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TECHNICAL ALTERNATIVES IN THE ALUMINIUM INDUSTRY.

A. Introduction.

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.

The first study should be based mainly on the studies 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 Secreteriat to prepare a study "Technological Alternatives in the Aluminium Industry" with the following terms of reference:

a/ To analyse the present situation of technology in the non-ferrous metals industries under study in the developed and developing countries;

b/ To examine the main research programmes presently being conducted in the field of technology, giving their objectives, characteristics, results and possible date of implementation;

c/ On the basis of the analysis of the present situation and research being conducted, to determine the possibilities of developing new technological alternatives that are more adquate for developing countries. Also to determine the main technical and economic charateristics of the possible technological alternatives concentrating on their main advantages and disadvantages for developing countries;

d/ To propose a possible programme of cooperation /both North-South and South-South/ to develop adequate technologies for the non-ferrous metals industries in developing countries.

The structure of the present study corresponds to the terms of reference indicated by the UNIDO Secreriat. As suggested a careful analysis of the previous studies was undertaken with particular attention to those prepared through the activities of the Consultation Branch /1/ and of the Metallurgical Industries Section /2/.

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 disavantages of the possible technological options. For this purpose a review of the relevant publications was undertaken in order to examine the research programmes actually being carried out in the field of Aluminium Industry technology and a tentative assessment was made about the possibility of application of their expected results in developing countries. Obviously the presented results should be considered with justified caution, which is 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 based solely on the relevant publications and the experience in Aluminium Industry of the drafter. Therefore it might be expected that during the process of preparation of the Consultation Meeting, through the contribution of collegues, experts in Aluminium Industry, 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.

a/ The Aluminium Industry.

Most of the integrated aluminium companies, in addition to the mining, chemical and metallurgical operations trasforming the ore into aluminium ingots and semis, are converting the metal into different products/beverage cans, radiators for home heating, cables, etc./. To increase their 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 Aluminium Industry, 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 will be given concerning the viable size of conversion processes and the quality and

quantity of semis requested for these technologies. They will be related to different levels of percapita aluminium consumption which could be envisaged in developing countries at corresponding steps of economic development. Nevertheless, in order to maintain the present study within coherent substantive limits, under Aluminium Industry bauxite mining, alumina-, aluminium and semis production will be understood.

b/ Selection of Technologies.

Most of the processes and devices being used in the Aluminium Industry 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./3/

The majority of the main pieces of equipment, used in this industry, 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 realisation 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 TNC's, 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: FRG, ITALY, JAPAN, USA, USSR, not directly connected with the above mentionned TNC's, having a technological knowledge close to that of these TNC's, either concerning the majority of the operations in the Aluminium Industry or regarding a part of them. These companies can be considered as possible sources of Aluminium Industry technology. It should also be noted that technology for this industry

can be purchased via the major industrial consultants.

One can agree with the opinion expressed by the UN Centre on Transnational Corporations /4/ that in the most cases there is no major difficulty in the purchase of Aluminium Industry technology. Exceptions might occur with regard to relatively recent technoiogical innovations, possibly under testing or concerning new very specific products. Generally speaking one could say that the market of the standard aluminium technologies is rather a buyer's market.

Attention is also drawn to the fact that in the cost of the aluminium 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 bauxite, the price of the electrical energy used in the smelter and finally the transportation costs involved in the whole process of transformation of the ore into metal. The individual or consolidated influence of these three items on the profit of the operations might be stronger than that of 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.

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 recurrins question of "appropriate technology"./5/

According to Mr.Biritz /5/ a technology is appropriate 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 indicated parameters establishing correlation among process technology; product , its application; raw materials; economic benefits; manpower; socio-political constraints. From his findings the following main issues are quoted:

I/ The adequacy of technology can only be defined for a single industrial plant and operation and it is not directly applicable to an identical factory somewhere else. The adequacy of products can be valid for a country or even for a subregion if prevailing economic conditions are similar. E.g. semis produced by strip casting can be suitable for covering the demand in several developing countries starting with broader application of aluminium for different purposes.

2/ The economic conditions under which the enterprise has to operate should be clearly defined:

I/ the plant is expected to make a profit;

II/ the plant is to be subsidized, at least for some period of time;

III/ the plant is to make a social or other contribution to the country, with profits being of secondary importance.

3/ Process industries technologies, e.g. chemical, petrochemical and metallurgical operations cannot practically allow changes, if basis economic conditions are to be met, the only variation to be considered is the size of the plant.

4/ The definition of appropriate technology is a continuing and never ending process for industry and its very survival depends on it, be it in developed or in developing countries.

