(4) fiscal regimes of the country to affect the decisions on new investment. The investigation into each of these items is made as below.

2.1.1 Capital cost

The capital cost of an alumina refinery depends on various factors. In other words, the capital cost is determined by a complex implication of the factors which are as follows: production scale, technology, acquisition of site, topography in and around the site in reference to environmental protection, availability of infrastructure, construction period, availability of skilled labor and materials and other industrial relations and general economic conditions. The estimated capital cost per annual tonne production is shown in Table B-11 in order to examine the capital cost clearly.

Although the differences in the contents of various projects; i.e. whether bauxite exploitation and aluminum smelting are integrated or not and the coverage of capital cost (including infrastructure or not), make it difficult to directly compare the capital cost of a specific project with that of others, a rough level can be indicated from these data. In almost every recent project, the capital cost exceeds US$1,000 per annual tonne. This implicates that an alumina plant, unlike a bauxite plant, is a modern factory affected to a relatively small degree by natural conditions. The capital cost is a leading element determining depreciation and interest in the calculation of indirect cost.

2.1.2 Bauxite price

One of the factors to determine the alumina production cost is, of course, the bauxite price. The bauxite production cost has already been discussed earlier, therefore, in this context Table B-12 is provided to show bauxite prices and costs per tonne of alumina.

As shown in this Table, the bauxite price as a part of the cost of alumina production must comprise the overall costs, including not only the costs of marine transportation and handling but also the factor of unit consumption, i.e. valuation of the grade of the bauxite. Estimates made in such a way seem to indicate that world bauxite prices lie in a wide range from approximately US$20 to US$80 per tonne of alumina.

Table B-11 Reported Capital Costs for Alumina Refineries

Company and Location	Capacity (1,000 MT/Y)	Date of Cost Estimate	Cost/tonne annual output (US$ 1980)
Completed:			
Eurallumina, Sardinia, Italy (1973)	600	1970	375
Aluminio Espanol, San Ciprian, Spain (1980)	800	1979	450
Queensland Alumina, Gladstone, Australia (1973)	2,032	1974	490
Under Construction:			
Alunorte, nr. Belem, Brazil	800	1978	660
Interalumina, Puerto Ordaz, Venezuela	1,000	1980	1,000-1,700
# ALCOA, Wagerup, W.A., Australia	500	1979	780
# Worsley, Worsley, W.A., Australia	1,000	1980	1,000
Auginish, Shannon, Ireland	800	1981	1,250
Planned:			
# Mine/refinery project, Cameroon	1,000	1979	1,130
# Mine/refinery project, Alugui, Boke, Guinea	1,000	1978	760
Sieromco, Pepel Harbour, Sierra Sierra Leone	500	1980	1,000
∅ Jamaica, S. Manchester	500	1980	830
∅ Bharat Aluminium Co., Andhra Pradesh, India	600	1977	1,130
∅ Bharat Aluminium Co., Gujarat, India	300	1980	1,230
∅ Kuala Tanjung, Sumatra, Indonesia	600	1981	1,250
Bauxite Parnasse, Kamiotissa, Greece	600	1978	730
Greek/USSR project, Greece	600	1980	1,250
# Aurukun Project, Cape York, Qld., Australia	1,200	1976	780

Includes costs of mine and infrastructure
∅ Includes cost of mine

Source: AME

Table B-12 Estimates of Costs of Bauxite at Various Destinations for 1979 - 1980

Refinery Location	Bauxite Source	Bauxite price (US$/ tonne)	Bauxite required per tonne alumina	Bauxite cost/tonne alumina (US$/tonne)	Bauxite cost/lb aluminum (US cents/lb)
USA, gulf	Jamaica	31.00	2.5	77.50	6.9
	Guinea	30.50	2.1	64.00	5.7
	Brazil	32.00	2.2	70.50	6.2
	Surinam	38.00	2.2	83.50	7.4
Germany, FR	Australia	28.00	2.3	65.50	5.8
Japan	Australia	22.00	2.3	50.50	4.5
France	Guinea	30.00	2.1	63.00	5.6
Australia:	Domestic:				
Gladstone	Weipa (incl. freight)	15.00	2.2	33.00	2.9
Gove	Gove	10.00	2.4	24.00	2.1
Kwinana/ Pinjarra	Darling Ranges	6.00	3.3	19.80	1.8
Jamaica	Domestic average				
	- before levy	5.00	2.5	12.50	1.1
	- after levy	29.00	2.5	72.50	6.4
Greece	Domestic	19.50	2.3	45.00	4.0

Source: AME

2.1.3 Cost of energy

The energy in alumina production is used in the form of heavy oil for alumina calcining, steam and electric power. The overall cost of energy, which is estimated to range from US$50 to US$80 per ton of alumina, is one of the main elements of the cost of alumina.1)

1) The standard energy consumption per tonne of alumina is as follows:

Fuel oil	80 - 160 l	
Steam	1.5 - 3 T	(in terms of fuel oil, 120 - 240 l)
Electric power	200 - 300 kWh	(" 50 - 75 l)
Total (in terms of fuel oil)	250 - 470 l	

Since alumina calcining requires clean fuel which will not contaminate the product, fuel oil is mainly used. And, where available, natural gas is used (Kwinana in Australia). Meanwhile, in the areas with abundant coke resources a time may come in the future when coal gas becomes economical. Although any fuel can be used for steam and power-generations, the same fuel as is used for calcination is usually used for them in consideration of convenience in the operation of the plants.

2.1.4 Fiscal regimes

The levies and royalties of the various countries are important factors in the bauxite cost, and similarly their fiscal regimes seriously affect new investment decisions in the case of alumina cost. In particular, it should be noted that bauxite producing countries have enhanced interest in obtaining revenue from new developments of further processed products. Table B-13 shows the fiscal regimes of the countries which are planning new investment in alumina refinery plants.

Table B-13 Fiscal Regimes in Countries Planning New Investment in Alumina Refinery Plants

Australia	Concessionary system, company tax 46%, dividend withholding tax 15%, royalty currently $1.75 per tonne alumina in Western Australia, accelerated depreciation, some government-financed infrastructure, local equity required.
Brazil	Concessionary system, company tax, royalties at $1.00 per tonne bauxite, tax holiday, government-financed infrastructure, local equity required.
Venezuela	Concessionary system
Yugoslavia	Collective ownership (direct equity participation)
Ireland	Concessionary system
Spain	Concessionary system
Guinea	Government equity, but bauxite levy in lieu of dividends and income tax
Greece	Concessionary system
India	Government equity and concessionary system
Turkey	Concessionary system

Source: IBA QR, August 1980

Main elements of the alumina production cost have been studied above. In addition, two examples of total cost estimation which are made by putting together these elements are given here. Table B-14 shows an estimate by IBA for a Caribbean Greenfield Refinery, and Table B-15 gives an estimate by AME for some existing Australian refineries.

The IBA estimate (US$277/T) is considerably higher than the AME estimate (US$109-156/T). This may be due to the fact that (a) a considerable levy or royalty has been added to the bauxite price; (b) the depreciation cost is high, reflecting a large capital cost; and (c) a considerable amount of return on capital investment has been allowed for. In conclusion, such comparison clearly indicates that the existing Australian refineries enjoy an overhelming competitiveness.

Table B-14 Bayer Alumina Production Costs — US$ per Tonne Alumina Undiscounted
(Caribbean Greenfield Plant, 1980 Start-up)

	Quantity	Price	Cost	Total cost %
Raw Materials				
o Bauxite (incl. levy)	2.3 tonnes	31.77	73.07	26
o Caustic Soda	0.1 tonnes	140.00	14.00	5
o Other			1.00	
			88.07	32
Utilities				
o Fuel - boiler	10 GJ *	3.00	30.00	11
- Calcination	4 GJ	3.00	12.00	4
o Other			2.00	
			44.00	16
Maintenance Supplies	1.5% capital investment		10.20	4
Direct Labor	1.5% man-hrs.	6.0	9.00	3
Supervision	20% direct labor		1.80	-
Labor Overheads	33 1/3% total labor		3.60	-
Rates & Local Taxes	0.5% capital investment		3.40	-
Depreciation	5% capital investment		34.00	12
Return on Capital	10% investment post-tax		68.00	25
Sales & Administration	5% selling price		15.00	5
			145.00	52
			277.07	100

* GJ = Giga Joule (4.184 Joule = 1 cal)

Source: IBA QR, June 1980

Table B-15 Estimates of Production Costs for Australian Refineries, 1980[a)] US$/Tonne Alumina

Item and Unit	Quantity required per ton alumina			Estimated cost per unit			Estimated cost per ton alumina		
	ALCOA	QAL	Gove	ALCOA	QAL	Gove	ALCOA	QAL	Gove
Raw Materials:									
Bauxite (tonnes)	3.3	2.2	2.4	6.00	15.00 b)	10.00	19.80	33.00 e)	24.00
Caustic soda (tonnes)	0.105	0.12	0.105	195.00	195.00	200.00	20.50	23.40	21.00
Other	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.20	1.20	1.70
Energy:									
Fuel oil (tonnes)	0.16	0.14	0.37	170.00	170.00	175.00	27.20	23.80	64.80
Natural gas (1000 m^3)	0.30	-	-	37.50	-	-	11.20	-	-
Coal (tonnes)	-	0.42	-	-	15.00	-	-	6.30	-
Diesel oil (tonnes)	0.001	0.001	0.001	200.00	200.00	205.00	0.20	0.20	0.30
Electricity (kWh)	240	240	240	- c)	0.02	- c)	n.a.	4.80	n.a.
Labor:									
Employees d)	0.00074	0.00055	0.00075	24,500	24,300	26,500	18.10	13.40	19.90
							98.20	106.10	131.70
Indirect Costs:									
Depreciation							7.00	7.00	10.00
Interest							3.00	10.50	13.00
Administration, etc.							1.00	1.20	1.50
Total Production Costs							109.20	124.80	156.20

a) A$ 1.00 = US$ 1.14 used in calculation
b) Includes freight from Weipa to Gladstone
c) Company power plants; cost included in other costs
d) Estimated cost per unit based on estimated average wage per employee per year; actual figures for QAL
e) QAL only toll refines bauxite for its shareholder; a bauxite cost is estimated for the purposes of comparison only.

Source: AME

2.2 Transportation Cost

When the alumina production facilities are located distant from the aluminum smelting facilities, the transportation cost is a significant element on the part of alumina consumers. For import and export transactions, in particular, long-distance marine transportation is one of the factors contributing to increase of consumer price of alumina. Though the cost level of alumina has a greater capacity to absorb transportation costs compared with the level of bauxite costs, it is necessary to always seek economical transportation. Table B-16 shows recent examples of marine transportation costs.

Table B-16 Selected Alumina Shipping Costs

Source of alumina	Destination of alumina	Freight costs US$/tonne	Date of freight cost
Australia:			
Kwinana/Bunbury, WA	Geelong, Vict.	11.50 *	May 1981
	Bahrain	26.00 *	May 1981
	US West Coast	18.00-19.00	Feb.-Apr. 1980
		20.00-23.00	May 1980
		15.00-19.00	Sept.-Nov. 1980
		22.00	Jan. 1981
	US East Coast	23.00-28.00	Jan.-Mar. 1980
		23.00	Dec. 1980
Gladstone, Qld.	Bell Bay, Tasmania	16.00 *	May 1981
	US West Coast	13.50	Oct. 1980
		22.00	May 1981
	US East Coast	29.50-32.00	Mar.-May 1980
	Netherlands	44.00	Dec. 1979
	Norway	42.00	May 1980
	USSR (Black Sea)	54.00	Mar. 1980
Gove, N.T.	Iceland	31.00	Sept. 1980
Jamaica:			
Port Kaiser	Louisiana, US	4.00- 4.25	Sept. 1980
	Virginia, US	6.00	Apr. 1980
	Spain	29.00	Oct. 1980
	Bahrain	37.00	Aug. 1980
Surinam:			
Paranam	Virginia, US	9.00	Apr. 1980
Japan	Kitimat, BC, Canada	14.00	Dec. 1980

* Estimate by Sydney-based shipping consultants

Source: AME

2.3 Construction of New Alumina Facilities and Items for Investigation

The above study has almost clarified what are the basic elements affecting the competitiveness of alumina plants, and the main points of investigation in deciding an investment for a new alumina refinery are summarized as below.

The first point is the integration with bauxite and aluminum productions. An alumina plant which can be constructed close to bauxite resources satisfies the first point in the sense that transportation costs can be reduced. Australia, Brazil, India etc., which have large ore deposits, may be promising in this sense. The best way to reduce the transportation cost of alumina, however, is the integration with aluminum smelting. In that case, a problem is the availability of the enormous electric power for aluminum smelting. In this regard, Australia, Brazil, Venezuela etc., which have abundant coal or hydroenergy potential, may be promising. It should, however, be considered that such integration requires a huge amount of funds and entails a burden of risk.

The second is to secure the energy required for alumina production. Though the energy consumption in alumina production is extremely less than that in aluminum smelting, this point cannot be neglected. In view of this, Australia and Venezuela with abundant coal, oil or natural gas are in an advantageous position.

The third is the problem of the investment climate. The operation and maintenance of alumina and aluminum production facilities requires a sufficient number of experienced engineers and skilled labors and the support from the other related industries. Therefore the absence of such an environment increases the investment risks. Moreover, government policies, needless to say, have a great influence on the investment climate. As can be seen in Australia, consistent government policies for the development and taxation and a good political stability of a country where few risks of requisition by the government occur are important factors to encourage investment. In contrast, excessive government intervention and possibility of nationalization reduce the incentives to investment. In conclusion, preparation of a stable investment climate, including the improvement of infrastructure, can be regarded as the most essential requirement for a positive investment decision.

3. Aluminum

As described in Chapter A, all of the existing aluminum smelting facilities commercially use the only method of Hall-Héroult process, which can be roughly divided into the prebaked system and the Soederberg system. These systems have essentially the same process, in which aluminum is produced by feeding the raw material of alumina into the electrolytic furnaces equipped with carbon electrodes (anode and cathode) and electrolyzing alumina in the bath composed of fluoride. Consequently, both systems have the same major cost elements for producing aluminum, which are summarized below:

- Direct operating costs
  - electric power
  - alumina
  - other raw materials (anode, fluoride etc.)
  - other direct costs (labor, pot reconstruction, maintenance etc.)
- Indirect costs
  - depreciation of capital cost
  - interest on capital cost
  - other costs (administration, working capital interest etc.)

Each of cost elements above is analyzed as below, starting with an analysis of capital costs for new aluminum smelters.

3.1 Capital Cost

The main items of capital costs are listed as follows:

- Pre-construction costs
  - feasibility studies
  - site acquisition
  - infrastructure for construction work
- Construction costs
  - plant construction, equipment cost (including freight, import tariffs etc.), labor, equipment installation, indirect costs etc.
  - infrastructure

Because these costs vary significantly depending upon various conditions of plant location and investment climate, it is difficult to make a general statement.

The first factor which affects the variation in capital cost is, of course, the conditions of the plant site, namely, whether or not a transportation to the plant site is available and whether or not the natural conditions such as topography, climate etc. are suitable.

The second factor concerns infrastructure, that is, whether adequate transportation facilities such as roads, harbors, railways etc. are available at the plant site, whether service facilities such as for water, sewage, electric power etc. are provided, and whether social facilities such as houses, hospitals, schools, churches etc. are located nearby. Whether these facilities exist already, exist inadequately or do not exist at all and whether the preparation of such facilities are implemented by public organizations such as the government or under the responsibility of the company etc. are very important factors affecting capital costs. In this regard, it is noted that capital costs in the developing countries tend to exceed those in the developed countries due to insufficient infrastructure in addition to a shortage of skilled labor.[1)]

The third factor is the quality and availability of labor. The shortage of high quality labor force exerts a considerable influence not only on capital costs but also on the construction work itself. Furthermore, the maintenance of a good relation with employees is an important element.

Fourthly, pollution control regulations in the areas surrounding the plant are also taken into account. At present, the developed countries have strict control regulations which require rather high expenditure for the pollution control equipment. Similar conditions should gradually come to apply to the developing countries.

In addition to these variations in investment climate, different timing of construction is also affecting the level of capital costs. In particular, the recent accelerated inflation has obviously caused continuous increase in capital costs.

With the various factors mentioned above in mind, the general level of capital cost is analyzed below.

Previously, this level in general term was as follows: "The

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1) Concerning this point, the followings are common views:
   a. "The capital cost index in the developing countries is 1.25 times that of the developed countries." (Monthly Bulletin of the Federation of Economic Organizations, the Monthly Bulletin, April 1976, p. 53)
   b. "The consensus is that it (the share of infrastructure in total capital costs) can account for as much as 40 percent of a project." (AME, Volume I, p. 242)

capital cost per tonne of annual aluminum capacity for the plants in the developed countries constructed around 1965 was approximately US$1,000, while for the various projects currently (in 1976) in the planning stage in these countries, the corresponding cost is estimated at approximately US$2,000".[1]

This level rises year after year, and a report of Chase Econometrics[2] estimates the capital cost of "a hypothetical greenfield facility located in the United States" as follows:

Year	Capital cost/annual tonne (US$ per tonne of annual aluminum capacity)
1979	2,662.85
1980	2,935.79
1981	3,214.41
1982	3,527.55

This trend of cost rise is even more remarkable in the developing countries, and it recently becomes obvious that the levels mentioned above are no longer applicable. The range of current levels is somewhere between US$4,000 and US$4,000 plus several hundred dollars per tonne of annual aluminum capacity and, if the infrastructure cost is added, it could eventually amount to even more than US$5,000.

Table B-17 summarizes level of capital cost in various projects. However, since the coverage of capital cost is unknown, the figures shown should be regarded as rough indices of level of capital cost.

3.2 Production Cost

3.2.1 Direct operating costs

(1) Electric power

(a) Electric power consumption

Aluminum consumes so much electric power for production

1) The Monthly Bulletin, April 1976, p. 53
2) Chase Econometrics, February 1982, p. 102

Table B-17 Reported Capital Costs for Smelters

Company and Location	Capacity (1,000 MT/ year)	Date of cost estimate	Cost/tonne annual output (US$ 1980)
NEW SMELTERS			
Completed:			
Aluminium Co. of Egypt, Nag Hammadi, Egypt (1975)	100	1974	2,120
Venalum, San Felix, Venezuela (1979)	280	1980	2,760
Dubai Aluminium, Jebel Ali, Dubai (1979)	135	1980	3,630
Alumax, Mt. Holly, S. Carolina, USA (1980)	179	1980	1,840
Alumina Español, San Ciprian, Spain (1978)	180	1979	1,820
Valesul, Santa Cruz, Brazil	86	1979	4,860
Under Construction:			
Albras, Para, Brazil	320	1978	3,860
Alumar, Marahão, Brazil	100	1980	4,000**
Nat'l Aluminium Co., Orissa, India	218	1979	1,940
Asahan Smelter, Sumatra, Indonesia	225	1981	4,400
Guiyang, Guizhou, China	80	1979	3,680
Energoinvest, Mostar, Yugoslavia	90	1977	3,330
ALCAN, Grande Baie, Que., Canada	171	1980	2,490
ALCOA, Portland, Vict., Australia	264	1980	3,050
Gladstone Aluminium, Gladstone, Qld., Australia	206	1980	3,300
Planned:			
Govt., Reynolds, Philippines	140	1979	3,640
Govt., Tema, Ghana	300	1975	2,300
Alusaf, Richards Bay, S. Africa *	87	1980	3,050
Alumax, Oregon, USA	170	1981	3,530
ALUSUISSE project, Banana, Zaire	160	1980	4,000
Alune, Pernambuco, Brazil	110	1980	3.640
Votorantim, Pará, Brazil	160	1980	4,060
Point Lisas project, Trinidad	180	1980	2,500
ALCAN, Bundaberg, Qld., Australia	98.5	1981	3,530
ALCOA, Bunbury, W.A., Australia	264	1980	2,880
Hunter Valley Aluminium, Lochinvar, N.S.W., Australia	236	1979	2,580
Tomago Aluminium, Tomago, N.S.W., Australia	220	1980	3,090
Westal Consortium, Worsley, W.A., Australia	220-250	1980	3,040-3,450
South Pacific Aluminium, S. Island, New Zealand	200	1981	3,125-3,250

* Old Japanese smelter to be shipped to South Africa and reconstructed.
** Capacity 300 thousand tonnes/year base

Source: AME

that it is called "canned electricity". Accordingly, electricity cost shares the largest part in aluminum production cost. Level of electricity required for aluminum production is indicated in Table B-18, based on IPAI statistics.

These statistics include not only the DC current necessary for aluminum electrolysis but other auxiliary electric power for rectification from AC to DC, environmental control facilities for the potroom etc. The proportion of DC electric power required for electrolysis alone is estimated at about 95% of the figures shown. According to this estimate, unit electric power consumption (DC) required for producing one tonne of aluminum is approximately 16,000 kwh as a world average. Therefore, in case that the price of electricity differs by US1¢/kwh (= 10 US mill/kwh), aluminum production cost will show substantial difference of as much as US$160/T (9% of US$1,750/T, the current ALCAN list price). This example makes it clear that the price of electricity is a highly significant factor in aluminum production cost.

Such being the case, efforts for improvements in aluminum smelting technology have been made to reduce electric power requirements for aluminum production. As a result, there is presently a wide variation in unit electric power consumption due to difference in level of technical improvements. As indicated in the IPAI statistics by region, the East Asian area, mainly Japan, shows much less electric energy consumption than other areas. This is particularly conspicuous in Japan, because most electricity for aluminum smelting in Japan is supplied from oil-fired thermal power stations and therefore serious efforts for technical improvements continue, trying to compensate the steep increase in electricity price caused by the sharp rise in oil prices. Europe is in a similar situation, and the level of unit electric power consumption is also relatively low.

Table B-18 Unit Power Consumption in kWH per Tonne of Primary Metal Produced (weighted average)

	Africa	North America	Latin America	East Asia	South Asia	Europe	Oceania	IPAI Total
1980	16,487	17,477	17,348	14,948	17,829	16,669	16,678	16,951
1981	16,348	17,151	17,396	14,849	17,517	16,550	16,094	16,776

Source: IPAI, Electrical Power Utilization 1980/1981, May 13, 1982

On the contrary, in Canada, the United States and Latin America including Brazil and Venezuela, where relatively cheap electricity is generally available from hydroelectric power stations, and in South Asia which includes the oil-producing countries where electricity is supplied from natural gas power stations, the unit consumption of electric power is relatively high.

The technology improvements made in the developed countries, however, are gradually applied in other areas through export of plants and technology license. For this reason, in Africa and Oceania where many new smelters were constructed, the application of improved technology resulted in relatively low unit electric power consumption despite a good availability of relatively cheap electricity from hydroelectric or coal power stations. On the other hand, unit electric power consumption at old smelters in North America and Europe still remains at relatively high level.

