them amenable to subsequent chemical leach by speeding up the oxidation of the sulphide minerals.

Leaching is relatively cheap and simple technology, easy to introduce since it requires little in the way of sophisticated euqipment. Leach liquors obtained either by in situ, heap, vat or agitation leaching are conducted for purification to a solvent extraction unit and then subjected to reduction to the metallic state by electrowinning (to copper cathode).

While sulphide ores can be cheaply leached by ferric solutions helped by bacterial leaching technology, with oxides treated by more conventional acid leaching, the new solvent extraction technology gives a possibility to effectively clean such solutions for their final electrowinning step to produce high-purity (99.9% Cu) cathode. This SX/EW technology is now highly popular in developed countries, such as the USA and Canada.

More than anywhere else, cost cutting technologies have spread in the pyrometallurgical area, where costs are high because of high energy consumption. One way to do this is to decrease the temperature of conversion of minerals into metal, such as is accomplished in the Segregation Process.

The other method is to intensify the process with oxygen injection, through which reactions are sped up, capacity of furnaces increases and products are obtained at a lower cost.

The most successful new smelting process is doubtlessly the Outokumpu Flash Smelting which combines roasting, melting and partial converting into a single process. When only preheated air (to 450°C) was used to supplement the heat generated by the exothermic oxidation of FeS, mattes assayed then only 45-50% Cu, and fuel oil needed to be added to finish the reaction. With the introcuction of oxygen enriched air, the process became completely autogenous and the copper content of the matte increased to 65-70%. With a higher grade of matte, the required converting capacity and energy consumption fell sharply by as much as 40 to 50 percent. Also, addition of oxygen reduces the volume of gases and increases their SO_2 content from the normal 10-15% to as much as 30%.

The flexibility of the flash smelting process in terms of treating concentrates of varying composition and controlling matte grade is based on the fact that the degree of oxidation in suspension (flash) smelting can be regulated rapidly and easily by changing the ration of concentrate to oxygen in the process air.

Among other up-to-date copper smelting technologies the El Teniente, Inco, Mitsubishi and Noranda processes should be mentioned. Regarding selection of main technological options for the production of copper semis the following might be taken in consideration: (27)

- In every technological route continuous casting processes are recommended to apply, which offer increased yield, low energy consumption and capital investment, decreased environment pollution, flexible production capacity, good productivity, high product quality.

- Wire rod production technology should be matched to the local or regional demand. Where the demand is low and excessive ore resources are not available, flexible or low capacity processes should be selected, like Outokumpu, Ge dip-forming or horizontal casters. The best solution is to have a possibility for casting not only different sizes, but even different alloys on the same equipment.

- Cold rolling mills equipped with hydraulic screwdown and automatic thickness regulation are recommended to apply. Combination of two-high/four-high or four-high/Z-mill may considerably cut investment costs. Hot mills should be selected only for very high demand or special cases.

- For heat treatments of strips, wires and coiled tubes bright annealing bell furnaces offer the best solution at the lowest capital investment.

- Indirect presses offer a number of advantages, but at present horizontal direct presses are more flexible regarding the product mix. Having a suitable extrusion press a lower demand for wire rod can be temporarily covered too compromising on the size of the coils.

- Highly efficient, very productive manufacturing methods are in operation in several countries for the low-cost production of brass rods using almost 100% scrap. Considering this fact careful attention has to be paid to the demand side in this sector too. The best technological alternative in this field seems to be the use of extrusion and some Schumag type continuous drawing, finishing, chamfering machines.

- Technological route for copper tube manufacturing should be selected on the basis of several factors. In a plant having free capacity on a cold rolling mill, welding tubes from strip and drawing them on skinner blocks could be an ideal solution. In case of a plant having free capacity on the existing extrusion press, reduction on drawing benches is the optimal solution offering a very wide product mix. The most efficient way for the production of medium and small size tubes is the continuous casting - pilger rolling - spinner black drawing.

- When establishing copper and copper alloy semifinished product manufacturing, special emphasis has to be made on recylcing production and collected scrap. The better the scrap is separated the higher is its value. High economy can be achieved using every scrap for its proper purpose.