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 Aluminium Industry /Chapter D/.

A description of the sequence of operations for defining industrial manufacturing technologies, established by Mr.Biritz is attached for easy reference./Annex I/.

C. Present situation of the aluminium industry.

1/ Demand - supply

World consumption of primary aluminium shows a rapid increase from about the fifty's. About 2 million metric tonnes /hereinafter: tonnes/ of primary aluminium were produced in 1950, but 3 milliontonnes 5 years later and 4,5 million tonnes in 1960. The level of production increased rapidly and reached the 10 million tonnes in 1970.

Recently this trend changed considerably. Annex II. gives the relevant picture 1973 to 1983. All though the World total aluminium consumption /primary + secondary/ surpassed the 20 million tonnes in 1983, a considerable part of it was secondary metal /over 25%/ and the increase was not more than 3800 thousand tonnes during this period. More than half of this amount represented however additional secondary consumption, so the total increase on primary metal amounted only to about 1700 thousand tonnes.

According to Zorn /6/ the consumption growth rate between 1970 and 1983 was 3% per annum in primary aluminium. Regarding a shorter period however the increasing represented only about 1,9% per annum in the World less CPE countries during the period of 1973 to 1979 and even less, only 0,5% per annum during the period of 1979 to 1985 /Bird /7/ /. The increase of CPE countries' consumption was somewhat higher, about 3% per annum.

It can be stated hence that the previous dynamic growth in consumption of this metal stopped and the actual trend of it is rather a very modest one.

Actually the growth of aluminium consumption is usually smaller than the annual growth of rate of industrial production in most MEC-s. On contrary the growth of aluminium end-uses is greater than that of industrial production in most developing countries.

The production of the primary metal did not always follow the demand. Consumption of the primary aluminium was decreasing in the early eighties, but production cut-backs came late, so inventories increased rapidly and reached a level in the vicinity of 3 million tonnes. This caused a rapid decline in prices. High interests worked in the same direction.

Consumption of aluminium is very different in various areas of the world. The World-average is 3,5 kg /capita/ year. Three countries: USA, Japan,

FRG consume over 20 kg /capita/year. The relevant figure for most of the developed countries is 9-15 kg recently. Developing countries use much less. There are some with a consumption of about 1 to 3 kg /capita/ year /e.g. Brasil 2,9 kg/ c; Mexico 1,7 kg/c/ and even the 5 kg /capita/year is reached e.g. in Hong Kong and Venezuela, but most developing countries consume below 1 kg /capita/ year, even below 0,5 kg /capita/ year /e.g. Egypt 0,9 kg/c; India 0,4 kg/ c; Ghana 0,5 kg /c / and the use of aluminium of most LDC-s is even below this level.

2. Capacities

Capacities of metallurgical grade alumina plants, smelters and semi-fabrication are shown in Annexes III.IV. and V. per continent based on 1984 and 1983 data resp ectively./ King /8/ and / 9//.These data indicate clearly that there is a considerable surplus capacity in all phases of aluminium production. The total smelter capacity was over 18 million mtpy in 1984, whilst the demand in primary aluminium was only about 15 million tonnes in the world at the same time. This demand would need less than 30 million tonnes of metallurgical grade alumina, but the capacities amounted to nearly 40 million tonnes in 1984. Semi-fabrication capacities were also in excess in 1983.

An increase of these capacities is foreseen within the next years. There are slight differences in various forecasts for smelters /e.g. between King /8/ and Bird /7//, but it is expected that the smelter capacity of the World less CPE countries shall increase by about 2 million mtpy till 1991. Differences between the estimations of increase of alumina capacities are larger; Bird /7/ expects a small increase only, while King /8/ could imagine even an increase of 3 million mtpy. At the same time however the possible close-downs have also to be considered in respect of both smelters and alumina plants. Considering these as well, the smelter capacities might increase by 1,5 million mtpy only and the increse of alumina capacities could be very little. There are no large expectations in increasing semi-fabrication capacities in the near future /till 1987/.

3. Prices.

The price of the primary metal grew stadily - apart from shorter recession periods - up till 1980. A strong recession resulted however in the steep drop

in prices thereafter and they are "sick" since. There are smelters which can hardly cover even their marginal/variable/costs, not speaking about their total costs including capital charges. According to Bird /7/ the marginal costs on average smelters amounted to 51,7 cent per pound /1137,4 USD/mt/ and the total costs to 63,4 cent per pound /1394,8 USD/mt/ in 1984. At the same time LME aluminium prices have been below the top 52,7 cent per pound level of July 1984 /they were however over this figure previously/.