The most modern technology improves unit power consumption (DC) to the level of 13,500 kWh/T or less. To realize such a low level, however, additional investments in equipment automation etc. and highly stable operation techniques are required. Consequently, there may be a case where reduction in electricity costs by applying modern technology is partially offset by increases in depreciation costs, interest cost on capital investment and other factors. In adopting such technology, therefore, it is important to give full considertion to the relationship between the level of electric power cost and overall production cost.

It should be noted that the unit electric power consumption (DC) of 13,500 kWh/T above is the level during the normal operation only. In starting electrolytic furnaces, electric power much exceeding this level is required.[1)] Therefore, at aluminum smelters, efforts are always made to operate the plants for 24 hours a day in order to continue the highest possible stability of operation. To realize this, stable supply of raw materials is indispensable. In particular, electricity, being hardly stored, must be always available on a constant basis. Assuming that unit power consumption is 13,500 kWh/T (DC) and plant capacity is 200,000 T/y which is the average size of recent smelters, the annual requirement of electricity amounts to 2,700 GWh [2)], and in terms of regular electricity supply, the requirement is 308,000 kWh. Frequent fluctuation of the electricity supply

1) It is estimated that approximately 20 to 30% more electric power is required.
2) 1 GWh = 1 million kWh

makes operation unstable, causing a large increase in cost, even if other factors remain stable. Accordingly it is indispensable for electricity supply system to have sufficient surplus power generation capacity to cover all circumstances such as the maintenance and repair of power generators, the dry season in case of hydroelectric power generation, the maintenance of transmission line netwworks and any emergency.

(b) Cost of electric power

As discussed above, electric power is of great significance in aluminum production. How high then is the cost of electric power in various countries? Although the data are a little old, Table B-19 gives estimates of the cost of electric power for aluminum smelting in various countries in 1979.

Table B-19 Power Cost for Aluminum Smelters (1979)

Country		Production 1,000 tonnes	Power cost Mill/kWh	Power demand MW	Major energy source
		(1977)	2.8		
USA	BPA		3.2-8.7	3,000	Hydro
	TVA		24	1,300	Coal
	Others			3,900	-
USA	Total	4,117	15	8,200	-
Japan		1,118	36-41	2,200	Oil
Germany, Fed. Rep.		742	11-22	1,500	Coal
Canada		976	8	2,000	Hydro
Norway		637	6	1,270	Hydro
Venezuela		43	4- 5	90	Hydro
Great Britain		349	9-21	700	Coal/Nuclear
France		399	12	800	Coal/Hydro
Argentina		52	16	100	Hydro
Australia		243	16	480	Coal
Italy		170	13-15	340	Hydro
Total		14,201	15	28,400	

Notes: 1) BPA: Bonneville Power Administration
TVA: Tennessee Valley Authority
Both of the above are agencies of the U.S. Government.
2) According to the latest information provided in Aluminum Services, dated September 3, 1982 issued by Merner Research, USA, primary aluminum electric power costs in North America for 1983 are estimated as in the following table:

Source: JAF

	Production Capacity (1,000 MT/Y)	Power Cost Mills/kWh
USA	4,808	24
Canada	1,234	5
N. America *	6,042	20
ALCOA	1,415	16
Reynolds	895	24
Kaiser	657	23
Big 3	2,967	20
ALCAN	1,075	4
Big 4	4,042	16
Alumax	385	32
Anaconda	326	29
Conalco	286	27
Martin Marietta	250	27
Pechiney	205	31
Noranda	200	28
Revere	185	29
National Southwire	163	30
Minor 8	2,000	29
N. America Total	6,042	20

* Excludes 355,000 tonnes/year of economically inferior capacity (ALCOA - 174 thousand tonnes, Reynolds - 148 thousand tonnes, Conalco - 33 thousand tonnes).

Those data show considerable variation in the cost of electric power. The highest cost is that of Japan based on oil-fired thermal electric power, while the cheapest is that of BPA in the United States, Venezuela, Norway, Canada etc. based on hydroelectric power. Coal thermal electric power stands midway between them. Assuming that 16,000 kWh/T is the world average unit electric power consumption (DC) for aluminum smelter as discussed above, the cost of electric power for aluminum is as follows:

Electric power cost for 16,000 kWh/tonne aluminum

US mills	US$/tonne aluminum	US mills	US$/tonne aluminum
5	80	25	400
10	160	30	480
15	240	35	560
20	320	40	640

In other words, the difference in unit cost of electric power between 5 mills and 20 mills results in the difference in aluminum production cost of more than US$200 per tonne and the difference between 5 mills and 40 mills results in the difference of more than US$500 per tonne in the present aluminum producing countries in the world, although the unit electric power consumption (DC) in those countries may differ from 16,000 kWh/T above. A difference of US$500 per tonne for a plant with an annual production of 200,000 tonnes results in annual cost difference of as large as US$100 million.

Because of this situation, the aluminum smelters of all the countries, in particular in the developed countries, have been anxious to secure cheap energy sources. Table B-20 indicates changes in the structure of electric power sources in the aluminum smelting industries of the main countries in the world between 1974 and 1980, and in the structure of electric power sources in the developing country areas in 1980. According to this Table, oil fired thermal electric power in the main countries shows a leveling-off or somewhat a decline, and natural gas a drastic reduction, while the share of coal and nuclear electric power has risen. This clearly reveals the uneasiness of oil consumers, caused by the oil crisis, regarding oil price rises and instability in oil supplies.

On the other hand, Canada, Africa and Latin America are overwhelmingly dependent on hydroelectric sources. In South Asia, including the Middle East, hydroelectric power, coal and natural gas balance well with each other. In Japan, dependence upon hydroelectric power is declining because the Japanese smelting industry owns private or joint thermal power generation plants which take high share of total power generation [1)] and greatly depend upon oil, and, while fearing a high dependence on oil, has sidestepped a unit cost hike due to a decline in the operation rate of these private or joint power generation plants by comparatively reducing the purchase of electric power. In Oceania hydroelectric power is also declining, probably because the smelting companies with coal-fired thermal power stations as their energy source have expanded steadily the capacity of such power stations.

In summary, aluminum smelting energy sources may tend to shift in the future toward coal or nuclear power in the

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1) According to the JAF survey in 1977, private and joint power plants supplied 80.3% of electric power generated for the Japanese smelting industry.

Table B-20 Power Sources for 1974 and 1980

(%)

Country	Year	Oil	Hydro electric	Coal	Natural gas	Nuclear	Unknown	Total
Japan	1974 a)	71.10	13.40	6.80	8.70	0	0	100
	1980 d)	71.40	9.80	17.70	0	1.10	0	100
Canada	1974 a)	0	100	0	0	0	0	100
	1980 a)	0	100	0	0	0	0	100
USA	1974 a)	2.30	37.80	36.70	20.50	2.70	0	100
	1980 d)	2.28	41.45	38.89	11.52	5.86	0	100
Europe	1974 b)	11.40	47.50	22.40	10.50	7.50	0.7	100
	1980 b)	11.01	45.33	25.35	3.27	15.04	0	100
Oceania	1974 b)	0	59.25	40.75	0	0	0	100
	1980 c)	0	58.87	41.13	0	0	0	100
Africa	1980 c)	0	81.50	18.50	0	0	0	100
Latin America	1980 c)	4.50	93.60	0	1.90	0	0	100
South Asia	1980 c)	3.50	33.20	25.10	38.20	0	0	100

Sources: a) OECD Extraordinary Committee estimated values in 1980
b) Revue de L'Alminium 1974, Vol.2
c) IPAI 1980 Annual Report: Power Sources for 1980
d) Private sources

developed countries. But the worldwide share of hydroelectric power may possibly rise, since in the developing countries cheap hydroelectric power sources have been sought to develop new smelting projects.

The changes in the structure of the aluminum industry described before are largely based on these changes in energy sources. The pursuit of cheap energy sources develops a tendency of more production to take place in those areas where these energy sources are abundant. The recent trend of production clearly indicates this tendency.

It should be noted that cheap electric power is not always an absolutely favorable condition for aluminum production cost. As previously mentioned, aluminum smelting strongly requires constant electricity supply and a stable operation system. Accordingly, the unstable operation largely offsets any advantage gained through an inexpensive supply of electricity. Furthermore, the enormous capital costs which will be required for constructing an aluminum smelter in a developing country will drastically reduce the advantage of cheap electricity supply. Although the effect of electricity cost is indeed important to aluminum production cost, an overall judgment of these conditions should be of the highest importance.

(2) Alumina

Alumina is the principal raw material of aluminum production and is a major element of aluminum production cost like electricity. Since the quantity of alumina required to produce one tonne of aluminum is about 1.95 tonnes, an aluminum plant with, for example, an annual production of about 200,000 tonnes consumes about 390,000 tonnes of alumina annually. When an alumina refinery is integrated with an aluminum smelter, the alumina price is decided on the basis of alumina production cost plus the transportation costs from the alumina refinery to the aluminum smelter. In other cases, the alumina price is determined as a commercial market price reflecting alumina supply and demand situation. While alumina production costs have been previously analyzed, the market price is generally determined, in case of a long term contract by applying a certain ratio to the price of aluminum, by adjusting the price according to an escalation based on alumina production costs, or by combining the former two.

(3) Other raw material costs

The anode, which works as the positive electrode in the electrolysis, is made of coke and pitch. The prices of coke and pitch are determined as commercial market prices, which are in many cases calculated in reference to the price of oil depending upon their calorific value as energy source. The quantity consumed, which differs according to the type of electrolytic furnace, averages 400 to 450 kg for coke and 100 to 150 kg for pitch per tonne of aluminum produced. Therefore these costs are also a significant factor.

The fluoride which functions as the electrolyte in the electrolysis process consists of aluminum fluoride, cryolite etc. Their prices are determined as commercial market prices.

(4) Other direct costs

Other direct costs consist of labor costs, maintenance costs etc. as in the cases of all other manufacturing industries. In the aluminum smelting industry, which is a capital intensive industry, however, labor costs share only a small portion of the total cost. Nevertheless, the degree of skill of the workers still greatly affects operational performance in the present technology, and therefore it is important to secure a labor force with a certain quality. Because the level of skill of the workforce also influences the amount of maintenance cost, careful attention should be paid to this aspect.

In addition to the ordinary maintenance costs, pot reconstruction costs must also be considered as separate cost elements for aluminum smelters. A large number of electrolytic furnaces are installed in the potrooms [1] and on reaching the end of their life, each pot must be replaced by a new pot. The pot reconstruction cost, being the cost required for the replacement of pots which have reached the end of their life span, can recently reach approximately US$7,000 per pot, which represents a considerable amount. Therefore, technological efforts have been made to achieve longer pot life, shorter period of pot replacement and improvement in the replacement methods. Careful control of daily operation is also necessary.

3.2.2 Indirect costs

(1) Depreciation of capital cost

The capital cost of an aluminum smelter mentioned previously is first reflected in aluminum production costs in terms of depreciation cost. The depreciation cost, being calculated from the capital cost based on a certain formula, varies depending upon the variation in such formula, which is established by the various accounting principles and taxation systems in each country or the various accounting methods in each company. Furthermore, since depreciation cost is the cost which does not require the outflow of funds, it affects the financial position of each company or, on the contrary, the financial position of the company determines the depreciation cost calculation.

Although depreciation cost is a cost element which varies according to different depreciation methods as explained above, it is basically fixed by the actual capital cost.

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1) In recent cases, the number of pots installed in a potline reach as many as 240.

Consequently, it holds a large share in the production cost for the recently built plants due to the rise in capital cost. In addition, as with other fixed costs, depreciation cost is greatly affected by the plant operating rate. For example, in the case of the 20-year straight line method at a plant having a capital cost of US$4,000 per tonne of annual aluminum production, full production results in a depreciation cost of US$200 per tonne of aluminum produced, but this figure changes with declining rate of operation as follows:

Operating rate	100%	90%	80%	70%	60%	50%
Depreciation cost US$ per tonne	200	222	250	286	333	400
Ratio to cost under full-capacity operation		1.11	1.25	1.43	1.67	2

From this viewpoint also, it is clear that stable and continuous operation is indispensable for reduction of the aluminum production cost.

(2) Interest on capital cost

The capital cost of an aluminum smelter is also reflected in the interest on capital cost in the aluminum production costs. As previously mentioned, the continuous rise in capital costs compels the production scale to expand to secure cost effectiveness, and accordingly, requires an increase in the total capital cost. As in the previous case, for example, of a project of capital cost of US$4,000 per tonne of annual aluminum output with a production capacity of 200,000 tonnes per year, the total capital cost required for the plant reaches as much as 800 million dollars. The scheme of financing the required funds determines the amount of interest on capital cost.

The required funds are financed as capital and borrowings, and the ratio of capital to borrowings is a factor greatly affecting interest cost on capital cost. This is because there is no interest payments on capital on which dividend is paid from profit, but interest is paid on borrowings.

Accordingly, the conditions of financing these borrowings constitute principal factors in determining interest on capital cost. The conditions are interest rate, repayment period, grace period, security etc. With the required funds increasing, it takes a long time to recover through operation the funds originally invested, and therefore, it is desirable that the repayment period for borrowings also lengthens. For ordinary commercial borrowings, the longer the repayment period, the higher the interest rate will generally be, so that the burden of interest payment increases. For this reason, the arrangement for long term low interest borrowings is particularly desirable. Required for this purpose is the arrangement of funds not only from commercial financial institutions, but also from special financial institutions which are established to promote industrial development, for example, government related bodies. This particularly applies to the construction of plants in the developing countries, because it is an unfortunate possibility that borrowing of its funds from commercial financial institutions is difficult or that their conditions imposed are more severe.

Furthermore, to facilitate large-scale financing, there are many instances where several companies, institutions and/or governments organize a consortium to promote a project, and the financial arrangement is made from a number of countries in different currencies. In this case, it must be noted that the relative strength and exchange rates of different currencies affect capital cost.

(3) Other costs

Other elements of aluminum production cost include, similarly to other manufacturing industries, general plant expenses and interest on working capital for inventory, accounts receivable and payable and others.

3.3 General Level of Production Cost

Now that the analysis has been made with regard to aluminum production cost above, the present world level of cost can be summarized here. In fact, such a summary is very difficult to make because in the case of such products as primary aluminum which has little differences in quality to form the basis of market competition, cost is not public knowledge. A quote in this regard: "The aluminum industry is particularly secretive regarding its costs" [1], is appropriate.

Fortunately, however, AME provides data giving estimates of these cost levels.

According to these data, world aluminum cost levels show a considerable variation. The direct costs shown in Table B-21 have a range of approximately US$700/T to US$2,200/T. If these data

1) AME, Vol. I, page 255

Table B-21 Estimated Direct Operating Costs for Smelters in 1968, 1975 and 1980

(US$/T)

	1968	1975	1980
Raw Materials:			
Alumina	95 - 148	220 - 265	309 - 463
Other	55 - 68	77 - 99	88 - 132
Total	150 - 216	297 - 364	397 - 595
Energy:			
Electricity	37 - 95	57 - 375	99 - 1,323 *
Other	n.a.- n.a.	5 - 7	9 - 13
Total	37 - 95	62 - 382	108 - 1,336
Other:			
Labor	66 - 88	172 - 198	88 - 121
Administration, etc.			132 - 165
Total	66 - 88	172 - 198	220 - 286
Total direct operating costs	253 - 399	531 - 944	725 - 2,217
Average US list price	562	882	1,521

* Most producers' costs are currently in the range of $309 - 463 /T although Japanese and some W. European costs are higher than $1,323 /T.

Source: AME

are correct, the difference amounts to the astonishing figure of as much as US$1,500/T.

The major part of the cost difference is caused by differences in electricity costs ranging from approximately US$100/T to US$1,300/T. While some areas are favored with especially lowcost electricity, others such as Japan and Western Europe have plants where electricity cost is more than US$1,300/T [1)] which results in such a large variation. The world level of electricity cost is regarded as being roughly between US$310/T and US$460/T. If electricity cost is taken at US$400/T as a world standard level (25 mill/kwh in terms of unit price of electricity), the direct cost component of aluminum production cost is estimated to be in the range of aproximately US$1,000 to US$1,300.

1) This is equal to approximately 85 mills/kWh in terms of unit power cost. As of 1982, such high-cost plants are already closed.

Table B-22 provides estimates of the total cost, including indirect costs and normal profit as well as direct costs, for three areas; the United States, Australia and the Caribbean countries. The costs in these areas are close to each other in the range of US$1,500/T to US$1,800/T, and their level is regarded as a rough indication of the world level.

Such differences in production cost represent by themselves differences in the competitiveness of the plants. In particular, a difference in electricity cost amounting to US$1,200/T is a determining factor. It is therefore worth repeating here that the aluminum smelting industry has to always pursue competitiveness through securing cheaper electricity. This trend itself is the principal motivation giving rise to the present structural changes in the aluminum industry.

4. Aluminum Cost Model and Competitiveness

With the aluminum production cost mentioned above as a background, aluminum cost models are analyzed below to assist in the

Table B-22 Estimated Production Costs for Hypothetical Greenfield Smelters in the United States, Australia and the Caribbean

US$/T Aluminum 1980

	USA	Australia	Caribbean
Alumina	415 - 457	384 - 421	403 - 445
Other raw materials	93 - 108	97 - 110	99 - 110
Electricity	412 - 454	284 - 313	293 - 320
Direct labor	95 - 104	104 - 115	99 - 110
General sales, administration & maintenance	134 - 143	132 - 146	141 - 156
Delivery	22 - 24	64 - 70	44 - 49
Variable production costs	1,171 - 1,290	1,065 - 1,175	1,080 - 1,190
Servicing of capital	390 - 430	405 - 445	531 - 587
Total costs (including normal profit)	1,561 - 1,720	1,470 - 1,620	1,611 - 1,777

Note : *In the original form of both* Tables B-21 and B-22, the AME data unit was US cents/lb. In the Tables above, however, on our own responsibility, the unit is converted into US$/T.

Source: AME

future exploitation of aluminum projects and discuss the conditions of competitive aluminum smelting plants.

4.1 Aluminum Production Cost Model

As an illustration out of various aluminum production cost models which can be considered, Monthly Bulletin of Federation of Economic Organizations ("The Monthly Bulletin") classifies aluminum smelting plants into the following types.[1]

a. Developed country, hydropower type
Located in developed industrial countries and based on favorable hydroelectric power source.

b. Developed country, non-hydropower type
Located in developed industrial countries and based on other energy sources than hydroelectric power.

c. Developing country type
Located in developing countries and based on hydroelectric power source or other generally favorable power sources.

These types are further classified into a case of existing plants and the other of newly-constructed plants. Regarding the developed country hydropower type, however, "Since potential sites for large hydroelectric power development have already become scarce, expansion of aluminum production by this type will be almost negligible" [2]. Therefore the case of a-type with new plants is not considered in our analysis.

The above classification is made on the basis of two main elements of aluminum production cost, i.e. electricity cost and capital cost. The concepts of this classification can be summarized as follows:

a. Capital cost varies in the first instance depending on the timing of construction. Consequently, it is necessary to distinguish between existing plants and new plants. Secondly, capital cost varies according to the plant location, in particular, the quality of infrastructure provided. In the study, therefore, plants located in developed countries must be separated from those located in developing countries.

b. Electricity cost is greatly affected by electricity supply sources, and therefore hydroelectric power is distinguished from non-hydro power, and non-hydro power is divided into oil-

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1) The Monthly Bulletin, April 1976, p. 51, 54-55.
2) The Monthly Bulletin, April 1976, p. 52

fired thermal power and other energy sources (coal, natural gas, nuclear power etc.). Furthermore, on the basis of the timing of construction of power plants or the timing of conclusion of electricity purchase contracts, the existing plants are also separated from the newly-built plants. Additionally, classifications based on unit power consumption will also be considered. In other words, consideration is given to the differences in the technical level between newly-built plants and existing plants and also to the differences in the skills of the workforce between the developed countries and the developing countries.

The Monthly Bulletin model illustrates the characteristics of aluminum smelting plants so clearly that they are easily comprehensible. According to the Monthly Bulletin classifications, estimates are made by applying the present cost levels to the respective models, as given in Table B-23.

Although the above is a model calculated on certain assumptions and does not represent the actual costs, it is still meaningful to make a comparison and evaluate each model.

Table B-23 Aluminum Cost Model

Capacity: 200,000 T/Y
(US$/T Aluminum)

	Existing Plant			New Plant	
	Developed country	Developing country	Developed country	Developed country	Developing country
	Hydro power	Hydro power	Oil-fired power	Non-Hydro power	Hydro power
Power	150	160	980	338	290
Alumina	478	478	478	478	478
Anode	220	220	220	220	220
Other raw materials	30	30	30	30	30
Subtotal	878	888	1,708	1,066	1,018
Depreciation	100	125	100	200	250
Interest on capital cost	75	94	75	150	188
Other costs	280	296	313	349	379
Total cost	1,333	1,403	2,196	1,765	1,835

The assumptions of this model are as follows:

a. Unit power consumption and electricity costs are estimated as follows:

	Existing Plant		New Plant	
	DC power consumption kWh/T	Cost of power US mill/kWh	DC power consumption kWh/T	Cost of power US mill/kWh
Developed country				
- Hydro power	15,000	10	-	-
- Non-Hydro power	14,000	70	13,500	25*
Developing country				
- Hydro power	16,000	10	14,500	20

* According to the latest OECD report of "Structural Changes in the Aluminum Industry - Examination of the Energy Aspects" (1982.11.24), cost at new coal-fired power stations in Australia was 16 to 23 mill/kWh.

b. Unit consumption of alumina is estimated at 1.95 tonnes/tonne of aluminum and its price is 14% of present ALCAN list price for primary aluminum, i.e. US$245/tonne of alumina. Such particular conditions as a new plant being close to bauxite resources, where alumina price is determined based on the degree of integration with bauxite development and alumina refinery, are excluded from this assumption.

c. Capital cost is estimated at US$2,000/tonne of annual aluminum production for existing plants in the developed countries, being an estimate as of 1976, and at US$4,000/tonne of annual aluminum production for new plants in the developed countries. A capital cost ratio of 1.25 is assumed for the capital cost in the developing countries against that in the developed countries, which capital cost for existing plants in the developing countries at US$2,500/tonne of annual aluminum production and for new plants' capital cost at US$5,000/tonne of annual aluminum production. Depreciation cost is estimated by the 20-year straight line method, and the operating rate is assumed as 100%. Interest cost is calculated at the interest rate of 10% p.a. based on equal installments during 20 year repayment period. In addition, capital is estimated at 25% of total funds required.

d. The costs for anode and other raw materials are based on 1982 prices.

e. Other costs including labor, maintenance, pot reconstruction, plant general expenses, interest on working capital etc. are assumed in principle on the basis of 1982 levels. For actual calculations, however, the following assumptions are made:

Maintenance cost: 3% of capital cost
Interest on working capital:
6 month inventory period at an interest rate of 8% p.a.

f. This model estimates only production costs without profits. Inclusion of profits requires the addition of 7 to 10% of capital cost to these figures.