3. Lead and zinc

The complexity of lead-zinc ores has led to numerous flowsheets for rational recovery of different metal components in the different ore combinations. The major types of ores so far have been lead-zinc-copper ores, lead-zinc ores, copper-zinc ores, and lead-copper ores. the overall recovery of metals in such complex ores, when calculated on their recoverable content into a finished concentrate, rarely exceeds 80%. These recoveries are even lower if sulphides are mixed with oxides. In fact, flotation recoveries do not present any difficulties as far as bulk flotation concentrates are concerned. Metal losses start principally in selective flotation.

Therefore, in the treatment of complex lead-zinc sulphide ores two new basic approaches have emerged in these last years: one, which tries to start pyrometallurgical treatment of bulk concentrates right from the beginning, without previous separation of individual concentrates, and the other, which improves technologies for teatment of the individual concentrates.

In the first case, excessive loss of metals in their flotation separation is avoided, and typically 90-95 percent metal recoveries are obtained against the average 80 percent recoveries by other classical methods. The most outstanding in this respect is the Imperial Smelting Process with 13 industrial installations to its credit so far offering an overall recovery of about 95% of the metals. However, in some cases the Imperial Smelting Process is not quite suitable for solving all problems, and new, chemical processes are being developed for the same purpose.

In the area of direct smelting of concentrates, like with copper, there are two types of new processes in development: those which use bath smelting, such as the Boliden Kaldo (TBRC) Process, and the QSL Process. The other group of direct smelting furnaces are the flash smelting technologies as developed by Outokumpu and Kivcet.

At any rate, it should be clear that these emerging technologies should be still convincingly proven in full scale industrial plants.

4. Tin

Under the present conditions of the tin market economically more effective methods are particularly important for this industry. Among them the fuming process and an efficient method of flotation for tin fins merit special attention.

During the 1970's, an increasing proportion of lode tin has been mined, due to the gradual exhaustion of sources of alluvial tin. It has become increasingly difficult to obtain high-grade tin concentrates at a high recovery from lode material. Rather than lose increasing amount of tin by attempting to upgrade the concentrates, there has been a trend towards the fuming processes, which can give a medium grade concentrate of 40-50% Sn at high recovery rates of over 90%. This compares with 50% or less recovery for obtaining concentrates of about 60% Sn by mineral processing methods.

Fuming, in favourable cases, may replace mineral processing alltogether to produce a concentrate directly from the ore. But this certainly requires high-grade ores to start with. Fuming normally requires products of 7% Sn and more.

In an endeavor to recover more of the fine tin produced by ever finer grinding to liberate cassiterite, particularly if this is intimately associated with sulphide minerals, flotation has been widely introduced, not merely to float sulphides away from cassiterite concentrates, but also to float cassiterite from the gangue minerals. Although the production of this flotation concentrate can boost tin recovery significantly, by 20% and more, the pproduct is very low-grade, around only 20% SN, and calls for new methods of treatment.

5. Nickel (28)

The treatments used to recover the nickel from sulfide and lateritic ores differ considerably because of the ores' different physcial characteristics. The sulfide ores, in which the nickel, iron, and copper occur in a physical mixture as distinct minerals, are amenable to initial concentration by mechanical methods, eg, flotation and magnetic separation. The lateritic ores are not susceptible to these physical processes of beneficiation and chemical means must be used to extract the nickel.

Pyrometallurgical Processes. Sulfide ores first undergo crushing and milling operation to reduce the material to the necessary degree of fineness for separation. Froth flotation or magnetic separation processes reparate the sulfides from the gangue. Most sulfide ores then undergo a series of pyrometallurgical processes consisting of roasting, smelting, and converting.

Nickel oxide ores can also be processed by pyrometallurgy, they are smelted with a sulfiding material, e.g., gypsum, to produce an iron-nickel matte, that can be treated similarly to the matte obtained from sulfide ores.

Both types of ores can be leached with ammonia. Lateritic ores can also be leached with sulfuric acid. Because of possibilities of energy saving and rate of metal recovery this process seems to attract some interest.