Bird /7/ had set up an analytical supply curve for 1985 to indicate the amount of smelter capacity that can profitably stay in production at different levels of the aluminium price/Annex VI./This demonstrates clearly the situation. It is easy to understand that smelters working much above their costs are cutting back their production.

The situation is similar, if even not worse, regarding alumina plants.

4. Role of energy prices.

Energy prices increased since 1973. Aluminium smelting consumes a considerable amount of power, about 14500 KWH A.C. per ton of metal. The cost of this power differs however considerably in various regions of the world. According to the indications of a staff review of the World Bank /10/ 1980 KWH prices for existing aluminium smelters were between 3 to 26 mils, if low ones, and 20-50 mils were estimated for new smelters. These prices are higher today and they vary between about 8 mils to 50 mils or even higher per KWH. So smelters have to pay a power bill within the wide range of about 116 USD to 725 USD per mt of metal. This explains some close-downs as well as the relocation tendencies of this industry towards cheap energy sources / as observed by e.g. Zorn /6/ too/.

Alumina plants processing expensive bauxite deposits and operating with unsatisfactory technology concerning energy conservation were also closed.

5. Recycling

Annex II. shows that share of secondary metal in the total aluminium consumption increased from 18% in 1973 to 25% in 1983.

In some developed countries the share of recycled metal was much higher than the indicated average value /Bird /7/ /:

Italy	41.1 %
FRG	30.3 %
Japan	26.4 %

USA	32.4 %
UK	26.1 %

Further increase of the share of secondary metal in the aluminium consumption might be expected.

6. Competitive materials.

"Specific property" is a very usefull characteristic when comparing competitive materials. This can be expressed as follows:

$$\text{Specific property} = \frac{\text{wanted property in end use}}{\text{specific gravity X weight unit price}}$$

The "wanted property" could be one of the following: tensile strength, yield strength, fatigue strength, conductivity, elastic module, etc.

Using the above equation the most suitable material for a given end-use may be determined, but only if a dominant single property is in the focus. Aluminium is on the top if conductivity is taken for wanted property. This is the reason why aluminium is generally preferred in power transport.

Aluminium has however an excellent or at least very good combination of properties which meet very well numerous end-use requirements. This is the reason of its wide range application in various branches of industry, but also of the limits of its use.

As indicated, aluminium is first only in one "specific property", therefore there are several materials and metals competing with aluminium, such as copper, wood, steel, high strength low alloyed /HSLA/steel and last but not least plastics. Synthetic materials seem to be the largest competitors for the future.

To a certain extent secondary aluminium is also a'competition"for the primary metal.

Competitors from the point of view of the growth of consumption of primary aluminium are the aluminium high quality products themselves.

Weight reduction of the finished products can be achieved by application of high-duty aluminium alloys and/or high quality extrusions. Price of such items is allthough higher, but less material is needed for the fabrication of the same end-product /e.g. higher strength by 10 % results in 3-5 % materials saving, when considering mechanically loaded structures/.

7. Reasonable expectations for the future.

The short term will bring no considerable changes, this is the essence of what e.g. Bird /7/ states. A very slight increase in the consumption may be expected till 1990, maybe 2 % per annum and the "sick" aluminium prices may "cure" to a certain extent. Recently no new capacities are necessary within this period.

This situation might change however considerably after 1990. Bird /7/ expects an annual growth rate in industrial production approching that of the pre-oil crisis in the period of 1990 to 1993. This should bring an increase in aluminium consumption too. The relevant data are shown in Annex VII.

The difference however between the periods 1964-73 and 1990-93 is respect of aluminium is, that in the period before the oil-crisis the annual growth of rate in aluminium consumption was in average much higher than that in industrial production, whilst in the 1990-93 period the annual growth rate of aluminium consumption is expected to be in average slightly below the annual growth rate in industrial production. Newertheless, the estimated 4.2 % increase per annum in world average indicates a brighter future for this industry.

This annual growth would mean however that capacities would be fully utilized by 1993 and new capacities have to be built to follow the demand. This would however be only possible if both aluminium and alumina prices raise considerably. An excessive increase in metal price would work against the expected growth of rate. This situation might foster further relocation of the aluminium industry towards good bauxite and cheep power possibilities and these circumstances might represent an opportunity for developing countries to further increase their share in different Aluminium Industry operations.

8. Is aluminium a mature metal ?

Comparing with other structural metals the aluminium is the youngest and it had the highest rate of growth in the last decades. Aluminium is the only metal of which intensity-of-use /i.e. consumption per GDP/ is estimated to increase in all group of countries by 2000 /11/. In this sence aluminium isn't a mature metal. According to another expectation /7/ average growth rate of world

aluminium consumption will be lower than the general industrial growth rate. A growth rate of aluminium consumption surpassing the world average might be expected however in developing countries, hence aluminium can not be considered a mature metal in repect of these countries.