As is clear in the above estimates, the production cost of the hydro type located in the developed countries is the lowest in the existing plants. The hydro type located in the developing countries comes next. The oil-fired thermal type is not competitive, and its cost is higher even when compared with new plants (coal-fired thermal or hydro type).

In the case of new plants, it can be concluded that the non-hydro type (coal-fired thermal or nuclear type) in the developed countries is more advantageous than the hydro type in the developing countries. Moreover, location in the developed countries not only provides lower capital cost than that in the developing countries, but also has definite advantages in all other aspects such as arrangement of infrastructure, operation stability, quality of workforce etc. with the exception of the electricity cost. If proximity to consumers is taken into consideration, location in the developed countries becomes even more advantageous.

In conclusion, cost competitiveness according to the above classification of aluminum smelting plants can be ranked as follows:

1. Existing plants - developed country location, hydro type
2. Existing plants - developing country location, hydro type
3. New plants - developed country location, non-hydro type
4. New plants - developing country location, hydro type
5. Existing plants - developed country location, oil-fired thermal type

In the case of new plants in the developed country location with the non-hydro type (coal or nuclear power), which ranks third, should the rising trend of energy prices continue, the prices of coal and uranium as fuels may increase and consequently the cost of electricity in this type may also rise. In contrast, rises in fuel costs have only a minor influence on operating costs for electricity generation based on hydroelectric power, once a power generation station has been fully constructed. Consequently, it should be taken into consideration that the developing country location hydro type, even if newly built, may possibly become advantageous in the future.

Furthermore, general betterment may be anticipated in a long term in the developing countries with regard to infrastructure and various conditions for industrial sites and special favorable measures by the government for financing the capital cost to promote industry development. Such betterment may reduce the advantage of the developed countries in the capital cost ratio little by little. This point, however, requires careful judgement, since even if such a situation can be expected in a long term, it is indeed a key for judging the competitiveness whether or not such results can be obtained rapidly in a medium term.

Althouth no estimate is made in this model, an additional category of existing plants in the developed country location of non-hydro (coal or natural gas) type is also included in the Monthly Bulletin classifications, which can perhaps be ranked between the second and the third above. On the other hand, it is difficult to rank another category of the existing plants in the developing country location of non-hydro (natural gas) type, because it is not possible to find out how natural gas price is valued by the country in question. For example, in case crude-oil-associated gas is used as fuel in the oil producing countries, it is possible to intentionally minimize the value of the associated gas. Taking into further consideration that the capital cost of a thermal power station is less than that of a hydroelectric power station, this type can be probably be placed above the second rank. Similar comment is applied to new plants located in the developing countries of non-hydro (natural gas) type and, depending upon the valuation of natural gas, this type may be higher than the third or fourth rank.

In addition, consideration should be given to the trend towards nuclear power generation in the developed countries. Although the capital cost is high with the nuclear power stations, it becomes obvious that the unit price of electricity from this source is relatively cheaper than other non-hydro energy sources. As has already been mentioned, nuclear power source, especially with the future possibility of the development of fast-breeder reactors, is a direction toward which the developed countries will move for their power source in the future. As has also been described, the rate of nationalization is high in the European countries from the standpoint of preservation of the domestic aluminum industry. Accordingly, should electricity relying on relatively cheap nuclear power be obtained in the developed countries, the new plants in the developed country location of nuclear power type will become a type worthy of full investigation under specific conditions. Although nuclear power cost of course cannot compete with hydroelectric power cost [1], the possibility for this type to achieve competitiveness with the third or fourth rank type is undeniable, if, taking the advantageous location of the developed countries into consideration, some measures are taken to narrow the differences in electricity cost.

In summary, it cannot be concluded that the developing country located hydro type, generally considered advantageous, is always the best choice for building a new aluminum smelter in the future. Somewhat conversely, it must be taken into full consideration that there are other competitive types; for example, at the present time, the developed country located coal-fired thermal type, the developing country located natural-gas-fired thermal type, and, in the near future, the developed country located nuclear power type. At present, the variations in electricity cost have brought about strong trends in world aluminum production, which have produced structural changes in the aluminum industry. However, as can be considered from a study of the above model, these trends do not always support a hypothesis that the developing country located hydro type new plants are absolutely advantageous.

4.2 Conditions of Competitive Aluminum Smelting Plant

A study of the above model, if traced in an adverse way, indicates the conditions of competitiveness of aluminum smelting plants. Since the sources of competitiveness have already been analyzed above, only the main points are stressed below:

a. Stable supply of cheap electricity and raw materials

As mentioned repeatedly above, it is important that electricity, alumina, carbon materials and other raw materials are supplied at cheap prices and in a stable manner.

b. Sufficient and low cost financing of necessary funds

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1) According to the Nihon Keizai Shinbun dated November 9, 1982, unit power generation cost in Japan by power source are as follows: (Generation cost at the power station, based on commencement of operation in 1983)

	yen/kWh	(US mill/kWh converted at 250 yen/US$)
Oil-fired	20	80
LNG-fired	19	76
Coal-fired	15	60
Nuclear	12	48

It is indispensable that huge amounts of funds are sufficiently financed at low cost. Particularly for the developing countries, it may be necessary that the arrangement of infrastructure and fiscal system are made from the national standpoint.

c. *Securing of stable market*

Irregular fluctuations in operating rate result in cost instability and consequent cost increases. To maintain stable operation, the securing of stable market is indispensable as well as stable supply of electricity and raw materials.

d. Others

*Such other conditions as the stable employment of high-*quality labor, the aquisition of advanced technology, a high-level plant maintenance system, the securing of effective transportation to market etc. are also necessary. In particular, in the developing countries, it is necessary to pay full attention to the quality of labor and plant maintenance system so that they do not cause problems to lose the fruits of development efforts.

Reference Table B-1 World Production of Bauxite

(1,000 tonnes)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Africa	2,134	2,215	2,333	2,878	3,188	2,288	3,557	3,641	4,847	8,640	9,508	12,236	11,893	12,694	13,093	14,302
Ghana	319	323	351	285	269	342	329	342	349	363	321	260	275	330	214	225
Guinea	1,600	1,609	1,639	2,118	2,459	2,490	2,630	2,600	3,800	7,600	8,466	11,316	10,871	11,648	12,199	13,311
Mozambique	6	6	6	3	4	7	8	5	5	5	5		2	-	-	-
Zimbabwe	2	2	2	2	2	-	-	-	-	-	-	-	-	-	-	-
Sierra Leone	207	275	335	470	454	449	590	694	693	672	716	660	745	716	680	766
North America	1,681	1,825	1,681	1,692	1,873	2,115	2,020	1,841	1,909	1,980	1,800	1,989	2,013	1,669	1,821	1,559
USA	1,681	1,825	1,681	1,692	1,873	2,115	2,020	1,841	1,909	1,980	1,800	1,989	2,013	1,669	1,821	1,559
Latin America	17,442	19,426	19,904	19,665	23,271	24,702	25,856	27,069	26,935	28,511	22,409	20,341	22,030	22,676	22,284	25,159
Brazil	188	250	303	285	351	510	566	765	849	858	969	998	1,040	1,131	1,642	4,152
Dominican Rep.	942	833	983	994	1,103	1,086	1,032	1,087	1,145	1,196	771	621	576	578	524	511
Guyana	2,919	3,358	3,381	3,723	4,306	4,417	4,233	3,668	3,622	3,606	3,828	3,108	3,344	3,479	3,354	3,052
Haiti	382	361	376	477	776	657	764	783	743	659	522	733	685	639	518	477
Jamaica	8,651	9,061	9,395	8,526	10,499	12,010	12,543	12,989	13,600	15,328	11,570	10,296	11,434	11,736	11,505	12,064
Surinam	4,360	5,563	5,466	5,660	6,236	6,022	6,718	7,777	6,976	6,864	4,749	4,585	4,951	5,113	4,741	4,903
South Asia	2,399	2,439	2,645	2,640	3,089	3,795	3,886	4,516	3,975	3,974	3,349	3,513	4,004	3,735	3,548	4,326
India	707	750	804	961	1,085	1,374	1,517	1,692	1,251	1,071	1,094	1,449	1,519	1,663	1,951	1,740
Indonesia	688	702	920	879	927	1,229	1,238	1,276	1,229	1,290	993	941	1,301	1,008	1,052	1,249
Malaysia	994	955	900	799	1,073	1,139	978	1,076	1,143	947	704	660	616	615	387	920
Pakistan	-	-	-	1	2	1		1		1			1	-	1	-
Turkey	10	32	21	-	2	52	153	471	352	665	558	463	567	449	157	417
Europe	5,764	6,490	6,853	6,846	7,098	7,656	8,202	8,100	7,945	8,145	7,916	6,952	7,029	7,242	7,853	8,349
France	2,664	2,811	2,813	2,713	2,797	3,051	3,183	3,402	2,970	2,950	2,563	2,330	2,059	1,978	1,970	1,892
Germany, Fed. Rep.	4	4	2	3	3	3	3	2	2	1	1		-	-	-	-
Greece	1,274	1,529	1,661	1,836	1,948	2,292	2,861	2,409	2,748	2,783	3,006	2,551	2,882	2,664	2,837	3,286
Italy	244	255	241	216	217	206	191	84	50	32	32	24	34	24	26	23
Spain	4	4	5	6	5	5	5	6	8	9	8	14	10	10	8	10
Yugoslavia	1,574	1,887	2,131	2,072	2,128	2,099	1,959	2,197	2,167	2,370	2,306	2,033	2,044	2,566	3,012	3,138
Oceania	1,186	1,827	4,244	4,955	7,921	9,256	12,733	14,437	17,596	19,995	21,034	24,084	26,086	24,293	27,585	27,178
Australia	1,186	1,827	4,244	4,955	7,921	9,256	12,733	14,437	17,596	19,995	21,034	24,084	26,086	24,293	27,585	27,178
Free world	30,606	34,222	37,660	38,676	46,440	50,812	56,254	59,604	63,207	71,245	66,016	69,115	73,055	72,309	76,184	80,873
China (Mainland)	400	400	400	400	450	600	650	700	800	900	1,000	1,100	1,200	1,400	1,500	1,700
Hungary	1,478	1,429	1,649	1,959	1,936	2,022	2,090	2,358	2,600	2,751	2,890	2,918	2,949	2,900	2,976	2,950
Romania	108	206	460	595	632	776	899	894	900	817	779	680	702	708	710	700
USSR	4,700	4,800	5,000	5,000	5,200	6,500	7,000	7,400	7,900	8,400	6,600	6,700	6,700	6,700	6,500	6,400
C.P. Economies	6,686	6,835	7,509	7,954	8,218	9,898	10,639	11,352	12,200	12,868	11,269	11,398	11,551	11,708	11,686	11,750
World Total	37,292	41,057	45,169	46,630	54,658	60,710	66,893	70,956	75,407	84,113	77,285	80,513	84,606	84,017	87,870	92,623

Source: Metal Statistics, 1965-1975, 1970-1980

Reference Table B-2 World Production of Alumina

(1,000 tonnes)

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Africa	525	530	542	577	610	661	663	615	636	639	552	562	622	662	708
Guinea	525	530	542	577	610	661	663	615	636	639	552	562	622	662	708
North America	6,210	6,582	6,489	7,283	7,156	7,078	7,263	7,796	8,150	6,269	6,296	7,291	7,184	7,479	8,212
Canada	900	1,000	1,000	1,005	1,105	1,140	1,149	1,134	1,265	1,134	490	1,061	1,054	824	1,202
USA	5,310	5,582	5,489	6,278	6,051	5,938	6,114	6,662	6,885	5,135	5,806	6,230	6,130	6,655	7,010
Latin America	1,581	1,939	2,167	2,519	3,191	3,625	3,922	4,356	4,615	3,969	3,392	3,880	4,004	4,114	4,637
Brazil	68	87	81	87	119	167	192	201	240	268	306	341	352	449	506
Guyana	302	273	269	270	317	305	265	269	316	294	285	277	250	280	296
Jamaica	804	838	925	1,202	1,719	1,876	2,087	2,506	2,874	2,259	1,639	2,047	2,141	2,074	2,395
Surinam	407	741	892	960	1,036	1,277	1,378	1,380	1,185	1,148	1,162	1,215	1,261	1,311	1,440
East Asia	697	741	864	1,105	1,327	1,646	1,697	2,042	1,846	1,611	1,710	2,096	1,818	1,881	2,298
China (Taiwan)	35	31	37	41	42	43	53	55	45	46	48	51	51	59	80
Japan	662	710	827	1,064	1,285	1,603	1,644	1,987	1,801	1,565	1,662	2,045	1,767	1,822	2,218
South Asia	170	200	240	270	327	362	447	459	423	419	581	557	562	575	650
India	170	200	240	270	327	362	363	350	299	337	442	387	488	500	512
Turkey	-	-	-	-	-	-	84	109	124	82	139	170	74	75	138
Europe	2,019	2,272	2,371	2,490	2,619	2,832	2,943	3,362	3,969	3,872	4,157	4,394	4,664	5,052	5,771
France	845	920	952	991	1,004	1,046	1,112	1,112	1,107	1,089	1,013	1,081	1,221	1,239	1,339
Germany, Fed. Rep.	603	633	652	680	757	837	916	922	1,307	1,246	1,333	1,454	1,555	1,539	1,608
Greece	73	181	223	287	313	464	467	470	498	475	462	474	478	496	505
Italy	269	286	294	292	313	263	206	486	689	697	798	788	819	854	900
Norway	15	16	15	12	-	-	-	-	-	-	-	-	-	-	-
Spain	-	-	-	-	-	-	-	-	-	-	-	-	-	-	62
UK	119	135	117	106	107	99	116	97	95	82	96	98	94	88	102
Yugoslavia	95	101	118	122	125	123	126	275	273	283	455	499	497	836	1,255
Oceania	307	854	1,310	1,931	2,152	2,713	3,068	4,089	4,900	5,129	6,206	6,659	6,776	7,415	7,247
Australia	307	854	1,310	1,931	2,152	2,713	3,068	4,089	4,900	5,129	6,206	6,659	6,776	7,415	7,247
Free world	11,509	13,118	13,983	16,175	17,382	18,917	20,003	22,719	24,539	21,908	22,894	25,439	25,630	27,178	29,523
China (Mainland)	180	180	240	260	350	400	400	450	500	500	600	650	700	800	800
Czechoslovakia	60	60	60	70	70	75	85	95	100	100	90	95	90	90	90
Germany, DR	51	51	54	53	55	47	45	47	48	48	44	39	38	41	47
Hungary	289	328	381	408	441	467	520	655	691	756	732	786	785	818	833
Romania	95	105	155	180	200	220	200	282	374	368	425	442	449	502	510
USSR	2,600	2,600	2,600	2,600	2,700	2,750	2,850	3,100	3,000	3,000	3,200	3,250	3,300	3,200	3,250
C.P. Economies	3,275	3,324	3,490	3,571	3,816	3,959	4,100	4,629	4,713	4,772	5,091	5,262	5,362	5,451	5,530
World Total	14,784	16,442	17,473	19,746	21,198	22,876	24,103	27,348	29,252	26,680	27,985	30,701	30,992	32,629	35,053

Source: Metal Statistics, 1965-1975, 1970-1980

Reference Table B-3 World Production of Primary Aluminum

(1,000 tonnes)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Africa	50	48	99	156	160	165	191	232	249	279	273	337	368	336	401	437	483
Cameroon	50	48	48	45	47	52	51	46	44	47	52	49	46	41	45	43	65
Egypt	-	-	-	-	-	-	-	-	-	-	2	59	90	100	101	120	142
Ghana	-	-	51	111	113	113	111	133	152	157	143	151	154	114	169	188	191
South Africa	-	-	-	-	-	-	29	53	53	75	76	78	78	81	86	86	85
North America	3,252	3,500	3,840	3,841	4,420	4,570	4,563	4,647	5,039	5,472	4,397	4,485	5,091	5,406	5,421	5,728	5,607
Canada	753	807	874	888	979	963	1,002	907	930	1,024	878	628	973	1,048	864	1,074	1,118
USA	2,499	2,693	2,966	2,953	3,441	3,607	3,561	3,740	4,109	4,448	3,519	3,857	4,118	4,358	4,557	4,654	4,489
Latin America	53	76	84	118	141	167	197	209	227	254	268	317	359	420	694	824	787
Argentina	-	-	-	-	-	-	-	-	-	1	22	43	50	50	125	137	134
Brazil	30	27	30	41	43	56	81	97	112	114	121	139	167	186	239	261	257
Mexico	19	21	21	23	32	34	40	40	39	41	40	42	43	43	43	43	43
Surinam	4	28	31	44	53	55	54	49	51	57	35	46	56	57	60	55	41
Venezuela	-	-	2	10	13	22	22	23	25	41	50	47	43	84	227	328	312
East Asia	311	352	394	498	594	772	932	1,056	1,149	1,168	1,059	963	1,235	1,126	1,084	1,171	818
China (Taiwan)	19	17	15	20	22	27	27	32	35	31	28	26	30	50	56	62	30
Japan	292	335	379	478	565	728	887	1,009	1,097	1,119	1,013	919	1,188	1,058	1,010	1,091	771
Korea, Rep. of	-	-	-	-	7	17	18	15	17	18	18	18	17	18	18	18	17
South Asia	64	84	97	120	132	161	188	249	290	297	347	399	378	386	370	396	517
Bahrain	-	-	-	-	-	-	10	63	102	118	116	122	122	123	126	126	141
India	64	84	97	120	132	161	178	179	154	128	167	209	184	205	201	185	213
Iran	-	-	-	-	-	-	-	7	34	49	46	31	21	26	11	16	16
Turkey	-	-	-	-	-	-	-	-	-	2	18	37	51	32	32	34	40
United Arab Emirates	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35	107
Europe	1,277	1,440	1,553	1,752	1,865	2,015	2,304	2,518	2,851	3,297	3,231	3,334	3,469	3,524	3,592	3,762	3,725
Austria	79	79	79	86	90	90	91	84	89	92	89	89	92	91	93	94	94
France	340	363	361	366	371	381	384	394	359	393	383	385	399	391	395	432	435
Germany, Fed. Rep.	234	244	253	258	263	309	427	444	533	689	678	697	742	740	742	731	729
Greece	-	36	72	77	83	87	116	131	143	147	135	134	130	144	141	146	146
Iceland	-	-	-	-	9	39	42	46	72	70	62	65	73	74	72	75	75
Italy	124	128	128	142	145	147	136	149	184	212	190	206	260	271	269	271	274
Netherlands	-	19	32	47	69	75	116	163	182	247	258	249	237	259	256	258	262
Norway	276	330	361	468	503	522	530	557	618	648	595	618	637	657	673	662	636
Spain	52	64	78	89	106	120	126	145	160	190	210	214	212	212	259	386	397
Sweden	30	29	33	57	67	66	76	78	83	82	78	82	82	82	82	82	83
Switzerland	67	69	72	76	77	91	94	83	85	87	79	78	80	80	83	86	82
UK	36	37	39	38	34	40	119	171	252	293	308	334	349	346	359	374	339
Yugoslavia	39	42	45	48	48	48	47	73	91	147	166	183	176	177	168	165	173

Reference Table B-3 (cont'd.)

(1,000 tonnes)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Oceania	88	92	93	97	126	206	246	294	324	329	323	372	393	415	424	460	535
Australia	88	92	93	97	126	206	224	206	207	219	214	232	248	264	270	304	380
New Zealand	-	-	-	-	-	-	22	88	117	110	109	140	145	151	154	156	155
Free World	5,095	5,592	6,160	6,582	7,438	8,056	8,621	9,205	10,129	11,096	9,898	10,207	11,293	11,613	11,986	12,778	12,472
China (Mainland)	90	90	90	120	130	180	210	250	280	280	300	320	350	360	360	350	350
Czechoslovakia	23	24	26	32	35	40	37	43	48	50	43	36	37	37	37	38	38
German Dem. Rep.	50	40	50	48	55	60	55	55	60	60	60	60	65	65	60	60	60
Hungary	58	61	62	63	64	66	67	68	68	69	70	71	71	71	72	74	74
North Korea	-	-	-	-	-	-	-	-	10	10	10	10	10	10	10	8	10
Poland	47	55	92	94	97	99	100	102	101	102	103	103	104	100	96	95	66
Romania	23	47	53	76	90	101	111	121	141	187	204	207	209	213	217	241	230
USSR	1,200	1,300	1,400	1,500	1,550	1,700	1,800	1,900	2,000	2,100	2,150	2,200	2,200	2,300	2,350	2,420	2,400
C.P. Economies	1,491	1,617	1,773	1,933	2,021	2,246	2,380	2,539	2,708	2,858	2,940	3,007	3,046	3,156	3,202	3,286	3,228
World Total	6,586	7,209	7,933	8,515	9,459	10,302	11,001	11,744	12,837	13,954	12,838	13,214	14,339	14,769	15,188	16,064	15,700

Source: Metal Statistics, 1965-1975, 1970-1980 and Metal Statistics Preliminary Figures 1981

Reference Table B-4-1 Bauxite/Alumina: Balance of Supply and Demand for Main Producing Countries: 1981

Bauxite Surplus Countries

(1,000 MT)

Bauxite producing country	Alumina production capacity	Bauxite unit consumption	Bauxite demand	Bauxite production capacity	Bauxite surplus
Australia					
Weipa	2,440	2.15	5,250	11,000	5,750
Darling Ranges	4,000	3.31	13,240	14,250	1,010
Gove	1,100	2.44	2,680	5,100	2,420
Subtotal	7,540		21,170	30,350	9,180
Guinea	690	2.1	1,450	13,700	12,250
Jamaica	2,990	2.5	7,480	14,170	6,690
Sierra Leone	-	-	-	800	800
Dominica	-	-	-	1,400	1,400
Surinam	1,330	2.2	2,930	7,500	4,570
Guyana	320	2.1	670	4,500	3,830
Brazil	480	2.2	1,060	4,980	3,920
Greece	500	2.3	1,150	5,400	4,250
Yugoslavia	1,540	2.3	3,500	4,210	710
India	680	2.2	1,500	1,950	450
Malaysia	-	-	-	750	750
Indonesia	-	-	-	1,260	1,260
Total	16,070	(2.55)	40,910	90,970	50,060

Bauxite Shortfall Countries

(1,000 MT)

Alumina producing country	Alumina production capacity	Bauxite unit consumption	Bauxite demand	Bauxite production capacity	Bauxite shortfall
USA	7,300	2.4	17,500	2,000	15,500
Canada	1,230	2.3	2,830	-	2,830
Japan	2,640	2.3	6,070	-	6,070
Germany, FR	1,640	2.25	3,690	-	3,690
France	1,320	2.2	2,900	1,800	1,100
Italy	800	2.15	1,720	-	1,720
Spain	800	2.2	1,760	-	1,760
USSR	4,790	2.7	12,900	12,500	400
China	850	2.5	2,100	1,800	300
UK	130	2.2	290	-	290
Total	21,500	(2.4)	51,760	18,100	33,660

Reference Table B-4-2 Alumina/Primary Aluminum: Balance of Supply and Demand for Main Producing Countries: 1981

Alumina Surplus Countries

(1,000 MT)

Alumina producing country	Primary aluminum production capacity	Alumina unit consumption	Alumina demand	Alumina production capacity	Alumina surplus
Australia	370	1.95	720	7,540	6,820
Japan	615		1,200	2,640	1,440
Yugoslavia	380		740	1,540	800
France	450		880	1,320	440
Germany, FR	740		1,440	1,640	200
Italy	280		550	800	250
Guinea	-		-	690	690
Jamaica	-		-	2,990	2,990
Surinam	70		140	1,330	1,190
Guyana	-		-	320	320
Hungary	75		150	900	750
Total	2,980		5,820	21,710	15,890

Alumina Shortfall Countries

(1,000 MT)

Primary aluminum producing country	Primary aluminum production capacity	Alumina unit consumption	Alumina demand	Alumina production capacity	Alumina shortfall
USA	4,960	1.95	9,670	7,300	2,370
Canada	1,180		2,300	1,230	1,070
Norway	800		1,560	-	1,560
UK	390		760	130	630
Netherlands	270		530	-	530
Switzerland	90		180	-	180
Iceland	90		180	-	180
Bahrain	170		330	-	330
Dubai	130		250	-	250
Argentina	140		270	-	270
Venezuela	400		780	-	780
Ghana	200		390	-	390
New Zealand	230		450	-	450
Egypt	170		330	-	330
South Africa	170		330	-	330
USSR	3,130		6,100	4,790	1,310
Total	12,520		24,410	13,450	10,960

Note : Only bauxite for alumina and alumina for aluminum smelting are regarded as demand. Operating rate is estimated at 100%. Countries not listed by AME are added by the writer.