D. MAIN DIRECTIONS OF R+D ACTIVITIES

In this context, the most promising areas for technological development in developing countries seem to be those related with:

- Energy savings and materials handling in mining operations;

- Energy savings and processing efficiency increments in comminution operations, including semi-autogenous grinding and cyclone classification.

- Substantial improvements in flotation technology through greater volume flotation c lls, introduction of new types of flotation cells, such as column cells, and improved reagent formulae.

- Greater use of hydrometallurgical energy and capital saving technologies as reflected in bacterial leaching, solvent extraction and electrowinning technologies.

- Introduction of processes which perfrom conversion of the metal content of minerals, both of sulphide and non-sulphide character, into the metallic state with the lowest consumption of energy, as for example in the SX/EW and Segregation processes.

- Improvement of the effectiveness of the Bayer alumina production technology through better adjustment of digestion and precipitation where appropriate, intensification of red-mud washing in order to reduce caustic consumption and produce a less environment polluting mud.

- Greater emphasis on byproduct recovery in all phases of base metals production, including flotation separation, hydrometallurgical, pyrometallurgical or electrometallurgical separation. A number of important metals, such as gold, silver, molybdenum, cobalt, bismuth, selenium and rhenium, gallium and vanadium, can serve as valuable byproduct credits to reduce production costs of base metals. Also, non-metallic components such as sulphur and arsenic may be recovered at a profit.

Organization of the processing and better valorization of intermediates. If appropriate manufacturing of the following products, e.g: on aluminia basis; artificial white bauxite; special aluminas; different metal compounds sulphats, oxides etc; aluminium 199.99.

Organization of collection, processing and use of recycled metals. Introduction of modern oxygen technology in base metals smelting in all its possible forms, with a clear aim towards optimization of results both economically and capacitywise.

Realisation of systematic cost reduction ir the existing alumina smelters through improved control of electrolyte composition, temperature and of cell operation.

- Possibilities of production of broader spectrum of semis from alumina and copper alloys through continuous casting.

- Reconstruction of existing rolling mills and equip them with hydraulic screw-down system, electronic drive regulating circuits, automatic thickness and shape control and regulation.

- Confection of studies related with optimization of scale of operations for a determined process or technology, which can come from economy of scale or through miniaturization of plants more in accordance with national necessities and possibilities.

- Systematic study of potential advantages to expansion of existing facilities through improved and intensified technologies versus construction of new plants.

- Initiation of the design and manufacture of equipment for the production of semis, suitable for serving the multiple variety of small orders typical in the majority of cases for developing countries.

It is particularly gratifying to note that several of the above explained ideas are reflected in Table 3, illustrating the activities of Latin American R+D institutions, and are related to the technical co-operation programme of UNIDO:

Greece: Establishment of the techno-economic viability of industrial scale production of artificial refractory bauxite and via oxide using indigenous raw material.

China: Erection in the ZHENG-ZHOU aluminium complex of an industrial experimental tube digestion unit for the processing diasporic ores.

Chile: A multi-disciplinary R+D programme is under implementation to boost the application of the bacterial leaching of copper ores.

India: Decreasing the specific oil consumption by at least 20% of one of the alumina calciners in Korba and increase the production capacity of the kiln by about 60%.

India: Verification of the advantages of adopting periodic reverse current technology in terms of increase in the refining rates at the Indian Copper Complex, Ghatsila.

Indonesia: Provision for the Indonesian Government of the information necessary before taking an investment decision regarding the establishment of aluminium downstream industries.

China: Conversion of the Guang-Zhou steel window frame factory into a model aluminium window and door frame plant leading to the establishment of similar plants in other locations of the country.

It is also worth mentioning that UNIDO constituting in several developing countries to the creation and expansion of capabilities for carrying our R+D activities in metallurgy.

The above excerpts from UNIDO's programme demonstrate the validity of an integrated downstream oriented approach to the development problems of non-ferrous metals industries.