Technologies used for bauxite mining, alumina and aluminium production are well established. Their theoretical background is well-known. Important possibilities of economy of scale seem to be exhausted, smaller developments particularly concerning energy conservation might be continously expected. A radical change in these processes will very probably not happen during the present century. Computer process control may bring however important economic results.

Theoretical background of the mechanical technologies is yet less clarified, rather technologies based on empirical results prevail. The future might bring hence more important development in semi-fabrication processes. Computer process control might bring additional economic results.

Regarding the products and their application one could rather say that these are not mature yet. Aluminium is not too young but there are still avenues to be explored for using it in the most economic way. Recycling of aluminium reached already a considerable level, but "designing for scrapt-aptness" is still not yet implemented in many fields of application

New developments expected in the fabrication technology, the production of new alloys and composite-materials might strengthen then the position of the aluminium in the competition with other materials for the different fields of application.

9. Conclusion

The situation of the aluminium industry is not bright today, but it might change and even considering non-optimistic forecasts one might expect a considerable additional consumption, mainly in developing countries. A further relocation of the aluminium industry towards high quality bauxites and cheapest energy resources might be expected after 1990. These phenomena justify a carefull review of possibilities for creating additional aluminium facilities in these countries. Probable technological alternatives suitable to correspond to possible needs of these countries merit special attention.

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Aluminium consumption

1973 - 83

thousand tonnes

1. Total world consumption / primary + secondary /

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
World less CPE	13787	13901	11065	13958	14463	15334	16141	15572	15117	14861	16355
CPE countries	3020	3550	3500	3750	3900	4100	4175	4135	4115	4180	4245
Total	16809	17451	14565	17708	18363	19434	20316	19707	19232	19041	20600

2. Consumption of primary aluminium

World less CPE	11189	11296	8619	11095	11366	12027	12618	11969	11318	10948	12124
CPE countries	2578	2763	2840	3024	3175	3316	3374	3321	3301	3336	3342
Total	13767	14059	11459	14119	14541	15343	15992	15290	14619	14284	15466

3. Consumption of secondary aluminium

World less CPE	2598	2705	2446	2863	3097	3307	3523	3603	3799	3913	4231
CPE countries	444	687	660	726	725	784	801	814	814	844	903
Total	3042	3392	3106	3589	3822	4091	4324	4417	4613	4757	5134

Note : Primary consumption of World less CPE countries in 1984 : approx. 12450 th. tonnes

Basis : Metallgesselschaft AG. : Metallstatistik 1984.

Capacities
of
metallurgical grade alumina plants per continent
in 1984

in Thousand tonnes

Europe /including Yugoslavia and Turkey but excluding CPE countries/	6445
Europe / CPE countries/	6755
North America	7105
Latin America	607o
Oceania	911o
Far-East /excluding CPE countries/	2772
CPE countries of Asia	92o
Near-East	-
Africa	7oo
Total	39877

Based on Kings' data /8/ /partially revised/

Annex IV.

Aluminium smelter capacities
per continent
in 1984

in Thousand tonnes

Europe /including Yugoslavia and Turkey but excluding CPE countries/	4008
Europe /CPE countries/	3735
North America	5933
Latin America	1059
Oceania	847
Far-East /excluding CPE countries/	1292
CPE countries of Asia	569
Near-East	377
Africa	622
Total	18432