Source: AME

Reference Table B-5-1 Primary Aluminum: Balance of Supply and Demand (1977)

Main Surplus Countries

(1,000 tonnes)

Country	Production	Consumption	Surplus
Canada	973	332	641
Norway	637	96	541
USSR	2,200	1,760	440
Ghana	154	0	154
Netherlands	237	102	135
New Zealand	145	23	122
Bahrain	122	9	113
Australia	248	170	78
Greece	130	57	73
Iceland	73	0	73
Egypt	90	30	60
Romania	209	149	60
Surinam	56	0	56
South Africa	78	53	25
Cameroon	46	23	23
Yugoslavia	176	154	22
Korea, Dem. Rep.	10	0	10
Total	5,584	2,958	2,626

Main Shortfall Countries

(1,000 MT)

Country	Production	Consumption	Shortfall
USA	4,118	4,756	638
Belgium	0	235	235
Japan	1,188	1,420	232
Germany, FR	742	912	170
China (Mainland)	350	510	160
German DR	65	215	150
France	399	534	135
Italy	260	382	122
Hungary	71	169	98
Czechoslovakia	37	125	88
UK	349	419	70
Brazil	167	230	63
Korea, Rep. of	17	75	58
Poland	104	149	45
Bulgaria	0	45	45
Spain	212	251	39
China (Taiwan)	30	68	38
Switzerland	80	110	30
Thailand	0	29	29
Finland	0	29	29
Total	8,189	10,663	2,474

Note : Total world production 14,339 - Total world consumption 14,526 ≈ Total world shortfall - 187

Source: Metal Statistics, 1970-80

Reference Table B-5-2 Primary Aluminum: Balance of Supply and Demand (1981)

Main Surplus Countries

(1,000 MT)

Country	Production	Consumption	Surplus
Canada	1,118	299	819
USSR	2,400	1,860	540
Norway	636	111	525
USA	4,489	4,140	349
Venezuela	312	74	238
Spain	397	202	195
Ghana	191	0	191
Netherlands	262	73	189
Australia	380	235	145
New Zealand	155	27	128
Bahrain	141	17	124
United Arab Emirates	107	0	107
Egypt	142	45	97
Romania	230	140	90
Argentina	134	53	81
Greece	146	66	80
Iceland	75	0	75
Surinam	41	0	41
Cameroon	65	28	37
Brazil	257	241	16
Total	11,678	7,611	4,067

Main Shortfall Countries

(1,000 MT)

Country	Production	Consumption	Shortfall
Japan	771	1,567	796
Germany, Fed. Rep.	729	1,022	293
Belgium	0	215	215
China (Mainland)	350	560	210
German Dem. Rep.	60	240	180
Italy	274	413	139
France	435	539	104
Rep. of Korea	17	112	95
Czechoslovakia	38	125	87
Poland	66	142	76
Hungary	74	143	69
Mexico	43	110	67
Bulgaria	0	50	50
China (Taiwan)	30	78	48
Thailand	0	45	45
Portugal	0	42	42
India	213	250	37
Turkey	40	75	35
Finland	0	30	30
Iraq	0	26	26
Total	3,140	5,784	2,644

Note : Total world production 15,700 − Total world consumption 14,549 = Total world surplus 1,151

Source: Metal Statistics, 1970-80

Reference Table B-6-1 Bauxite Mining Companies Related to Six Major Producers (1981)
[Ownership percentage shown in ( )]

(1,000 tonnes)

Producing country	ALCOA		ALCAN		Kaiser		Reynolds		Pechiney		ALUSUISSE	
France			SA. des Bauxites et Alumines de Province (100)	400					Aluminium Pechiney (100)	1,400	Alusuisse France (100)	400
Italy												
Greece									Bauxites Helleniques de Distomon (53)	300		
India			Indian Aluminium Co.(INDAL)(55)	500								
Ghana												
Malaysia			Johore Mining & Stevedoring Co. (53)	750								
Guinea	Guinea Bauxite Co. (13.77)	9,000	Guinea Bauxite Co. (13.77)	9,000					Friguia (18.6) Guinea Bauxite Co. (5.1)	3,000 9,000	Friguia (5.1)	3,000
Cameroon												
Sierra Leone											Sierra Leone Ore & Metal Co.(100)	700
Jamaica	ALCOA Minerals of Jamaica (94) (JAMALCO)	1,270	ALCAN Jamaica Ltd. (JAMALCAN) (93)	2,700	Kaiser Bauxite Co. (49) Aluminium Partners of Jamaica (ALPART) (36.5)	4,200 3,100	Jamaica Reynolds Bauxite Co. (49) Aluminium Partners of Jamaica (ALPART) (36.5)	3,200 3,100				
Surinam	Surinam Aluminium Co. (SURALCO) (100)	4,500										

Reference Table B-6-1 (cont'd.)

(1,000 tonnes)

Producing country	ALCOA	ALCAN	Kaiser	Reynolds	Pechiney	ALUSUISSE
Dominican Republic	ALCOA Exploration Co. (100) 600					
Brazil	Cia. Mineira do Aluminio (100) (ALUCOMINAS) 600	Aluminio Pacos do Caldas SA (100) 600 Mineracao Rio do Norte (19) 3,400		Mineracao Rio do Norte (5) 3,400		
Haiti				Reynolds Haitian Mines Inc. (100) 900		
Guyana						
USA	ALCOA Mining Co. (100) 850			Reynolds Mining Co. (100) 900		
Australia	ALCOA of Australia (51) 13,500		Comalco Ltd. (45) 9,600			Nabalco Pty. Ltd. (70) 5,000
Total capacity calculated by ownership percentage	15,900	6,100	7,500	4,700	2,600	4,800

Note : Six Major Producers total capacity: 41,600 Free world total capacity: 95,700 (Share 43%)

Source: UNCTAD Report, 1981

Reference Table B-6-2 Alumina Producing Companies Related to Six Major Producers (1981)
[Ownership percentage shown in ( )]

(1,000 tonnes)

Producing country	ALCOA		ALCAN		Kaiser		Reynolds		Pechiney		ALUSUISSE	
France									Aluminium Pechiney (100)	1,320		
Italy					Euroallumina (8) (Comalco 18x45=8)	720						
Greece									Aluminium de Grece (73)	500		
Germany, Fed. Rep.			ALCAN Aluminium-Werke GMBH (100)	150			Aluminium Oxid Stade GMBH (50)	600			Martinswerk (99)	350
India			INDAL (55)	240								
Guinea									Friguia (18.6) (Frialco 51x 36.5)	700	Friguia (5.1) (Frialco 51x10)	700
Jamaica	JAMALCO (94)	550	JAMALCAN (93)	1,100	ALPART (36.5)	1,130	ALPART (36.5)	1,130				
Surinam	SURALCO (100)	1,320										
Brazil	ALCOMINAS (50)	220	ALCAN Aluminio do Brasil (100)	120								
Guyana												
USA	ALCOA (100)	2,450			Kaiser (100)	1,660	Reynolds (100)	2,000			Ormet Corp. (50)	600
Canada			ALCAN (100)	1,250								
Japan			Nippon Light Metal (50)	870								
Australia	ALCOA of Australia (51)	3,800	Queensland Alumina Ltd. (QAL) (21.4)	2,400	QAL (41.9)	2,400			QAL (20)	2,400	Nabalco Pty. Ltd. (70)	1,000
Total capacity calculated by ownership percentage		6,330		3,620		3,130		2,710		2,300		1,380

Note : Six "Major Producers" total capacity: 19,470 Free world total capacity: 30,600 (Share 64%)
[illegible]

Reference Table B-6-3 Aluminum Smelting Companies Related to Six Major Producers
[Ownership percentage shown in ( )]

(1,000 tonnes)

Producing Country	ALCOA	ALCAN	Kaiser	Reynolds	Pechiney	ALUSUISSE
France					Aluminium Pechiney (100) 447	
Italy						Aluminio Veneto (50) 60
Greece					Aluminium de Grece (100) 143	
Germany, Fed. Rep.		ALCAN Aluminium-Werke GMBH (100) 44	Kaiser Aluminium Europe Inc.(100) 72	Hamburger Al.-Werke GMBH (33.3) 100		Leichtmetall-Gesellschaft GMBH. (100) 133 Aluminium-Hutte Rheinfelden GMBH (100) 64
UK		ALCAN Aluminium (UK) Ltd. (100) 125	Anglesey Aluminium Ltd. (66.7) 113			
Netherlands					Pechiney Nederland NV. (85) 170	
Switzerland						Swiss Aluminium Co. Ltd. (100) 76
Austria						Salzburger Aluminium GMBH(100) 12
Spain		Empresa Nacional de Aluminio SA. (Endasa) (42.69) 125 Aluminio Español SA. (23.4) 190			Aluminio Español SA. (20) 190 Aluminio de Galicia SA. (67) 92	
Norway	Elkem A/S (45) 177					Sor-Norge Aluminium A/S (75) 70

Reference Table B-6-3 (cont'd.)

(1,000 tonnes)

Producing Country	ALCOA		ALCAN		Kaiser		Reynolds		Pechiney		ALUSUISSE	
Iceland											Icelandic Aluminium Co. Ltd. (100)	88
Bahrain					Aluminium Bahrain Ltd. (17)	170						
South Africa											Alusaf (Pty) Ltd. (22)	86
Ghana					Volta Alu Co. Ltd. (90)	200	Volta Aluminium Co. Ltd. (10)	200				
Cameroon									ALCAN (100)	81		
India			INDAL (55.27)	118	Hindustan Aluminium Corp. (26.7)	110						
Japan			Nippon Light Metal (50)	136								
Korea									Aluminium of Korea Ltd. (50)	18		
Canada			Aluminium Co. of Canada Ltd. (100)	1,018			Canadian Reynolds Co. Ltd. (100)	159	Howmet Corp. (100)	-		
USA	Aluminam Co. of America (100)	1,565			Kaiser Aluminum & Chemical Corp. (100)	657	Reynolds Metals Co. (100)	885	Howmet Corp. (100)	204	Consolidated Aluminum Corp. (100)	281
Mexico	Aluminio S.A. de C.V. (44.3)	45										
Venezuela							Aluminio del Caroni SA.(28)	120				
Surinam	SURALCO (100)	66										

Reference Table B-6-3 (cont'd.)

(1,000 tonnes)

Producing Country	ALCOA		ALCAN		Kaiser		Reynolds		Pechiney		ALUSUISSE
Brazil	ALCOMINAS (68)	90	ALCAN Aluminio do Brasil SA. (100)	60			Valesul Aluminio S.A. (5)	-			
		-	Aluminio do Brasil Nordeste SA. (100)	28							
Australia	ALCOA of Australia (51)	169	ALCAN Australia Ltd. (70)	90	Comalco Ltd. (45)	120			Tomago Aluminium Ltd. (35)	-	
					Boyne Smelters Ltd.(33.5)	-					
New Zealand					New Zealand Aluminium Smelters Ltd. (22.5)	155					
Total capacity		2,112		1,934		1,597		1,464		1,345	870
Total capacity calculated by ownership percentage		1,878		1,569		1,132		1,131		1,129	756
Share in free world		13.1		10.9		7.9		7.9		7.8	5.3

Note : Six Major Producers total capacity: 7,595 Free world total capacity: 14,370 (Share 53%)

Source: Spector Report

Reference Table B-7 Percentage Share of Government-Owned Companies in Free World Production Capacity

Region	Country	Bauxite	Alumina	Primary aluminum		
		1980	1980	1970	1975	1980
Africa	Ghana	55	x	-	-	-
	Guinea	58	49	x	x	x
	Cameroon	x	x	42	42	25
	Egypt	x	x	x	x	100
	South Africa	x	x	x	66	66
	Sierra Leone	-	x	x	x	x
	Total	(55)	(49)	(12)	(33)	(48)
South Asia	Bahrain	x	x	x	78	78
	Dubai	x	x	x	x	80
	Turkey	100	100	x	100	100
	Iran	x	x	x	95	95
	India	18	36	7	7	33
	Indonesia	100	x	x	x	x
	Malaysia	-	x	x	x	x
	Total	(48)	(50)	(7)	(49)	(61)
East Asia	Korea, Rep. of	x	x	x	-	-
	Taiwan	x	100	100	100	100
	Japan	x	-	-	-	-
	Total	(x)	(4)	(10)	(6)	(12)
Latin America	Brazil	37	8	13	7	7
	Argentina	x	x	x	x	51
	Venezuela	x	x	72	72	76
	Surinam	-	-	-	-	-
	Dominican Rep.	-	x	x	x	x
	Guyana	100	100	x	x	x
	Jamaica	28	4	x	x	x
	Mexico	x	x	-	-	-
	Total	(31)	(9)	(27)	(20)	(42)
North America	USA	-	-	-	-	-
	Canada	x	-	-	-	-
	Total	(-)	(-)	(-)	(-)	(-)

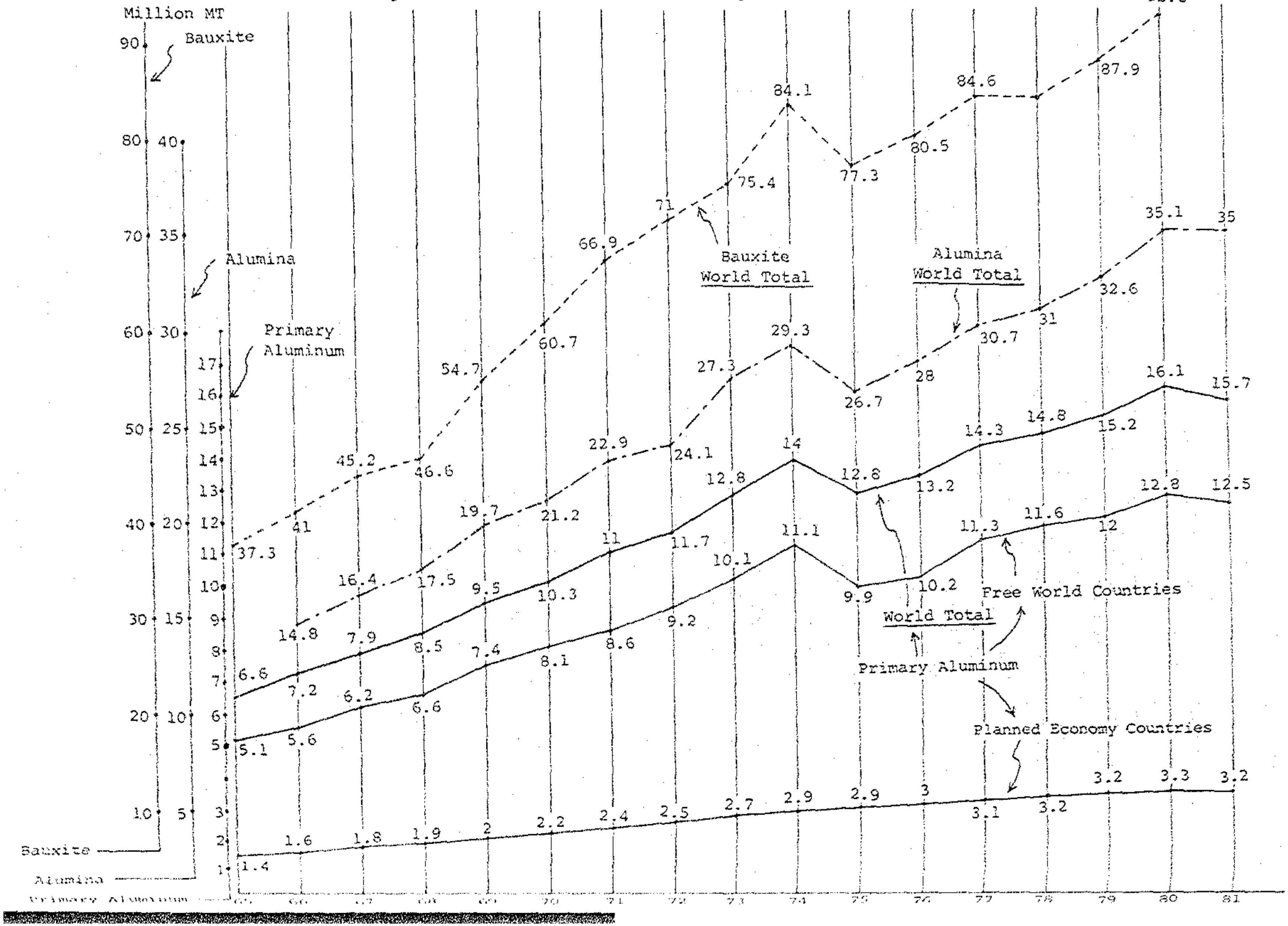
Unit : Weighted average percentage by country
x : No production
- : No share of government-owned companies
Total: Weighted average

Reference Table B-7 (cont'd.)

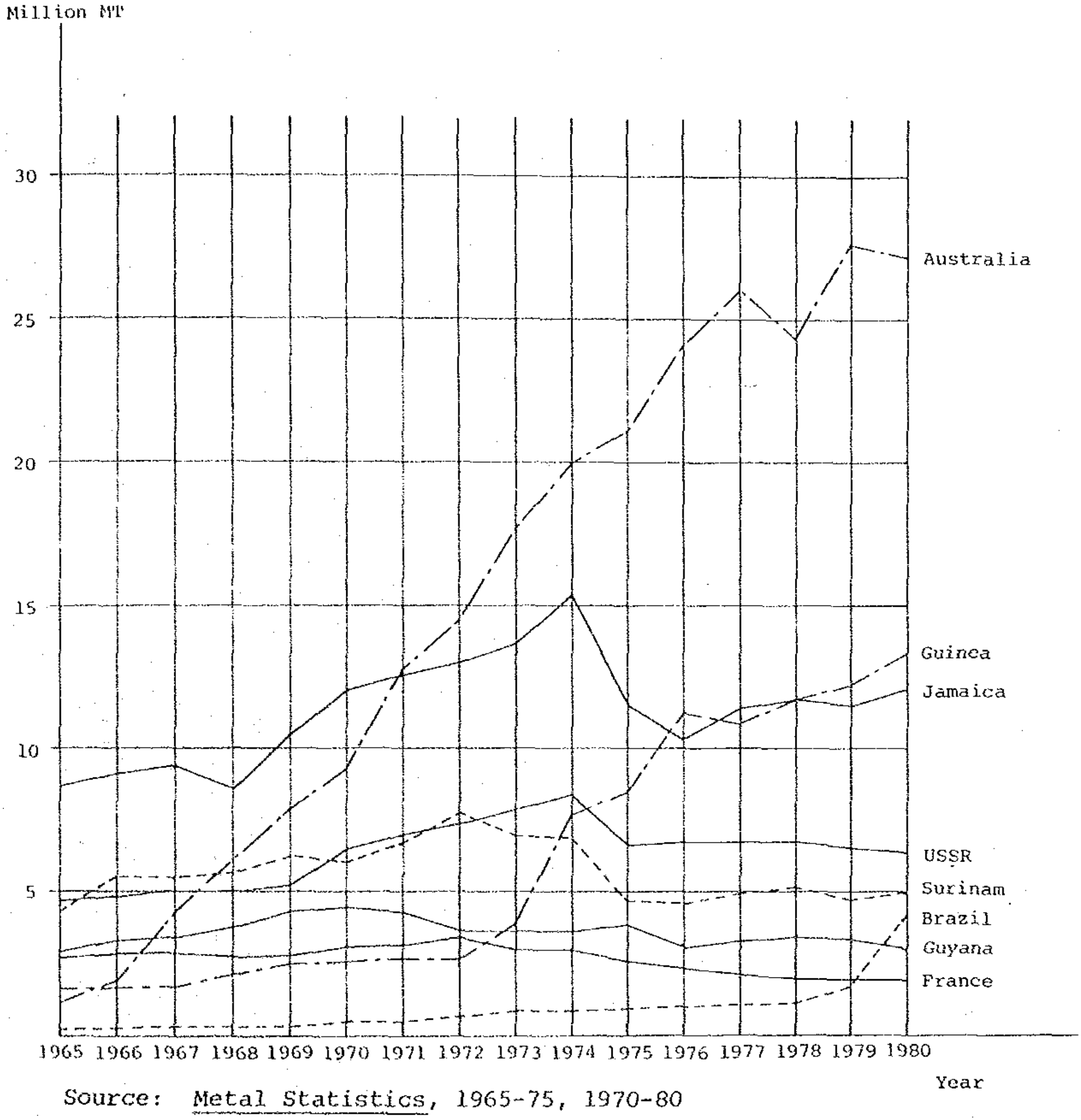
Region	Country	Bauxite	Alumina	Primary aluminum		
		1980	1980	1970	1975	1980
Europe	France	-	-	-	-	-
	Greece	-	30	30	30	30
	Italy	-	57	74	89	89
	Spain	-	30	43	43	48
	Germany, FR	x	52	71	58	58
	UK	x	-	-	-	
	Austria	x	x	87	87	87
	Iceland	x	x	-	-	-
	Sweden	x	x	-	-	-
	Netherlands	x	x	-	-	-
	Norway	x	x	66	59	59
	Switzerland	x	x	-	-	
	Total	(-)	(33)	(41)	(39)	(39)
Oceania	Australia	-	-	-	-	-
	New Zealand	x	x	x	-	-
	Total	(-)	(-)	(-)	(-)	(-)
Free World Total		22	10	13	16	20

Source: Compiled from Appendix Tables 2 to 4.