E. CONCLUSIONS

There is little doubt that some existing and emerging new technologies in the area of non-ferrous metals industries can be of great benefit for developing nations. The most significant seem to be those which are relevant to the mining and extractive metallurgy of copper and to the fabrication of aluminium and copper semis. The use of advanced technology in various countries can greatly contribute to vertical integration of metallurgical operations and horizontal integration with other productive sectors. Vertical integration in the area of non-ferrous metals not only reduces transportation costs related with shipping metals instead of concentrates but also generates new employment in smelting and refining and leaves in the country the added value of the metals. It also contributes to greater access and consumption of metals in the country through devlopment of semi-manufacturing and manufacturing industries, which can be both export and internal consumption oriented. Such is the case of converting copper cathodes into wire rod, which is then transformed into insulated and bare wire and cable. Kitchenware, conductors, window-frames, containers packaging materials are produced from aluminium. Zinc and copper are raw materials for brass mills which manufacture strip, rod, bars, mechanical wire and a number of manufactured products, such as plumbing and commerical tube. On the other hand, foundries process lead, zinc, tin and copper into a number of alloys and castings, while powder plants produce supplies of powdered metals.

All these products find practical uses in building, electrical, electronic, transportation and other industries, including industrial machinery and equipment, consumer and general products industries. Indeed, once cheap and ample supplies of metals are domestically available, they spur a number of activities related with their uses and contribute to horizontal integration of the metals sector with other production and manufacturing industries. This is apart from the creation of new activities related with operation of and supplies to metal industries themselves, such as energy supply, trrnsportation, all sorts of materials and food supplies, communications, etc.

Processing, whenever appropriate of the intermediate products of the different operations in the non-ferrous metals industries is obviously integral part of the vertical integration policy.

Iniciatives regarding co-operation among developing countries in the production of various semi-products could have sound bases even in lack of metal production in the area under consideration. Increasing demand in a region in different metal products might well justify such co-operations. The production of a broad variety of semi-products needs namely a market of considerable size which is seldom available in one country as illustrated by the example of several developed countries.

The vertical integration of the non-ferrous metals industries in developing countries is gaining an even greater importance when one considers the possibility of introducing new, integrated technologies for most effective and lowest cost produced technology. In several developed countries conditions for mining and metallurgical activities are deteriorating. Metal markets are not expected to improve substantially in years to come because of both the lesser growth in metal demand and the existing oversupply. Under these conditions of the strategies of developing countries in the non-ferrous metals industries are based on substantially decreased production costs and not on expectations of higher metal prices, they might acquire a bigger share in the supply of the industrial world with different products of non-ferrous metallurgy.

Practical implementation of new technologies in the non-ferrous base metals area in developing countries will require a rather complex and imaginative combination of work at existing research facilities at universities and national research centers, along with work at industrial type research organizations and engineering firms.

Creation and operating advisory services for metal customers should be included from the beginning in the national, possibly regional technology programmes. The purpose of these services is the following:

- to boost the economic use of non-ferrous metals as widely as possible;
- to explore and promote new outlets for these metals;
- to help producers and consumers by providing technical advice and documentation and by organizing training schemes for their staff.

Several high-standard R+D institutions are operating in developing countries in the non-ferrous metals industries. Their contribution will be important to the introduction of new technologies in the industrial practice; particularly the assessment of the viability of new processes and technology might be important. Direct technology transfer from important companies operating in developed countries is also to be envisaged.

Since its establishment UNIDO has always made particular efforts to contribute to the development of the metallurgical industries in developing countries. UNIDO operates on requests from individual governments through the programme of technical assistance. The operational activities supported by the organization of sympozia, seminars, export group meetings, workshops and the preparation of studies, papers and other documentation.

The convening of the First Consultation in the Non-Ferrous Metals Industries represents an important milestone in UNIDO's activities regarding non-ferrous metals industries and it has to be reflected in the relevant programme of the organization in the future.

Concerning operational activities it seems that the possible contribution of UNIDO in the following fields would be particularly appreciated:

- Technical evaluation, laboratory testing of raw materials and other products;
- Provision, of expertise for efficient operation and modernisation of existing production units;
- Planning, establishment of R+D units and new production facilities;
- Creation of advisory service for customers.