Based on Kings' data /8/ /partially revised/

Aluminium Semi-fabrication capacities per continent in 1983

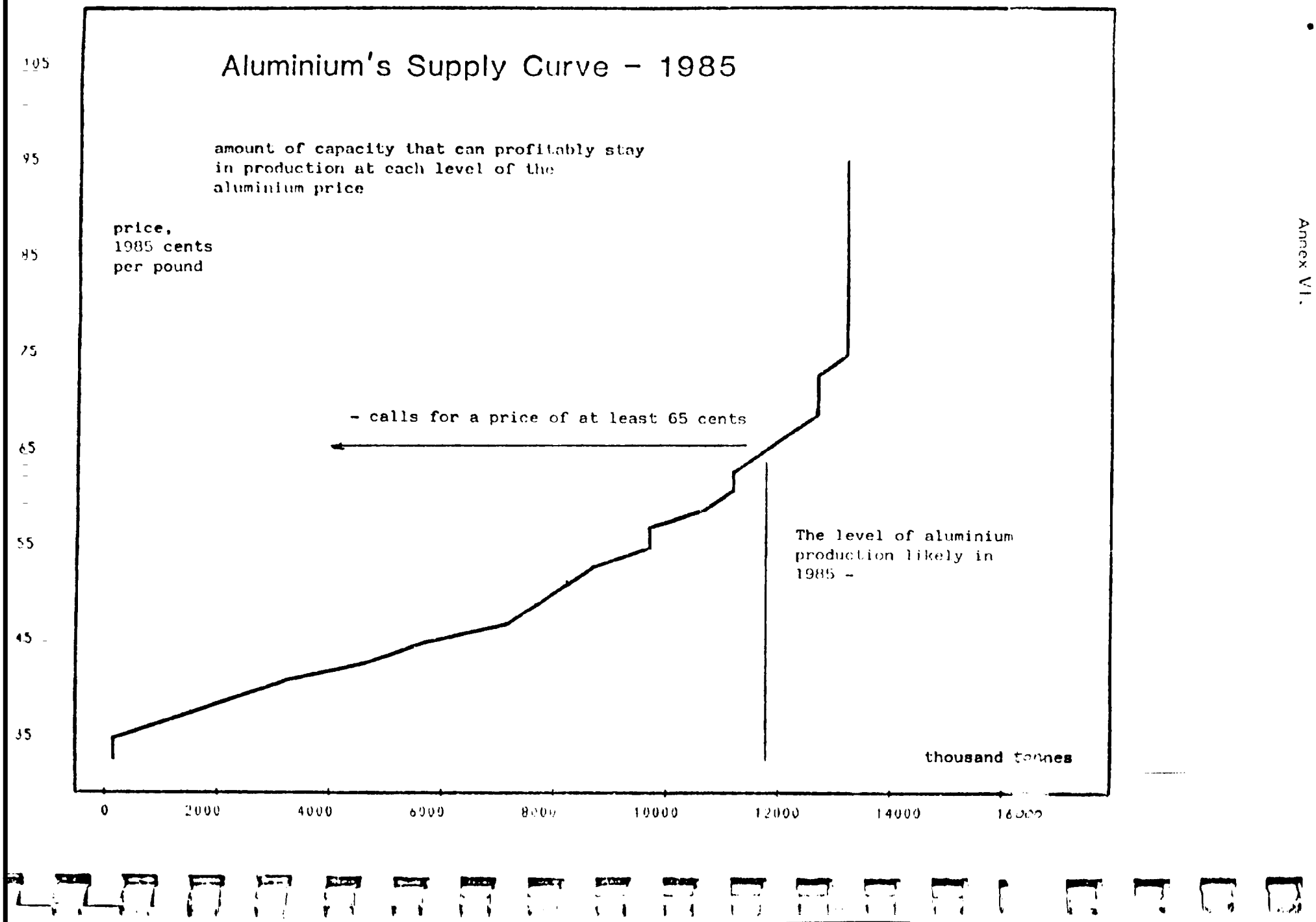
in Thousand tonnes

Europe /including Yugoslavia and Turkey but excluding CPE countries/		5103.5
Europe /CPE countries/	appr.	3500.-x./
North America		7910.5
Latin America		653.5
Oceania		322.5
Far-East /excluding CPE countries/		2667.6
CPE countries of Asia	appr.	570.-x./
Near-East		160.6
Africa		239.9
Total		21127.9

Notes:x./ estimated

- only primary semi-fabrication taken into consideration, i.e. only hot-rolling, but not cold-rolling and foil capacities; extrusion and rod-manufacturing capacities included, but not wire manufacturing. Does not include casting capacities !

Based on Kings' data /9/ /partially revised/


Aluminium's Supply Curve - 1985
amount of capacity that can profitably stay in production at each level of the aluminium price
price, 1985 cents per pound
105
95
85
75
65
55
45
35
- calls for a price of at least 65 cents
The level of aluminium production likely in 1985 -
thousand tonnes
0
2000
4000
6000
8000
10000
12000
14000

Expected

ANNUAL GROWTH OF RATES

1990-93

	in industrial production	in aluminium consumption
USA	4.6 %	4 %
Japan	5.8 %	4.8 %
France	4.8 %	4.8 %
Germany	3.8 %	3.1 %
Italy	4.8 %	3.8 %
UK	3.4 %	-0.2 %
Other Europe x./	4.1 %	3.8 %
Europen total x./	4.1 %	3.4 %
Rest of world x./	no data given	5.4 %
World x./	4.6 %	4.2 %

Note: x./ non-CPE countries only

Basis: Bird: Aluminium Annual Review 1985. /7/