Reference Fig. B-1 Production of Primary Aluminum, Alumina and Bauxite

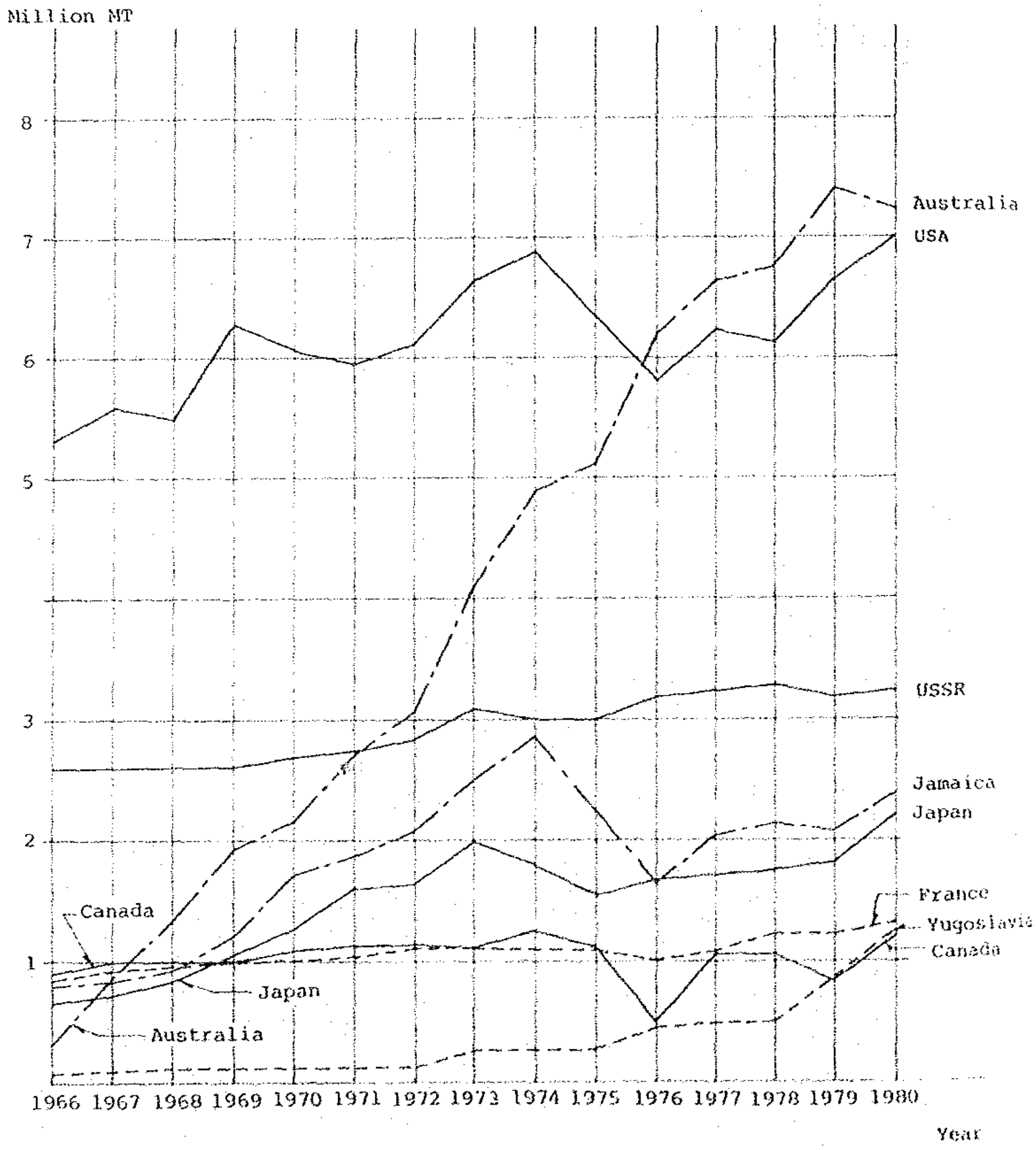


Reference Fig. B-2 Production of Bauxite for Main Producing Countries (1965 - 1980)



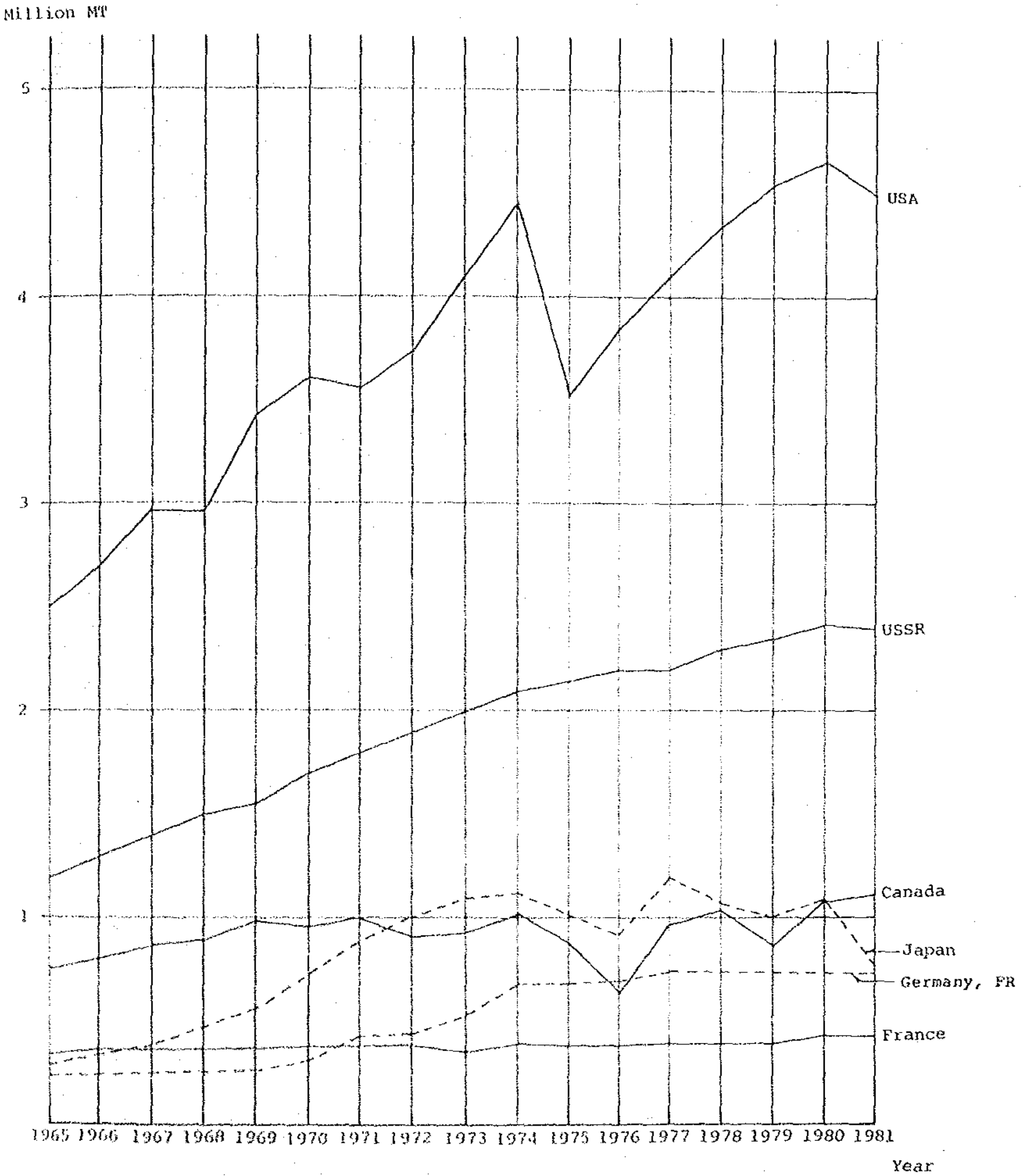
Source: Metal Statistics, 1965-75, 1970-80

Reference Fig. B-3 Production of Alumina for Main Producing Countries (1966 - 1980)



Source: Metal Statistics, 1965-75, 1970-80

Reference Fig. B-4 Production of Primary Aluminum for Main Producing Countries (1965 ~ 1981)



Source: Metal Statistics, 1965-75, 1970-80 and Metal Statistics Preliminary Figures 1981

Reference Fig. B-5 Main Primary Aluminum Producing Countries
[Figures in ( ) indicate production capacity, countries in ☐ indicate newcomers]

(1,000 tonnes/Y)

Year of production commencement	Africa	North America	Latin America	East Asia	South Asia	Europe	Oceania	The centrally planned economies
1960		USA (263)				France (113)		
61						Spain (78)		
62				Japan (76)	India (100)			USSR (280)
63		USA (125)	Mexico (45)			Germany, FR (155)	Australia (165)	
64								Romania (250) USSR (430)
65			Surinam (66)			Norway (72)		Poland (55)
66		USA (236)				Greece (145) Netherlands (96)		USSR (600)
67	Ghana (200)		Venezuela (125)	Japan (83)		Norway (157)		
68								
69		USA (163)		Japan (72)	India (73)	Iceland (87)	Australia (90)	
70		USA (160)	Brazil (90)	Japan (144)		Germany, FR (126) UK (101,113)		
71	South Africa (169)	USA (104,204,168)			Bahrain (170)	Germany, FR (72) Netherlands (170)	New Zealand (229)	
72			Brazil (58)	Japan (76)	Iran (50) Turkey (60)	Norway (82) UK (127)		Yugoslavia (110)
73		USA (163)		Korea, Rep. of (18)		Germany, FR (100,65) Italy (125)		Yugoslavia (120)
74								
75	Egypt (166)		Argentina (140)	Japan (100)	India (100)			USSR (500)
76								
77								
78			Venezuela (280)			Spain (180)		
79					Dubai (135)			
80		Canada (171) USA (179)						
81-82			Brazil (86)	Indonesia (225)			Australia (204)	Yugoslavia (90) China (80)

Source: Compiled from AME, Regional divisions based on IPAI.

Reference Fig. B-5 Definitions

Production of primary aluminum is defined as the weight of liquid aluminum as tapped from the pots, excluding alloying elements, returned scrap or remelted products.

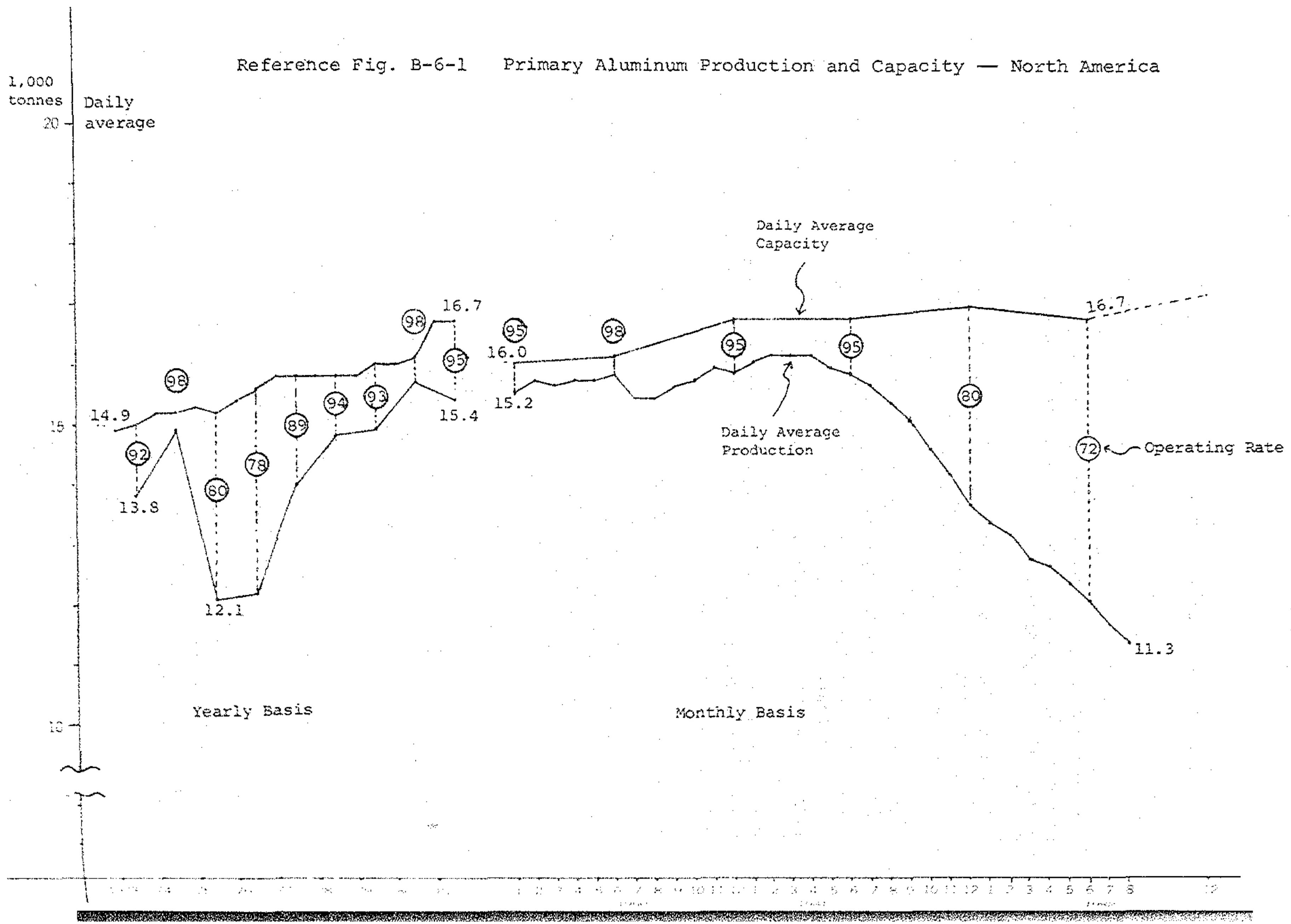
IPAI Form 150 records the primary aluminum production of IPAI Members and Official Correspondents by seven geographical areas for the month or the year stated.

1. AFRICA (South Africa, Camerron, Egypt, Ghana)
2. NORTH AMERICA (Canada, the United States)
3. LATIN AMERICA (Argentina, Brazil, Mexico, Surinam, Venezuela)
4. EAST ASIA (Japan, the Republic of Korea, Taiwan)
5. SOUTH ASIA (Bahrain, India, Indonesia, Iran, Turkey, United Arab Emirates)
6. EUROPE (Austria, France, Germany, FR, Greece, Iceland, Italy, Netherlands, Norway, Spain, Sweden, Switzeland, the United Kingdom)
7. OCEANIA (Australia, New Zealand)

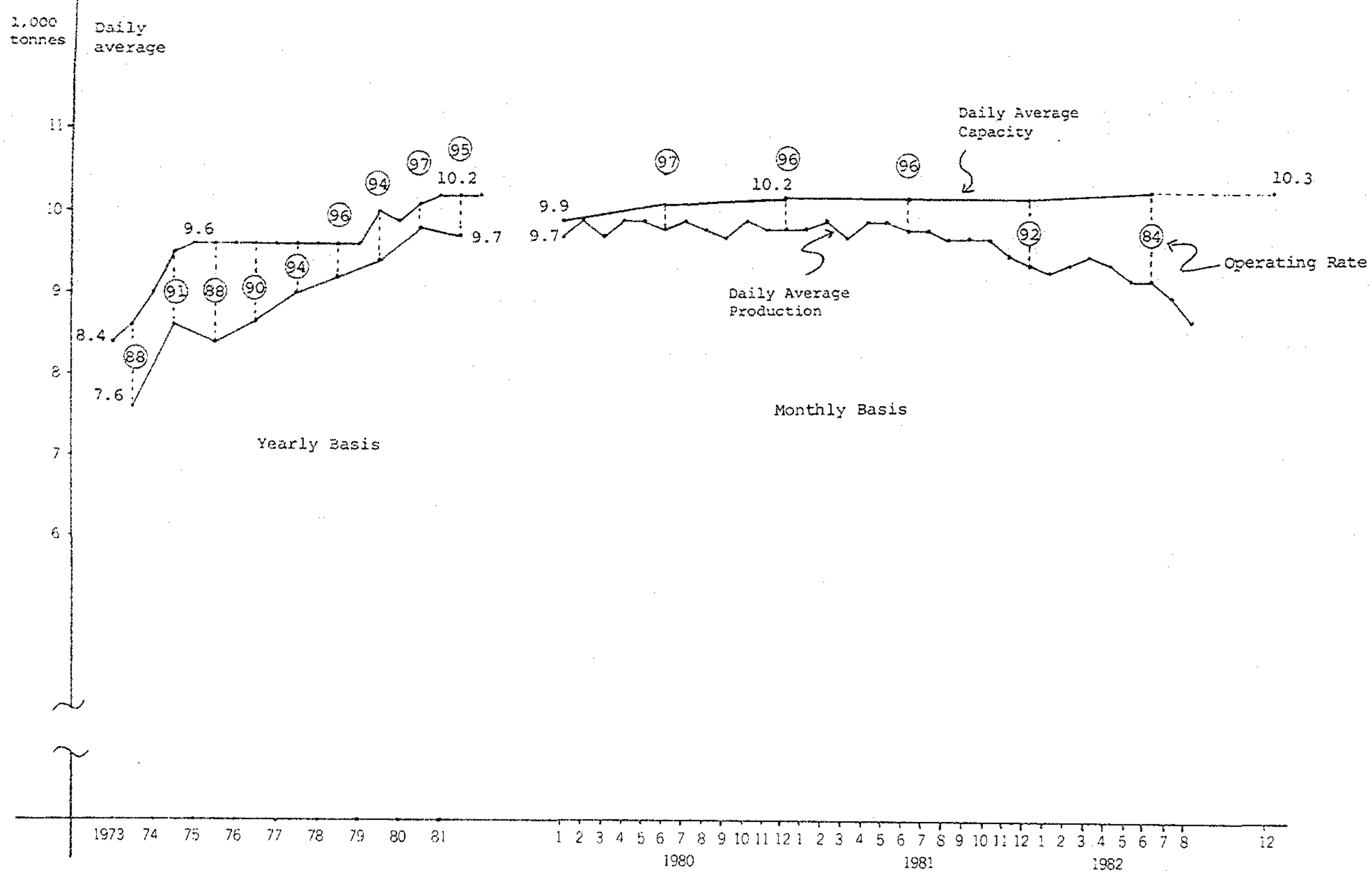
(Areas are based on U.N. Demographic Classification)

All primary aluminum production of companies is included with the exception of that in IPAI Geographical Area 8 and Yugoslavia.