The follow-up of the consultation meeting will also require a considerable expansion of the supporting activities of UNIDO principally with the objective to reveal further possibilities of the development of the non-ferrous metals industries in developing countries via subregional, regional and interregional co-operation. It seems to be desirable, that partiuclar attention should be payed to the development of semis and finished products manufacturing in developing countries. Action oriented studies as well as expert group meetings should also be initiated with a view to identify the possibilities of design and manufacturing of semi-fabrication equipment more suitable for the conditions prevailing in developing countries.

F. RECOMMENDATIONS

1. Developing countries may wish and companies operating in these countries are invited to consider:

- To follow-up the development of the technologies being used in the non-ferrous metals industries with a view to introduce in the practice of the country the most effective and suitable new findings;
- To establish the technological and production development programmes of the non-ferrous metals industries having in mind all possibilities deriving from the vertical and horizontal integration of the sector;

- To explore - when appropriate - all possibilities of subregional, regional and interregional co-operation, which could reasonably be conceived under fair and equitable conditions for the creation of the new objects for mining or extraction of non-ferrous metals. In all cases appropriate feasibility and marketing studies are required in the decision making process;

- Whenever appropriate, local subregional, regional and interregional market possibilities when examining the problems related to the establishment of semis fabrication facilities. This action might be profitable - in frequent cases - even based on imported metal. Similarly, installation of production of finished goods in a country without having any fabrication facilities might lead gradually to a demand in semis which can induce later on the erection of facilities for semis production;

- Technological possibilities of gradual development of semis-production particularly the viable size of capacities for the fabrication of extruded and rolled products through different suitable processes;

- The establishment respectively the strengthening of R+D institutes for the non-ferrous metals industries and advisory service for its customers.

2. Developed countries may wish and companies operating in these countries are invited to consider:

- When establishing new production facilities in the non-ferrous metals industries or replacing for different reasons existing ones to locate them possibly in developing countries following an objective analysis of the expected production costs and on the basis of mutually advantageous agreements including financing;

- To review with particular attention in the framework of relevant co-operation agreements the possibilities of involving companies operating in developing countries into the supply of semis of the market of developed countries;

- To provide for developing countries information in the activities of R+D institutions, advisory services and new technological achievements in the non-ferrous metals industries which might bbe useful for these countries in the selection among possible realistic options;

- To receive trainees from developing countries in particular in courses dealing with different problems of application of non-ferrous metals.

3. UNIDO may wish to consider:

- To circumscribe first the follow-up of the First Consultation in the Non-Ferrous Metals Industries to aluminium and copper, expanding the experience of these exercises to lead, zinc, tin and nickel;

- To strengthen its supporting activities via preparation of action oriented studies and the organization of expert group meetings cncerning the following important issues:

    - to review possibilities of subregional, regional and interregional co-operation in the transfer of the most effective and particularly suitable technological innovations to the non-ferrous metals and finished products of different regions;

    - to identify possibilities of co-operation among different countries in the supply with semis of non-ferrous metals and finished products of different regions;

    - to investigate the modalities of design and manufacturing of equipment for non-ferrous metals semis production suitable for the conditions prevailing in developing countries.

Staff members in the System of Consultations Division and in other units of the Secretariat were extremly helpful in providing guidance and information for the preparation of this report. The helpful attitutde of the colleagues was highly appreciated by the drafter;

REFERENCES

(1) Report on the First Expert Group Meeting of Non-ferrous Metals Industries, Vienna 18-21 March 1985/ID/WG 436/5/.

(2) Report on the Regional Expert Group Meeting in Latin America on Strategies and Policies for Further Processing of Non-ferrous Metals, Caracas, Venezuela, 23-26 February 1987.

(3) The Development and Restructuring of the Non-ferrous Metals Industries, discussion document prepared by the UNIDO secretariat for the Regional Expert Group Meeting, Caracas, Venezuela, 23-26 February 1987.

(4) Balázs, E.T.: Role and Assistance of UNIDO in the Aluminium Industry of Developing Countries. Paper presented to the 2. Arab Aluminium Conference, cairo, 23-26 October 1985.