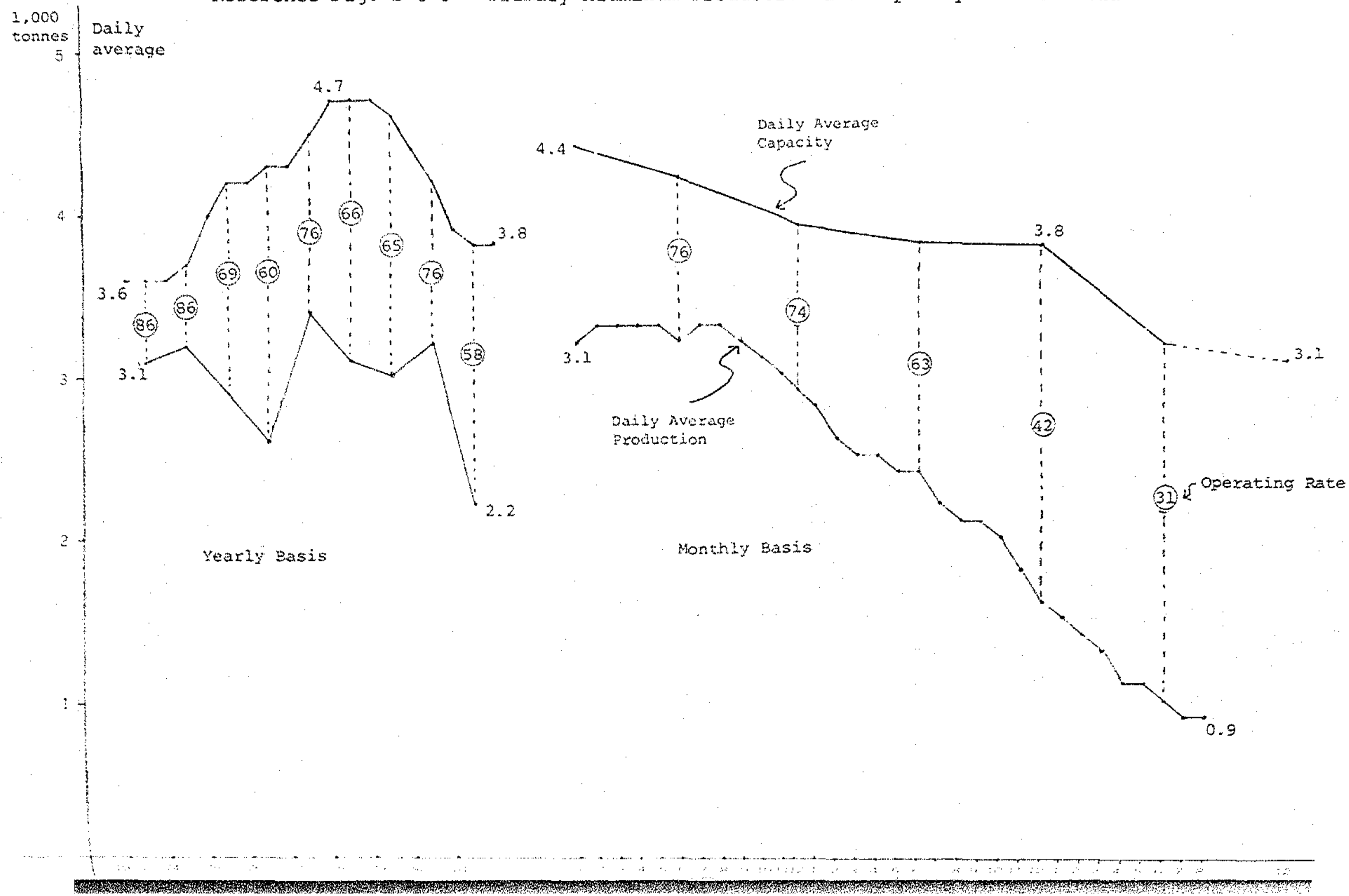
Reference Fig. B-6-1 Primary Aluminum Production and Capacity — North America



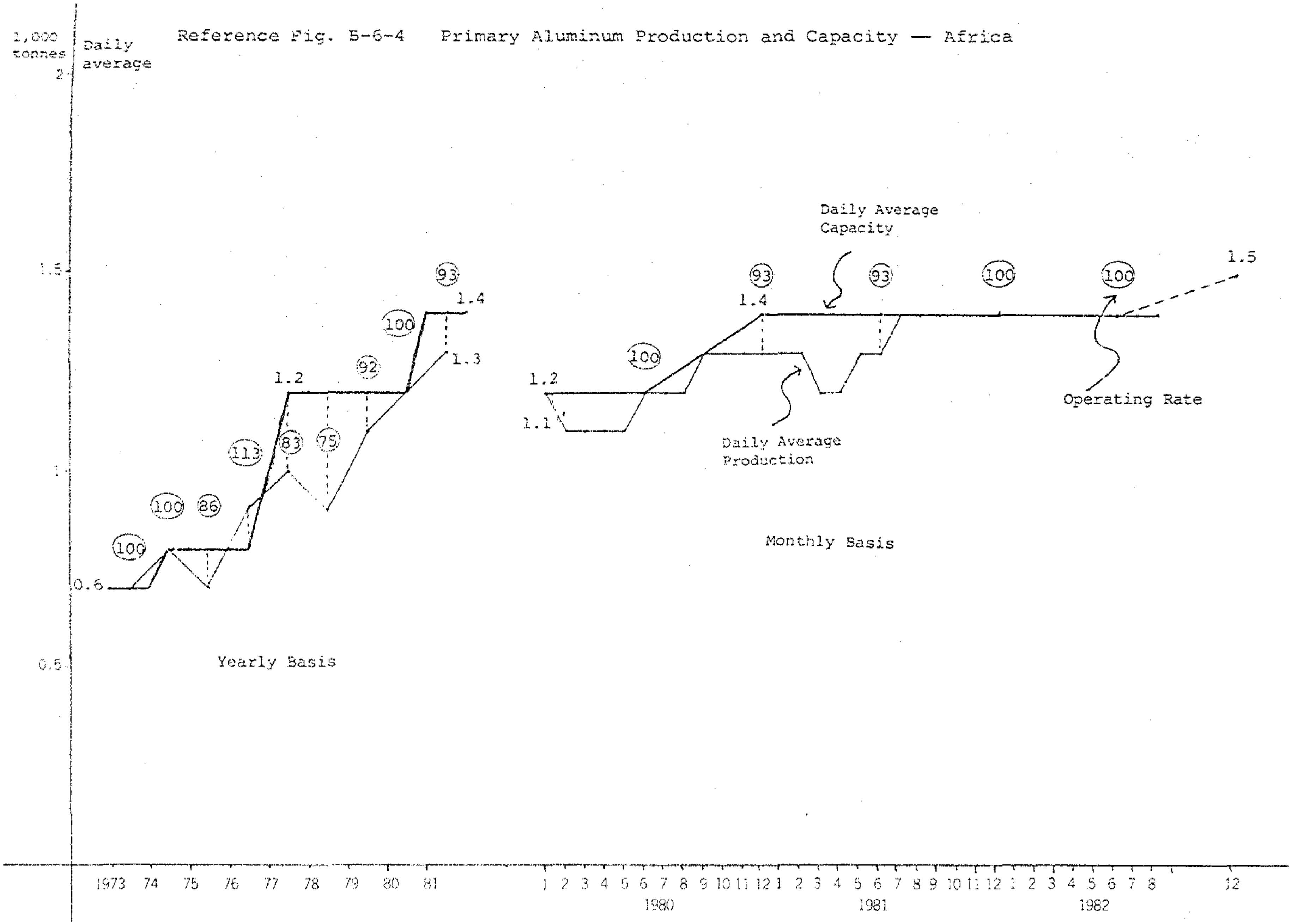
Reference Fig. B-6-2 Primary Aluminum Production and Capacity — Europe



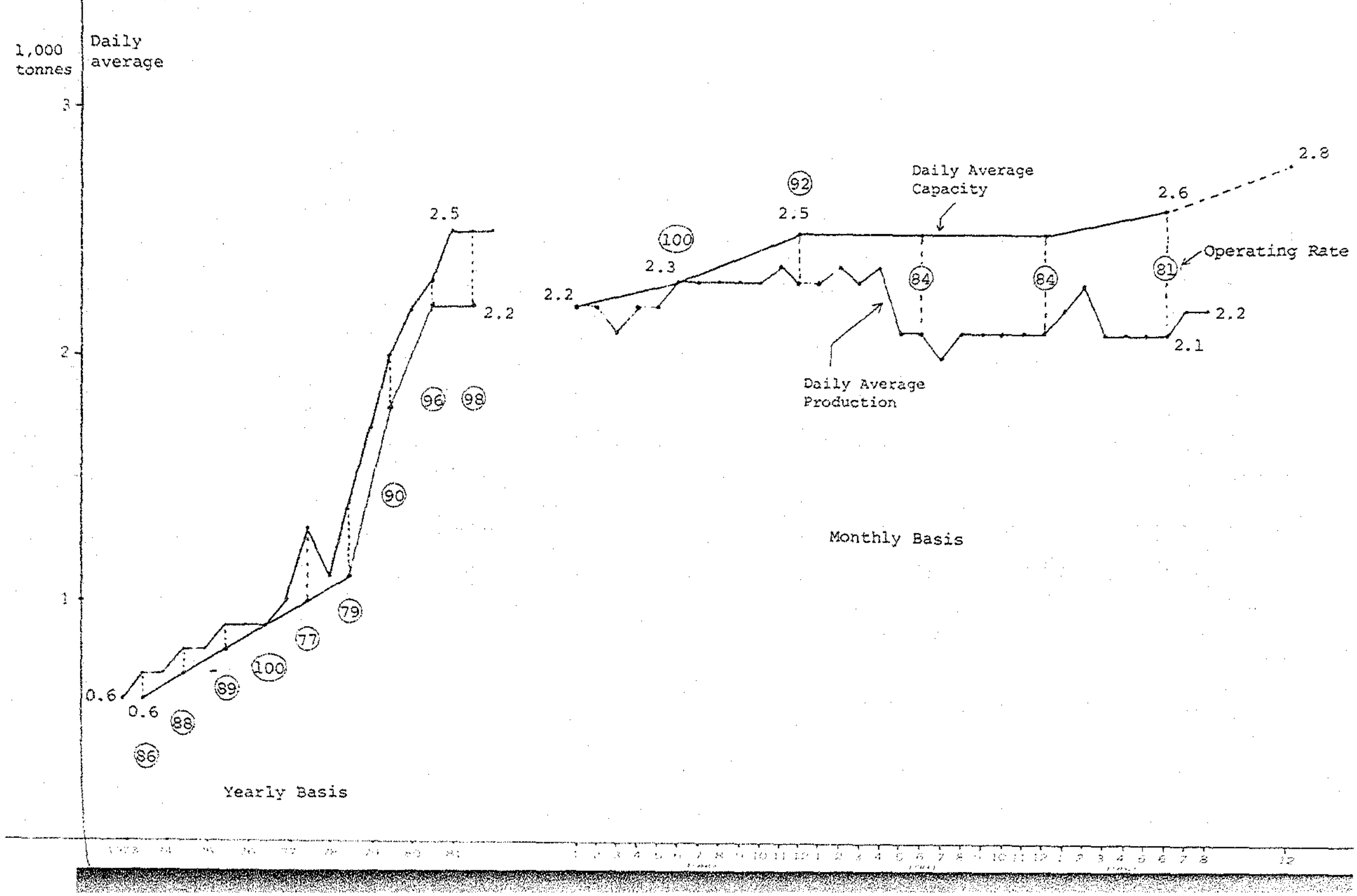
Reference Fig. B-6-3 Primary Aluminum Production and Capacity — East Asia



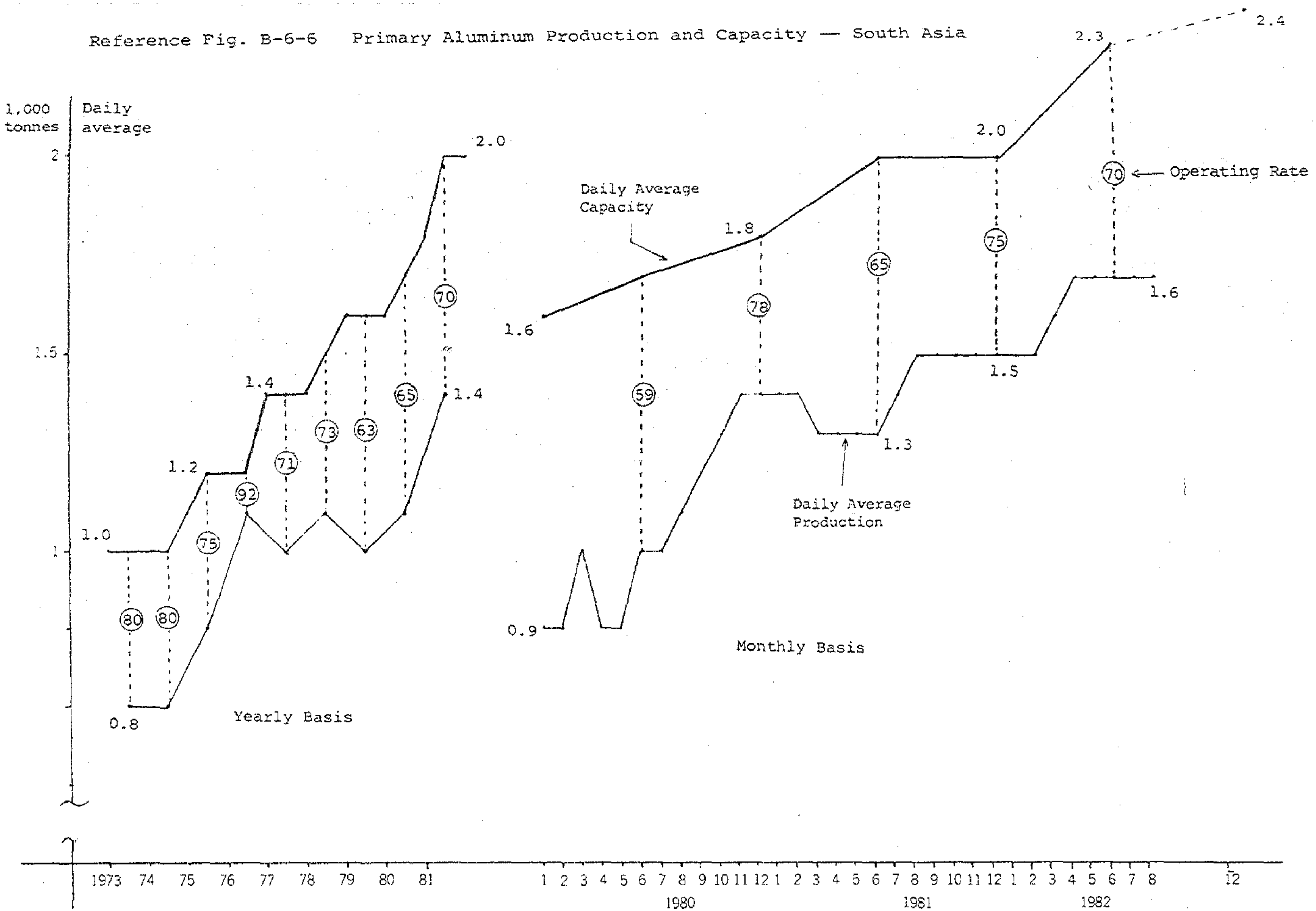
Reference Fig. 5-6-4 Primary Aluminum Production and Capacity — Africa



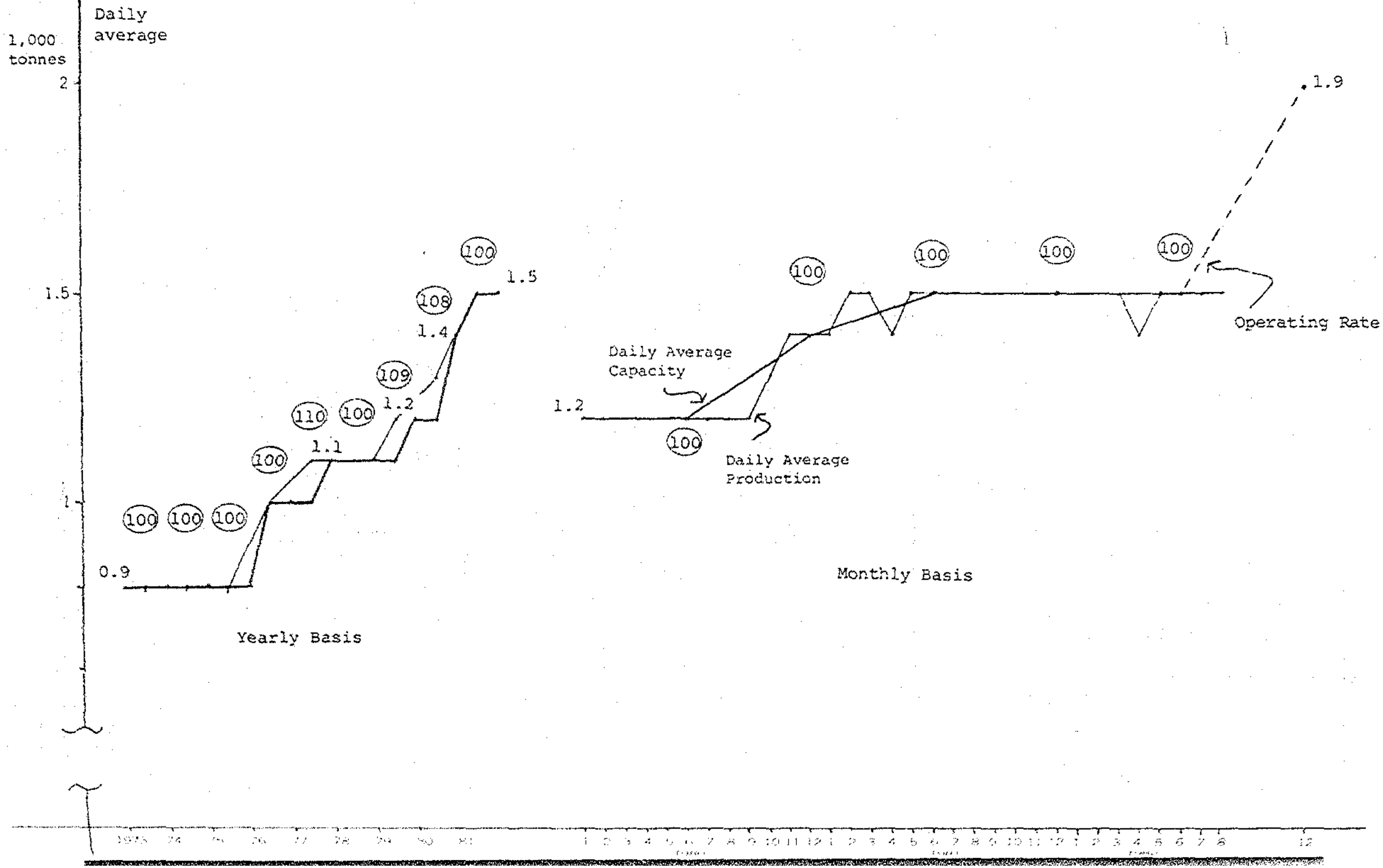
Reference Fig. B-6-5 Primary Aluminum Production and Capacity — Latin America



Reference Fig. B-6-6 Primary Aluminum Production and Capacity — South Asia



Regerence Fig. B-6-7 Primary Aluminum Production and Capacity — Oceania



Reference Fig. B-7-1 Vertical Integration of Six Major Producers (1981)

(Calculated by ownership percentage)
(1,000 tonnes/Y)

	Bauxite		Alumina		Aluminum		Share in Free World Production Capacity (%)	
ALCOA	USA	850	USA	2,450	USA	1,565		
					Norway	80		
	Guinea	1,250					Bauxite	16.6
	Jamaica	1,200	Jamaica	520			Alumina	20.7
	Surinam	4,500	Surinam	1,320	Surinam	66	Aluminum	13.1
	Domin. Rep.	600						
	Brazil	600	Brazil	110	Brazil	61		
					Mexico	20		
	Australia	6,900	Australia	1,930	Australia	86		
		15,900		6,330		1,878		
ALCAN			Canada	1,250	Canada	1,018		
	France	400	Germany, FR	150	Germany, FR	44		
	Malaysia	400	Japan	440	UK	125	Bauxite	6.4
					Spain	98	Alumina	11.8
	Jamaica	2,500	Jamaica	1,020	Japan	68	Aluminum	10.9
	Guinea	1,250						
	Brazil	1,250	Brazil	120	Brazil	88		
	India	300	India	130	India	65		
			Australia	510	Australia	63		
		6,100		3,620		1,569		

Source: Compiled from Spector Report, UNCTAD Report etc.

Reference Fig. B-7-2 Vertical Integration of Six Major Producers (1981)

(Calculated by ownership percentage)
(1,000 tonnes/Y)

Company	Bauxite		Alumina		Aluminum		Share in Free World Production Capacity (%)	
KAISER			USA	1,660	USA	657		
					Germany, FR	72		
			Italy	60	UK	75	Bauxite	7.8
							Alumina	10.2
	Jamaica	3,200	Jamaica	410	Ghana	180	Aluminum	7.9
					India	30		
					Bahrain	29		
	Australia	4,300	Australia	1,000	Australia	54		
					New Zealand	35		
		7,500		3,130		1,132		
REYNOLDS	USA	900	USA	2,000	USA	885		
					Canada	159		
			Germany, FR	300	Germany, FR	33	Bauxite	4.9
							Alumina	8.9
	Haiti	900			Ghana	20	Aluminum	7.9
	Jamaica	2,700	Jamaica	410				
	Brazil	200			Venezuela	34		
		4,700		2,710		1,131		

Source: Compiled from Spector Report, UNCTAD Report etc.

Reference Fig. B-7-3 Vertical Integration of Six Major Producers (1981)

(Calculated by ownership percentage)
(1,000 tonnes/Y)

	Bauxite		Alumina		Aluminum		Share in Free World Production Capacity (%)	
PECHINEY	France	1,400	France	1,320	France	447		
	Greece	150	Greece	370	Greece	143		
					Netherland	145	Bauxite	2.7
					Spain	100	Alumina	7.5
							Aluminum	7.8
					USA	204		
	Guinea	1,050	Guinea	130				
					Cameroon	81		
			Australia	480				
					Korea	9		
		2,600		2,300		1,129		
ALUSUISSE					Switzerland	76		
			Germany, FR	350	Germany, FR	197		
	France	400			Austria	12	Bauxite	5.0
					Iceland	88	Alumina	4.5
					Norway	53	Aluminum	5.3
	Sierra Leone	700			Italy	30		
	Guinea	200	Guinea	30				
			USA	300	USA	281		
	Australia	3,500	Australia	700				
					South Africa	19		
		4,800		1,380		756		

Source: Compiled from Spector Report, UNCTAD Report etc.

C. CONSUMPTION

I. Development of Aluminum Consumption

1. Trend of Primary Aluminum Consumption

As shown in Fig. C-1, world primary aluminum consumption continued to increase smoothly from 1960 to the beginning of the 1970s, tracing a smooth curve. However, this growth trend changed remarkably from 1975 and the two unprecedented large downward changes occurred.

The first change was due to the first oil crisis triggered by the fourth Mideast war broken out in october, 1973. The 1975 primary aluminum consumption was down 18.5% over the previous year, (23.6% decrease in free world consumption) nearly to the 1971 level.

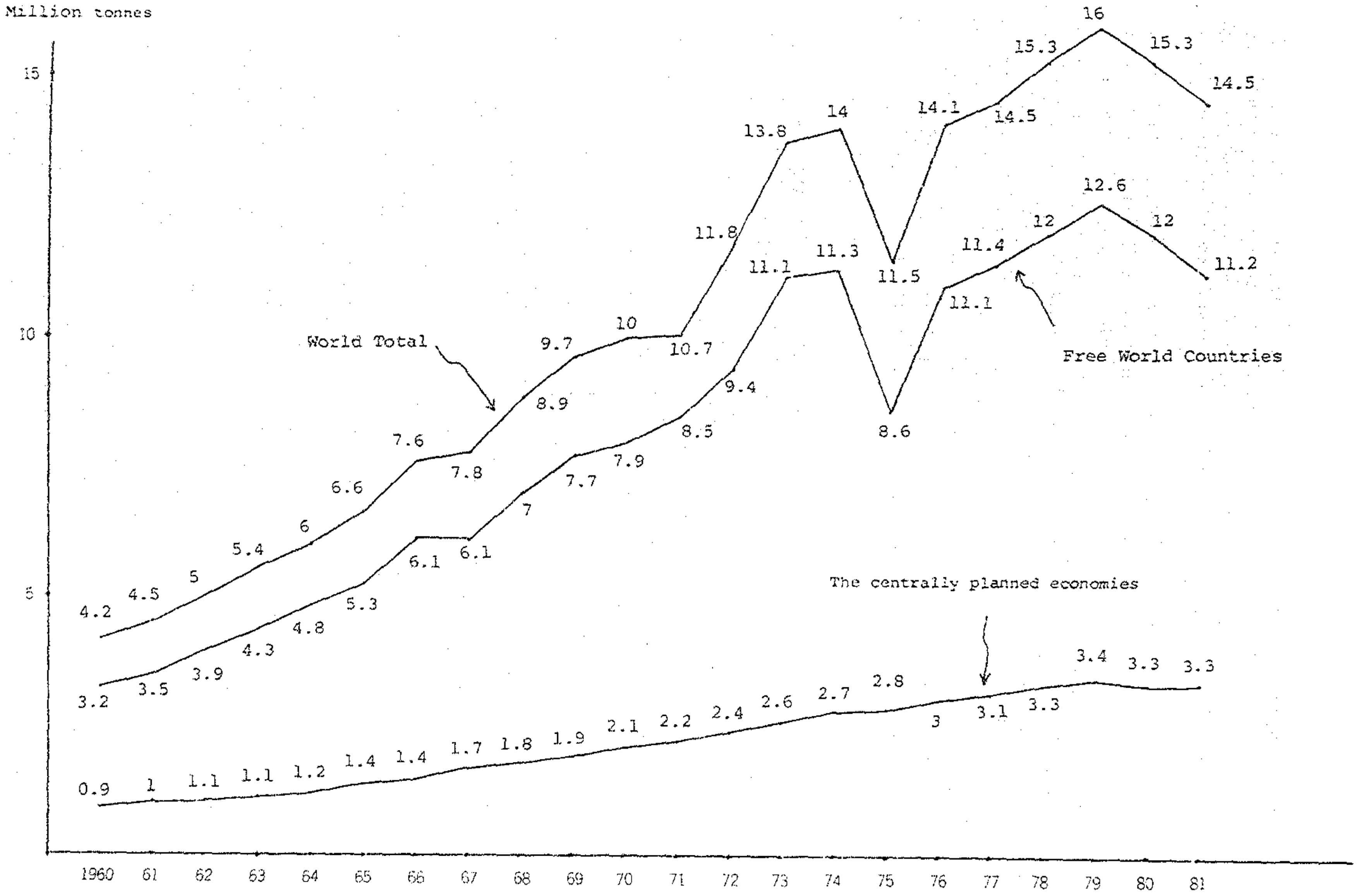
The second change was due to the world wide recession which emerged from the second half of 1980, stemmed from the second oil crisis.

Primary aluminum consumption, which recovered the decrease of the previous year in 1976 and showed an upward trend again, recorded the highest value in its history in 1979. After the peak in 1979, primary aluminum consumption decreased for the two consecutive years; 4.0% down in 1980 and 5.0% down in 1981 over the previous year (4.6% and 6.3%, respectively, in the free world). And there has been so far no signs of recovery from this decline. As for the growth trend of primary aluminum consumption during the period from 1960 to 1981 in terms of the average annual growth rate according to Reference Tables C-1 and C-2 showing developments and average annual growth rates of primary aluminum consumption, the high growth rate of 9.2% (Free world: 9.4%) in the 1960s decreased rapidly at the beginning of the 1970s and went down to 4.3% (Free world 4.2%) in the 1970s. Primary aluminum consumption entered a period of large changes and low growth in the 1970s.

2. Primary Aluminum Consumption by Region and Country

Fig. C-2 shows the primary aluminum consumption for 1981 by region and main country. According to this figure, the free world countries accounted for the 77.3% of the world consumption of 14.55 million tonnes, and the centrally planned economies for the remaining 22.7%.

Fig. C-1 Development of Primary Aluminum Consumption

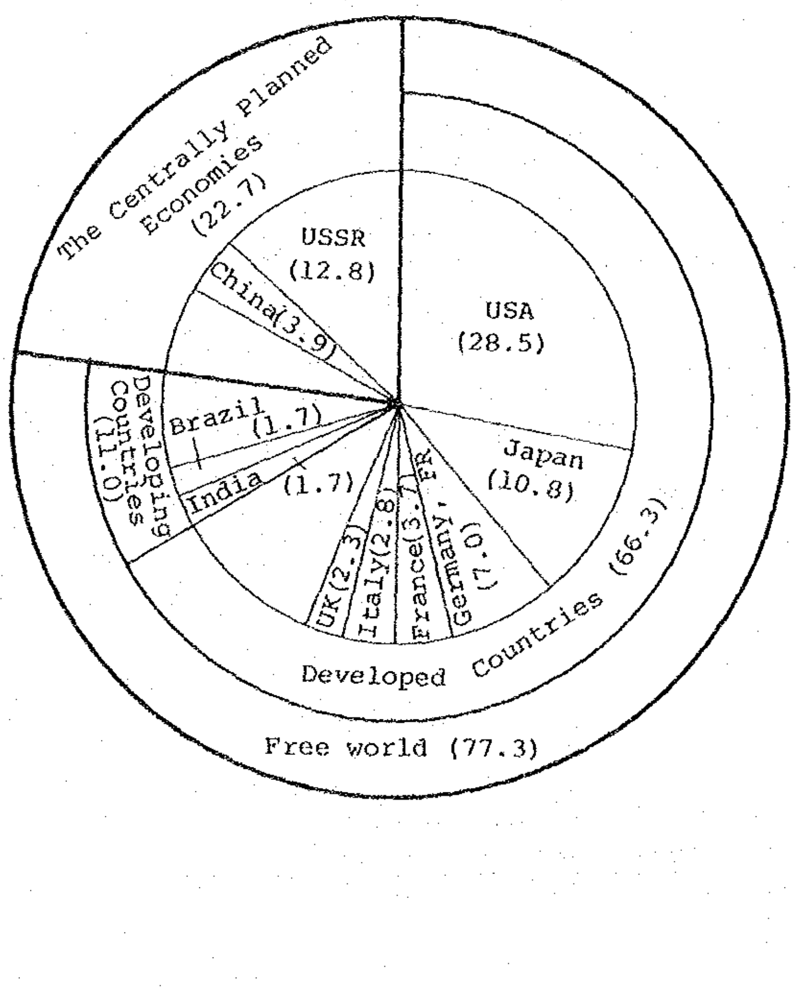


Source: Metal Statistics, 1961-70, 1965-75, 1970-80
1981: Preliminary Report

This ratio was almost the same as it was in 1960, about 20 years before (free world: 77.7%; the centrally planned economies: 22.3%). This shows that, over the long term, aluminum consumption in both economic blocs expanded together at almost the same growth rate.

Dividing the free world into developed countries and developing countries, the developed countries accounted for 66.3% of the total world consumption (85.7% of the free world consumption) and the developing countries for 11.0% of the consumption (14.3% of the free world consumption). However, the ratio of these two groups has been changing each year. The share of the developed countries decreased gradually; about 75% each in 1960 and 1965, about 74% in 1970, and about 66% in 1981. On the other hand, the share of the developing countries expanded: 2.8% in 1960, 3.9% in 1965, 5.2% in 1970; 7.7% in 1975, and finally exceeded the 10% level in 1981. The enlargement of consumption by the developing countries is quite remarkable.

Fig. C-2 1981 Primary Aluminum Consumption by Main Country and Region



Consumption by the developing countries has greatly increased especially in recent years but the share of each region in the world consumption is still small: Latin America, 5.2%; Asia (excluding Japan), 4.0%; Middle East, 1.1%; Africa (excluding S. Africa) 0.7%. The really predominant consumption regions are: North America, 29.0% (the United States, 28.5%), Europe, 24.2%; Japan, 10.8%; Australia and South Africa, 2.3%. The main consuming countries in Europe are: the Federal Republic of Germany, 7%; France, 3.7%; Italy, 2.8%; the United Kingdom, 2.3%. The 6 developed countries (the above main European countries, the United States and Japan) are the major consuming countries, occupying the 55% of the world total, 71% of the free world total, equivalent to about 8.0 million tonnes. In the centrally planned economies, the USSR (12.8%) and China (3.9%) are the major consuming countries. While the share of China has been expanding, the share of the USSR has shown a slight downward trend.

The proportions of the free world to the centrally planned economies in primary aluminum consumption have been almost the same since the 1960s. But among the free world nations, indications of structural change in consumption can be seen whereby the share of the developing countries, even if still small, has expanded and the share of the developed countries has decreased gradually.

3. Regional Trend in view of Contribution to Increased Consumption

As Reference Table C-2 shows, world primary aluminum consumption increased to 15.32 million tonnes in 1980, compared to 10.03 million tonnes in 1970. This was an increase of 5.29 million tonnes in annual consumption [1], out of which 4.08 million tonnes was for the free world, corresponding to the 77% of the total increase. If the proportion of each region's or country's increase to the total increase is considered to be its contribution to the increase (for example, the free world's contribution to the increase is 77%), one could expect to find a correlation between each region's or country's contribution to the increase and its consumption share.

The free world's contribution to the increase was 77% and the centrally planned economies' was 23%. These contributions were almost the same as the previously mentioned consumption shares, 77.3% for the free world and 22.7% for the centrally planned economies. This substantiated the fact that the free world and the centrally planned economies had grown in almost the same rate.

However, the relationship between share and contribution dif-

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1) Even if 1980 consumption was regarded as an unusual decrease and adjusted to the revised figure (Refer to the note in Reference Table C-2), the increase in consumption was 5.25 million tonnes.

fered from region to region. North America's consumption share was 29% but its contribution to the growth was no more than 20%. The same comparison for Europe was 24.2% versus 23.5%. Its contribution to the increase was less than the consumption share. This also applies to the USSR: 12.8% versus 9.8%. Compared to these countries, all the other regions including Japan (consumption share 10.8%, contribution to the increase 13.7%) had higher contributions to the increase than their shares of consumption.

In short, North America, Europe and the USSR, consuming large quantity, had large shares in consumption, but their contributions to the increase in consumption were relatively small. On the other hand, the other regions including Japan and developing countries, although their consumption were small, contributed relatively largely to the increase in consumption. This was also an indication of structural change in consumption.

In relation to the contribution to the increase itself, however, the overwhelmingly high contribution were made by 3 areas: Europe (23.5%), North America (20%) and Japan (13.7%). These areas combined accounted for 57.2% of the world total contribution (a 64% share of the total world consumption). Leaving aside the USSR with roughly 10% of contribution, the other regions stood at only a few percent level. Thus, the change in primary aluminum structure, though there was a sign of the developing countries increasing their share, quite differed from the production structure change as described in Chapter B. The consumption was still led by the developed countries, especially the United States, the main Western European countries, and Japan. Among them, the United States had gigantic consumption. Taking the example, the decrease in consumption of 550,000 tonnes in the United States (equivalent to 11% fall) from 1979 to 1980 alone was almost equal to the 1979 consumption of all of Latin American countries or Asian countries (excluding Japan). Japan is the biggest consumption country next to the United States, but consumes only about 1/3 of the United States. It does not seem to be an exaggeration to say that the analysis of balance of primary aluminum supply and demand cannot be meaningful unless the trends of demand in the main developed countries, especially the United States, are taken into consideration.

4. Consumption Growth Rate and GDP Elasticity

In order to make the trends in growth of primary aluminum consumption clearer, consumption growth rates and elasticity relative to the GDP growth rates are compared. As was already mentioned, because primary aluminum consumption decreased drastically in 1975 and 1980, the decrease in 1975 being particularly drastic, the study of medium and long term growth rates using figures of these years as the standard may result in wrong evaluation of trends. In the analysis below, a revised figure, being an average of three years' figures including a preceding year and a succeeding year, is used for each of 1975 and 1980.

4.1 Whole World

The average annual growth rate in primary aluminum consumption for the whole world, as Reference Table C-2, was high at 9.8% in the first half of the 1960s, but fell to 8.6% in the second half of the 1960s, 5.7% in the first half of the 1970s and further to 3.0% in the second half of the 1970s. A large declining trend was seen in the growth rate of aluminum consumption.[1)]

During the same period, the growth rate for the GDP for the whole world, as shown in Reference Table C-3, was 5.3% in both the first and second half of the 1960s, and declined gradually to 4.1% in the first half of the 1970s and 3.9% in the second half.

Therefore, the elasticity of the growth of primary aluminum consumption relative to GDP growth fell from 1.9 in the first half of the 1960s to 1.6 in the second half, and to 1.4 in the first half of the 1970s. In the second half of the 1970s, the elasticity declined to 0.8, which showed the fact that the growth rate of primary aluminum consumption fell below the GDP growth rate. Comparing the longer periods of ten years, elasticity declined from 1.7 in the 1960s to 1.1 in the 1970s.

In addition, while the swings in GDP from year to year were relatively small, primary aluminum consumption, especially since early 1970s, had quite large up and down swings. Because of this, the up and down movements of elasticity have become apparently frequent in recent years.

From those data, it can be concluded that primary aluminum consumption has now entered into the period of low growth and, at the same time, of large change. These trends are summarized below:

	60-65	65-70	70-75	75-80	60-70	70-80
Average annual growth rate						
-Primary aluminum consumption	9.8	8.6	5.7	3	9.2	4.3
-GDP	5.3	5.3	4.1	3.9	5.3	4
GDP Elasticity	1.9	1.6	1.4	0.8	1.7	1.1

1) The first half of the 1960s is from 1960 to 1965; the second half is from 1965 to 1970.

4.2 The Free World and the Centrally Planned Economies

In the first half of the 1960s, the free world's primary aluminum consumption growth rate (10.2%) was higher than the centrally planned economies' (8.4%), but this was reversed in the first half of the 1970s as the centrally planned economies' growth (6.3%) surpassed the free world's growth (5.4%). However, in the second half of the 1970s, both economic blocs were standing still at the same low 3% growth rate.

GDP elasticity in the free world of 2.0 in the first half of the 1960s fell below 1.0, plunging to 0.8 in the second half of the 1970s. Similarly, in the centrally planned economies, the 1.5 of the first half of the 60s plunged to 0.7 in the second half of the 1970s.

There has been a notable severe decline in GDP elasticity in recent years both in the free world and the centrally planned economies.

	60-65	65-70	70-75	75-80	60-70	70-80
GDP elasticity						
-Free world	2	1.7	1.5	0.8	1.8	1.2
-Communist Bloc	1.5	1.3	1.1	0.7	1.4	0.9

4.3 Developed Countries and Developing Countries

The growth rate for primary aluminum consumption in the developing countries was overwhelmingly higher than that in the developed countries, staying at high growth rate, over 10%, all the way from the 1960s to the 1970s. On the average, the growth rate for the developing countries was almost twice the developed countries. In the second half of the 1970s, however, with the growth rate slowing down to 2.2% in the developed countries, the developing countries' growth rate of 10% was five times higher than the developed countries. Moreover, despite the large declines in 1975 and 1980, their consumption continued strongly growing without decrease.

The GDP elasticity of the developed countries in the first half of the 1960s was 1.9, while the elasticity of the developing countries, 3.5, was higher. Compared to the large decrease to 0.6 of the developed countries' elasticity in the second half of the 1970s, the developing countries elasticity still remained at a high 2.0 rate, which resulted in large difference between the growth rates of those two groups.

In the medium and long term, while the growth in the developed countries has slowed down, the developing countries have maintained relatively high growth. This demonstrates the fact that the demand for aluminum in the developing countries is still at a growth stage. However, in terms of quantity, consumption in the developing countries (Its share in 1981 was 11% in the whole world and 14% in the free world.) is still small and does not greatly influence on worldwide trend. Moreover, it is necessary to note that while their growth rates have been high since the 1960s they kept declining over the same period.

	60-65	65-70	70-75	75-80	60-70	70-80
Average annual growth rate						
-Primary aluminum consumption						
Developed countries	9.9	8.2	4.9	2.2	9	3.6
Developing countries	17.8	15	11.5	10	16.4	10.6
-GDP						
Developed countries	5.3	5	3.1	3.5	5	3.3
Developing countries	5.1	6.1	6.2	5.1	5.6	5.6
GDP Elasticity						
Developed countries	1.9	1.7	1.6	0.6	1.8	1.1
Developing countries	3.5	2.5	1.9	2	2.9	1.9

4.4 Major Consuming Regions

Similar data being collected for the major consuming regions, there are marked differences among regions.

The growth rate of primary aluminum consumption for North America was at its peak of 13.1% in the first half of the 1960s, but continued to fall off thereafter. In the second half of the 1970s, it fell drastically to its lowest level, 0.7%. This was in part because the adjusted figures for 1975 were almost the same level as the adjusted figures for 1980. Even in terms of the actual figures, the 1980 North American consumption was almost equal to that in 1976, 5 years before. On the other hand, since a GDP growth level of 3% was sustained during the same period, the elasticity went down greatly, from 2.9 in the first half of the 1960s to 0.2 in the second half of the 1970s, falling well below 1.0. Since North American consumption almost equals to the U.S. consumption, the depressed consumption in the United States is one of the main causes for the suffering aluminum industry at present.

The European growth rate was higher in the second half of the 1960s (10.7%) than in the first half (4.2%), reflecting the greatly expanded consumption in the second half. However, since the beginning of the 1970s, the growth was kept at low levels of 4.3% for the first half and 3.0% for the second half. Accordingly, in the second half of the 1960s, the GDP elasticity was 2.3; aluminum consumption expanded at a growth rate more than twice that of the GDP, but in the 1970s the elasticity was down to 1.5 or 1; the consumption grew at about the same growth rate as the GDP.

As for Japan, it recorded the highest growth rate in the world in the 1960s; 14.7% in the first half and 25% in the second half. However, since the beginning of the 1970s, the growth has fallen drastically to 8.4% in the first half and 4.2% in the second half. In GDP, Japan sustained also the highest growth rate among the developed countries from the 1960s to the 1970s and the elasticity stood at between 1.3 and 2.3 on the average. But in the second half of the 1970s the primary aluminum consumption growth rate came down to lower than the GDP growth rate and the elasticity, at 0.8, fell below 1.0.

The fact that the three major aluminum consuming regions are all in the doldrums as above represents the bitter sufferings of today's aluminum industry.

	60-65	65-70	70-75	75-80	60-70	70-80
GDP elasticity						
-North America	2.9	1.2	1.8	0.2	2.1	0.9
-Europe	0.8	2.3	1.5	1	1.5	1.4
-Japan	1.3	2.3	1.7	0.8	1.8	1.1

5. Aluminum Consumption per Capita

Another way to study aluminum consumption trends is to analyse the annual aluminum consumption per capita, which is calculated on the American Aluminum Association (AA) method.[1] According to this method there were only 3 countries in which consumption per capita exceeded 10 kg in 1965: the United States, Switzerland and Sweden. However, in 1981, the number of country increased to 14, led by the United States, the Federal Republic of Germany, and Japan.

As Reference Table C-4 shows, the largest consumer was, of course, the United States, which outstriped the other countries, with 25.4 kg per capita. Next was the Federal Republic of Germany with 20.3 kg. Japan, Norway, Australia, Canada, Switzerland and other developed countries followed at between 15 and 20 kg. Compared to these developed countries, almost all the developing countries were at the level of below 5 kg, a very small consumption per capita.

From the viewpoint of the growth rates for consumption per capita, the countries who grew remarkably in the 1970s were, Greece

1) The A.A. method: Aluminum consumption per capita = [Primary aluminum production ± reserves + aluminum imports + imports of aluminum mill products + production of secondary aluminum - aluminum exports - exports of aluminum mill products (=apparent consumption) + stockpiles at the beginning of the year - stockpiles at the end of the year] (=consumption) ÷ population

(12.9%), Iceland, Hong Kong, Taiwan, Brazil, Turkey, and other developing countries. Among the developed countries, Italy, Japan and the Federal Republic of Germany showed an outstanding growth, but the United Kingdom, which had shown a downward trend since 1970, suffered the negative growth rate over the 1970s. Among the developing countries, there were also such countries as experienced negative growth rates, like Argentina and Panama. Not all the developing countries showed high growth rates.

As described above, as far as the growth of consumption per capita was concerned, the aluminum consumption growth was, generally speaking, very rapid in the developing countries and gradual in the developed countries, but it varied from country to country. If the consumption per capita is analyzed in relation to income levels, a clearer trend is found.

As shown in Fig. C-4, which compares the aluminum consumption per capita and GNP per capita, countries with large GNP per capita consume large amount of aluminum per capita. On the other hand, countries with small GNP per capita consume small amount of aluminum per capita. This relationship is almost a general rule and there are no exceptions. As it seems that aluminum consumption per capita depends on income levels, it is appropriate to analyze aluminum consumption per capita in accordance with a group of high income countries and middle and low-income countries rather than a group of developed countries and developing countries.

In other words, if income levels can be expected to improve in low and middle income countries in the future, aluminum consumption can be also expected to grow. On the other hand, if the rise in income levels is slow, the increase in aluminum consumption is also slow. It seems unrealistic to forecast a growth of aluminum consumption in the developing countries if the above relationship is not taken into account.