(5) Dobos, G.: Technological Alternatives in the Aluminium Industry. Paper prepared for the UNIDO System of Consultations Division, February 1986.

(6) Balkay, B.: A technika transzfer szerepe a müszaki-gazdasági fejlödésben. OMIKK Budapest 1985.

(7) Zorn, S.: Defining Appropriate Technologies. Unpublished paper.

(8) Dryden J., Tegen A.: Basic Factos on the World Copper Industry, Raw Materials Report, Vol 2, No.3.

(9) Biritz L.F.: Defining Appropriate Technologies. Unpublished paper.

(10) Mineral Processing in Developing Countries, UNIDO/ID 253.

(11) Estadísticas del Cobre. Comisión Chilena de Cobre, 1983, DAE 1/84.

(12) Potencial de Chile en la Mineria del Cobre. Comisión Chilena del Cobre, IDT 2/184.

(13) Draft Directory of Research and Development Institutions, sector: Metallurgy and Non-ferrous Metals, UNIDO Industrial and Technological Information Section.

(14) A. Russel, Allen S.: Aluminium Technology, responds to change. Journal of Metals, February 1986, pp 16-23.

(15) Brown, M.; Damm t, A.; Meeraus, A.; Stoutjesdijk, A.: Worldwide Investment Analysis; The Case of Aluminium, World Bank Staff Working Papers No 603-1983

(16) L'Aluminium, Ingenierus de Pechiney, Eyrolles. Paris 1964, p. 26.

(17) Balázs, E. and Molnár, I.: Bauxite-Alumina-Aluminium: Main Factors for Decision-making on Industrial Development, UNIDO ID/WG 273/8.- 1978

(18) Zámbó, J.: Bauxite and Alumina Production, Historical Retrospection, Review of the present Situation and Prognosis, UNIDO ID/WG 273/9. -1978.

(19) UNIDO: Study on the Disposal and Utilization of Bauxite Residues. Final report, Aluterv-FKI, Budapest, October 1980.

(20) Anthony Bird Association, UK: Aluminium Annual Review, 1985 and Aluminium Analysis No 24 to 26.

(21) Domony, A.; Várhelyi, R.: Some considerations on the development of aluminium semiproducts manufacturing industries. The Second Arab Aluminium Conference, Cairo, 1985.

(22) Domony, A.: Guidelines for processing aluminium semi-fabricated products, UNIDO/I.O.619, 1985

(23) Hertwich, E.: Kompakt-Umschmeltzanlage für die kontinuierliche Herstellung von Strangpressbaren aus Kreislaufschrott und Rohmetall. Aluminium, Düsseldorf, 60, 1984, 6 pp 436-439

(24) Altenpoyl, D.: Materials in World Perspective, Springer Verlag, Heidelberg, New York 1980, pp 153-154.

(25) Varga, I.: Fülöp, S.: Establishing of aluminium finished product industries in developing countries. Magyar Aluminium 21/1984/7-8, pp 281-286

(26) Sutulov, A.: Technological Alternatives for Non-ferrous Base Metals in Developing Countries. Paper prepared for the UNIDO System of Consultations Division, June 1986.

(27) Gróf, T.: Technological Alternatives for the Fabrication of Semi-Finished and Finished Products of Copper. Paper prepared for the UNIDO System of Consultations Division, December 1986.

(28) Kirk, O.: Encyclopedia of Chemical Technology, 3rd, 1978-84, Viley, New York

GLOSSARY

R+D = Research and Development

TNCs = Trans-national corporations

UNIDO = United Nations Industrial Development Organization

tpy = tons per year

IMII = Centro de Investigación para las Indústrias Minerales

CEPED = Centro de Pesquisas e Desenvoltimento

CTP = Centro de Technología Promon

IPT de Sao Paulo = Instituto de Pesquisas Technologicas do Estado de Sao Paulo

CIMM = Centro de Investigación Minera y Metalúrgica

INTEC = Comite de Investigaciones Tecnologicas de Corfo

INACAP = Instituto Nacional de Capacitación Profesional

CIDI = Centro de Investigaciones para el Desarollo Integral

INGEMMET = Instituto Geologico Minero y Metalúrgico