In the high income countries, growth rates for aluminum consumption per capita surpassed those of GNP per capita as shown below in the three major consuming blocs:

	Average Annual Growth Rates for 1970-1980 (%) [1]	
	GNP per capita	Aluminum consumption per capita
USA	2.1	2.4
Europe	2.4	4.4
Japan	4.2	6.4

However, aluminum consumption has shown a sharp decrease in the developed countries in recent years as already mentioned and it

1) Source: Same as Fig. C-3

Fig. C-3 Development of Aluminum Consumption per Capita in Main Countries (A.A. Method)

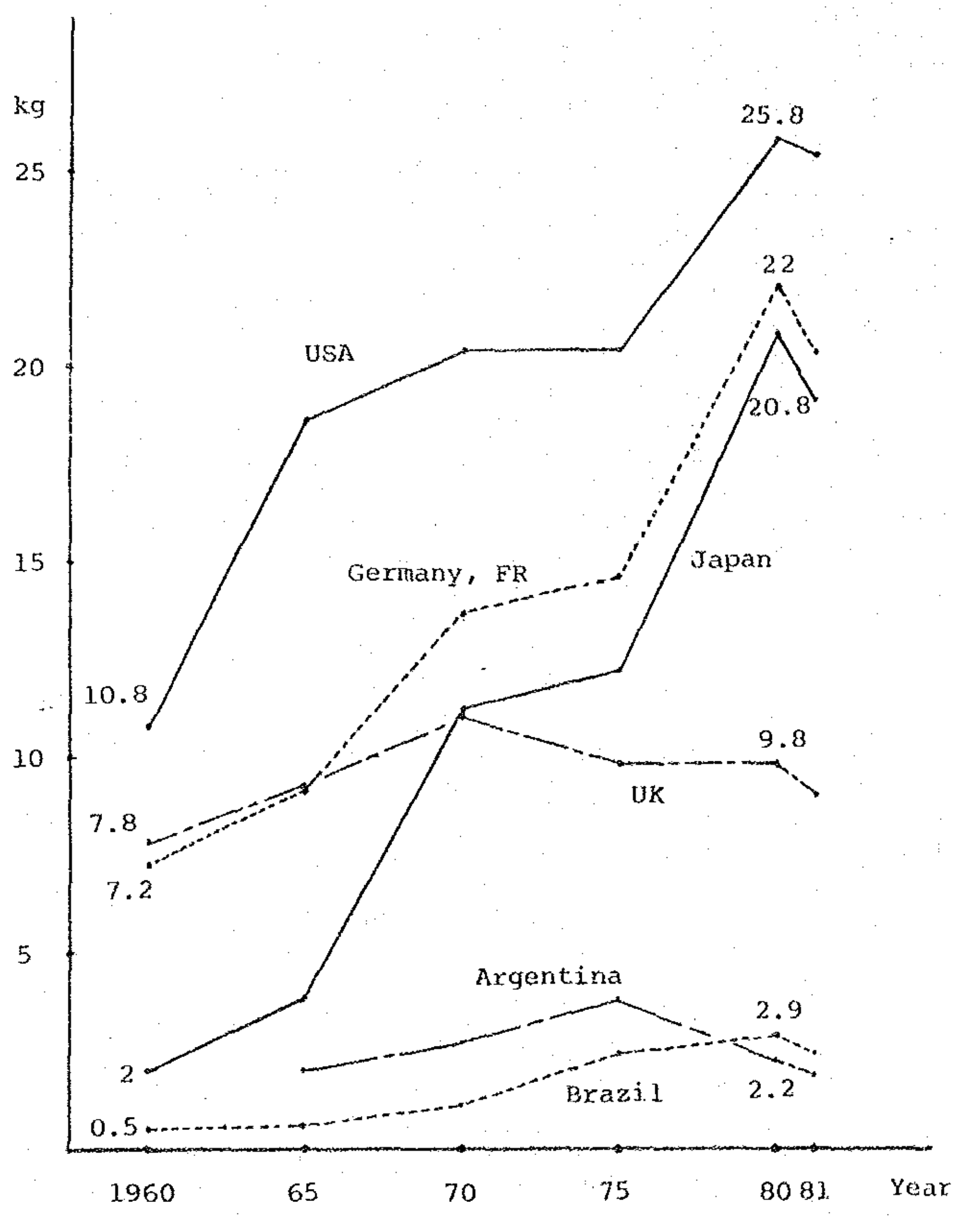
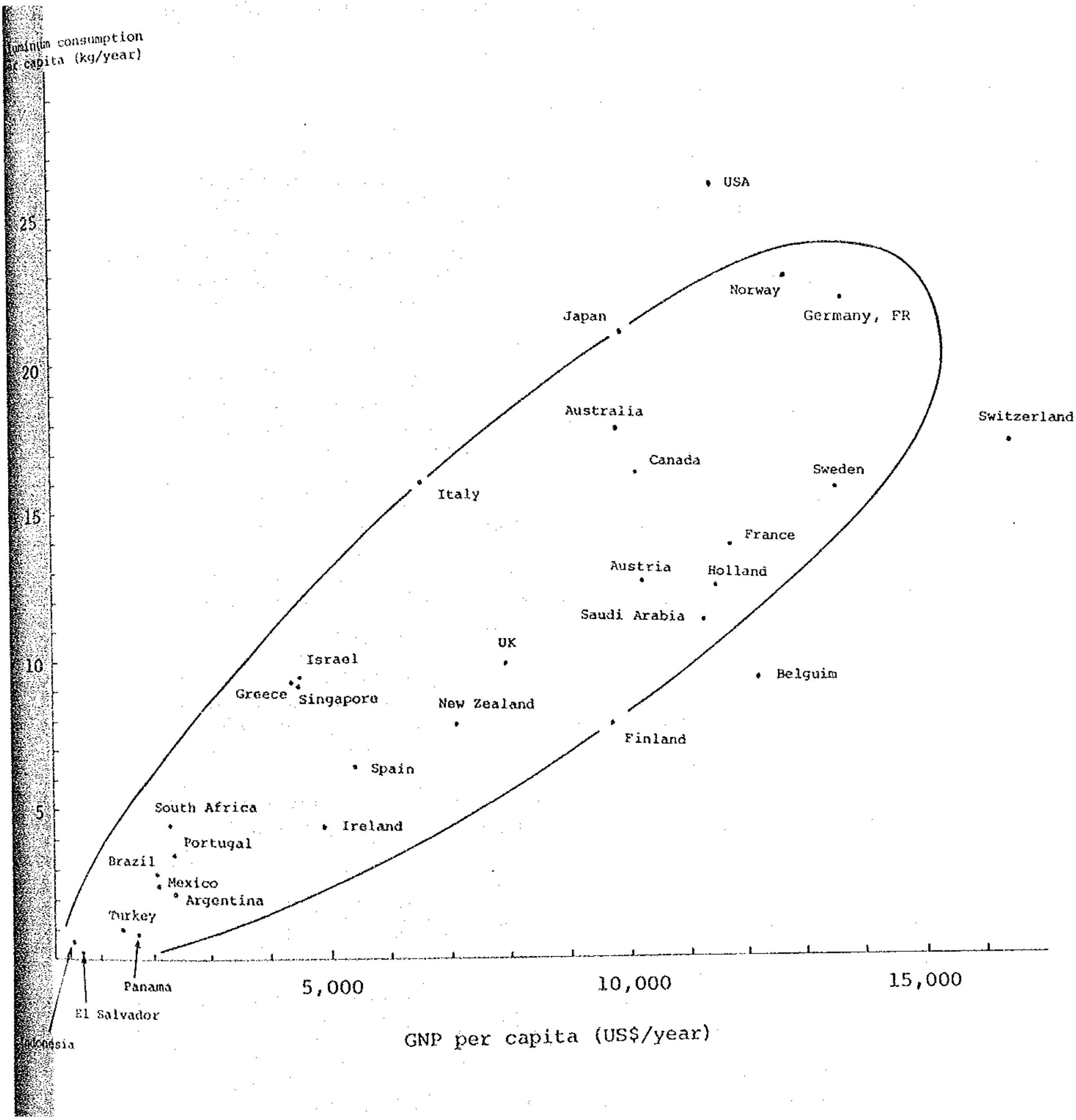


Fig. C-4 Comparison of Aluminum Consumption per Capita and GNP per Capita (1980)



Sources: GNP — World Bank, World Development Report 1982
Aluminum consumption — Reference Table C-4

appears doubtful whether the similar rate of growth to the past can be expected to continue in the future. A relationship between income levels and aluminum consumption in the high income countries will become clearer only after future consumption trends become clear.

6. Total Aluminum Consumption

Up to this chapter, developments of aluminum consumption has been discussed on the basis of primary aluminum consumption in order to analyse the primary aluminum smelting industry. However, the total aluminum consumption should include recycled aluminum produced from scrap and scrap directly used at fabricators in addition to primary aluminum, in order to give an entire picture of the aluminum consumption.

Based on Fig. C-5 and Reference Tables C-5 and C-6 which show the developments of total world and free world total aluminum consumption and primary aluminum consumption and of secondary aluminum production in the free world, some facts are pointed out as below.

a. World total aluminum consumption is equal to 25 or 30% larger than primary aluminum consumption (29% in 1980).

b. The difference (a little over 20% if the world total consumption is taken as the denominator, 22% in 1980) can be considered as secondary aluminum consumption.

c. The proportion of the free world to the centrally planned economies in consumption of secondary aluminum is almost the same as in primary aluminum consumption, being about 80% to 20% (82% to 18% in 1980).

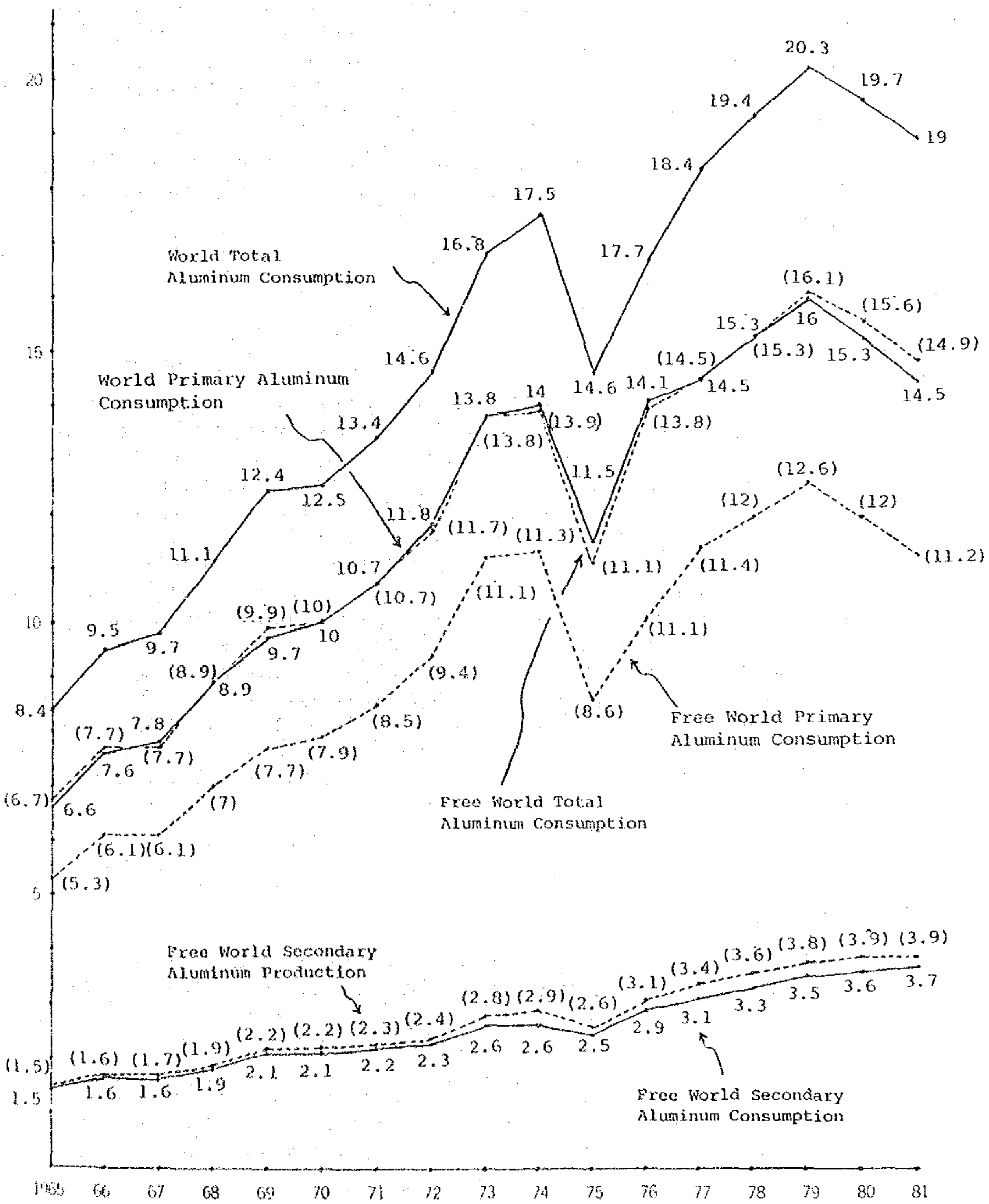
d. Production and consumption of secondary aluminum in the free world are almost entirely in the developed countries. Share of the developing countries is quite small.

e. World total aluminum consumption and primary aluminum consumption have a similar growth trend.

However, in recent years, a tendency for the growth rate of total aluminum consumption to be slightly higher than that for primary aluminum consumption has emerged.

For example, the 1980 world consumption of primary aluminum had -4.4% growth rate over the previous year and the 1981 had -5.0% figure (the corresponding free world figures were -4.6% and -6.3%), while total aluminum consumption growth was -2.9% and

Fig. C-5 Total Aluminum Consumption and Primary Aluminum Consumption



-3.4% respectively (-3.4% and -4.2% for the free world). The fall of primary aluminum consumption was quite severer than that of total aluminum consumption.

On the other hand, the secondary aluminum production has shown a smooth growth. After declining slightly in 1975, it did not show another drop, not even in 1980 and 1981. The consumption of secondary aluminum in the free world also showed positive growth, rather than negative, in 1980 and 1981.[1)]

It should be noted that, in recent years, the consumption of secondary aluminum has been encroaching upon consumption of primary aluminum.

II. Demand Structure of Aluminum

Aluminum metal is consumed as a raw material for many types of aluminum products including mill products, castings and die-casting which in turn are used in a wide range of industries as basic materials such as construction materials, automobile, machine parts and general consumption materials. Figs. C-6 and 7 are flowcharts showing the flow of aluminum products from metal to finished products, following the processing steps. Outlined below are demand structures of aluminum products and end market and their trends, though analyses are limited to the six countries; the United States, Japan and the four European countries; the Federal Republic of Germany, Italy, France, and the United Kingdom because of the difficulty to obtain the relevant data for the centrally planned economies and the developing countries. Since these six countries are the major consuming countries and accounted for about 60% of the world total aluminum consumption in 1980 (75% of free world consumption), the world trend can be analyzed by understanding their trends.

1. Demand by Aluminum Products

Aluminum products covers a wide range of forms, which, in this report, are divided into the following six types according to OECD statistics [2)]: rolling (sheet, strip, foil, disc, and slug), extru-

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1) Since there are no data for secondary aluminum consumption, the difference between total aluminum consumption and primary aluminum consumption is regarded as the consumption of secondary aluminum.
2) OECD Non-Ferrous Metal Statistics

Fig. C-6 Flowchart for Aluminum Products by Shape

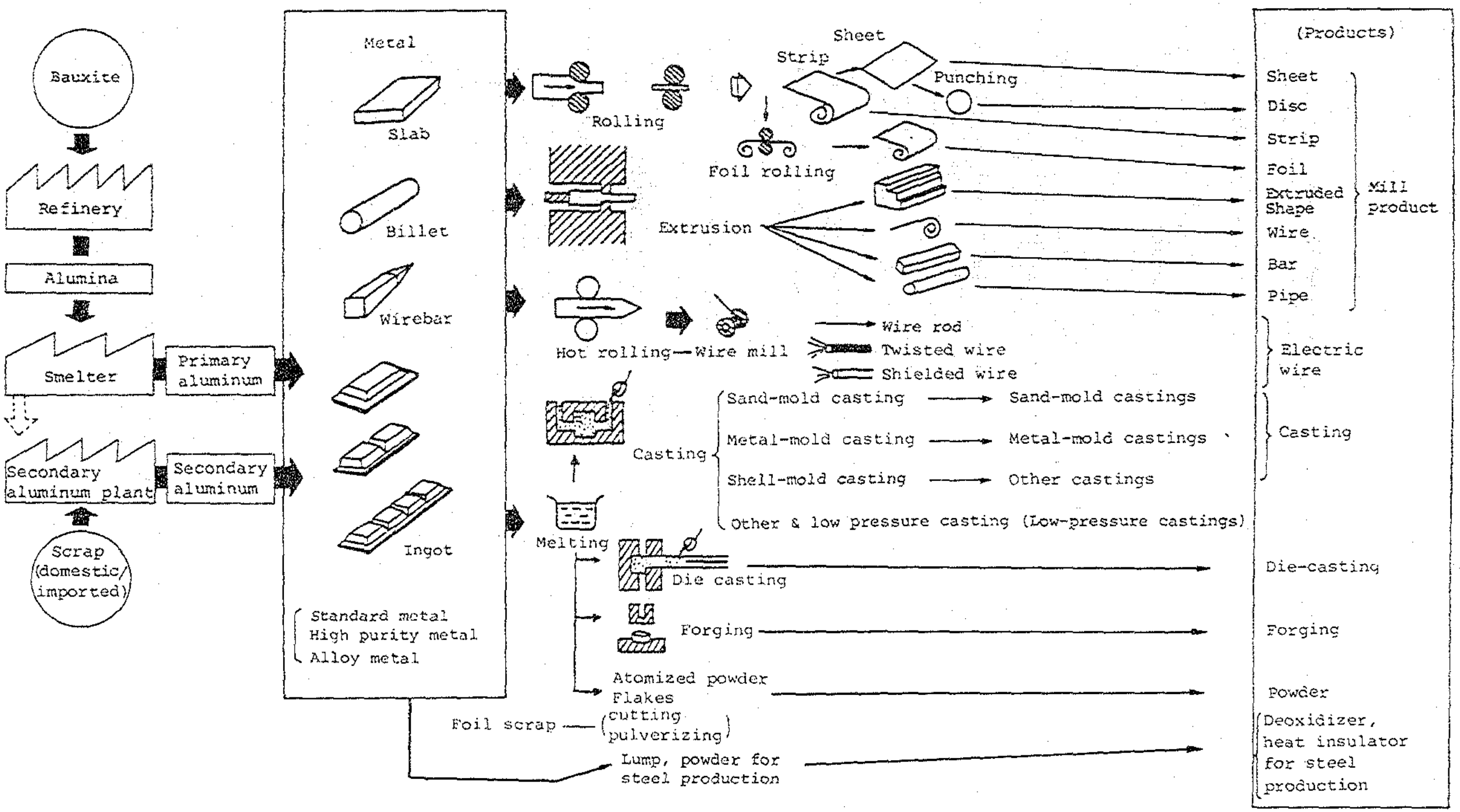


Fig. C-7 Aluminum Products by Shape and their Usage

- **Electric wire** — Steel core aluminum wire, twisted wire, shielded cable
- **Sheet, Strip, Wire, Extruded shape, Pipe, Bar, Foil**
  - Building — Roof board, sash, ceiling board, side wall, door, handrail, stair, curtain wall, furniture, etc.
  - Vehicle — Parts of train, automobile, motorcycle, scooter
  - Ship — Superstructure, rigging
  - Aircraft — Body, accesories
  - Household goods — Electric appliance, container, kitchen utensil
- **Foil** — Packaging, decoration, condenser, etc.
- **Casting**
  - Vehicle — Engine, parts, wheel, etc.
  - Ship — Window, instrument, engine components
  - Tool and equipment — Body of movie camera and camera, parts of scientific equipment, escalator step, body of electric drill, electric fan, arm for sewing machine, etc.
- **Forging** — Aircraft propeller, Kappe for coal mines, wheel for automobile, etc.

sion (bar, extruded shape, pipe); wire (electric wire), forging, casting and powder (powder or paste).[1]

According to the OECD statistics in Reference Table C-7, in 1965, the total demand for these 6 types of products in the six countries was 6.676 million tonnes.[2] In 1980, it increased to 11.184 million tonnes, about 1.7 times. The average annual growth rate for those 15 years was 3.5%. If 1970 is used as the starting point, the average annual growth rate for the 10 years up until 1980 is 4.0%, a little higher than the 3.6% average annual growth of primary aluminum consumption over the same period in the developed countries in the free world discussed earlier.

Analysis of the growth rate by product type over the ten years indicated extrusion enjoyed the highest at 5.6% and rolling the second highest of 4.3%. These two products types, i.e., mill product in the broad sense, led the increase in demand. Out of the 3.653 million tonne increase from 1970 to 1980, the 2.96 million tonne increase resulted from these two product types. The growth of these two product types contributed to 81% of the total growth.

The next important product type was casting, which grew at an average annual rate of 2.8% and contributed to 15% of the growth.

In contrast, the growth of the other product types; forging wire, and powder and paste were low and their contributions to the increase were small. Fig. C-8 showed the movement of the demand for each type of products.

As shown above, the majority of demand for aluminum products are covered by mill products in the broad sense (rolling and extrusion) and casting. In 1980, these three major product types accounted for 71% of all the demand.

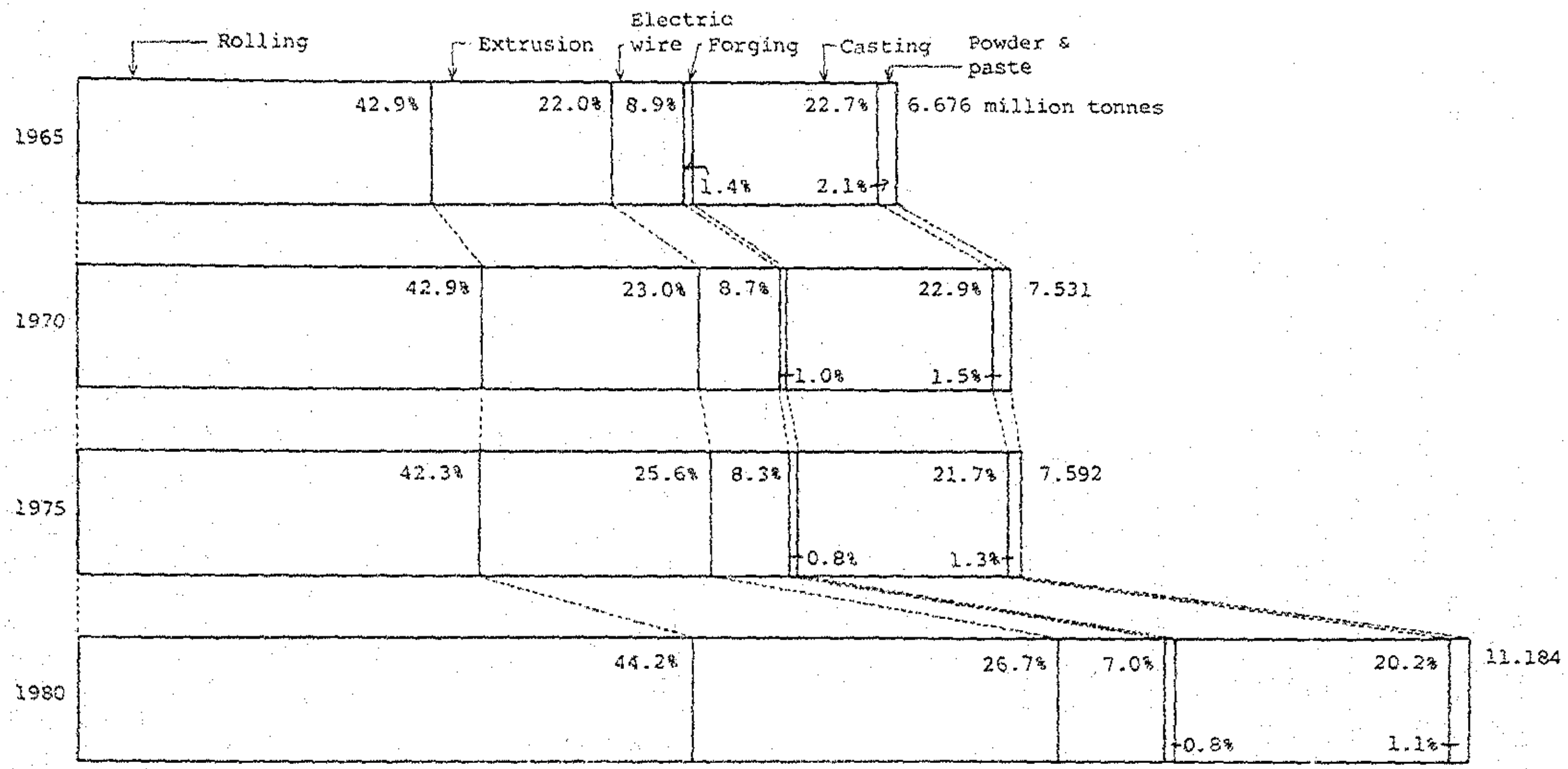
According to Fig. C-9, the aluminum demand structure in 1980 is discussed.

1.1 The United States

Rolling products alone accounted for 56% of the entire demand. Added to the 23% for extrusion, mill products in the

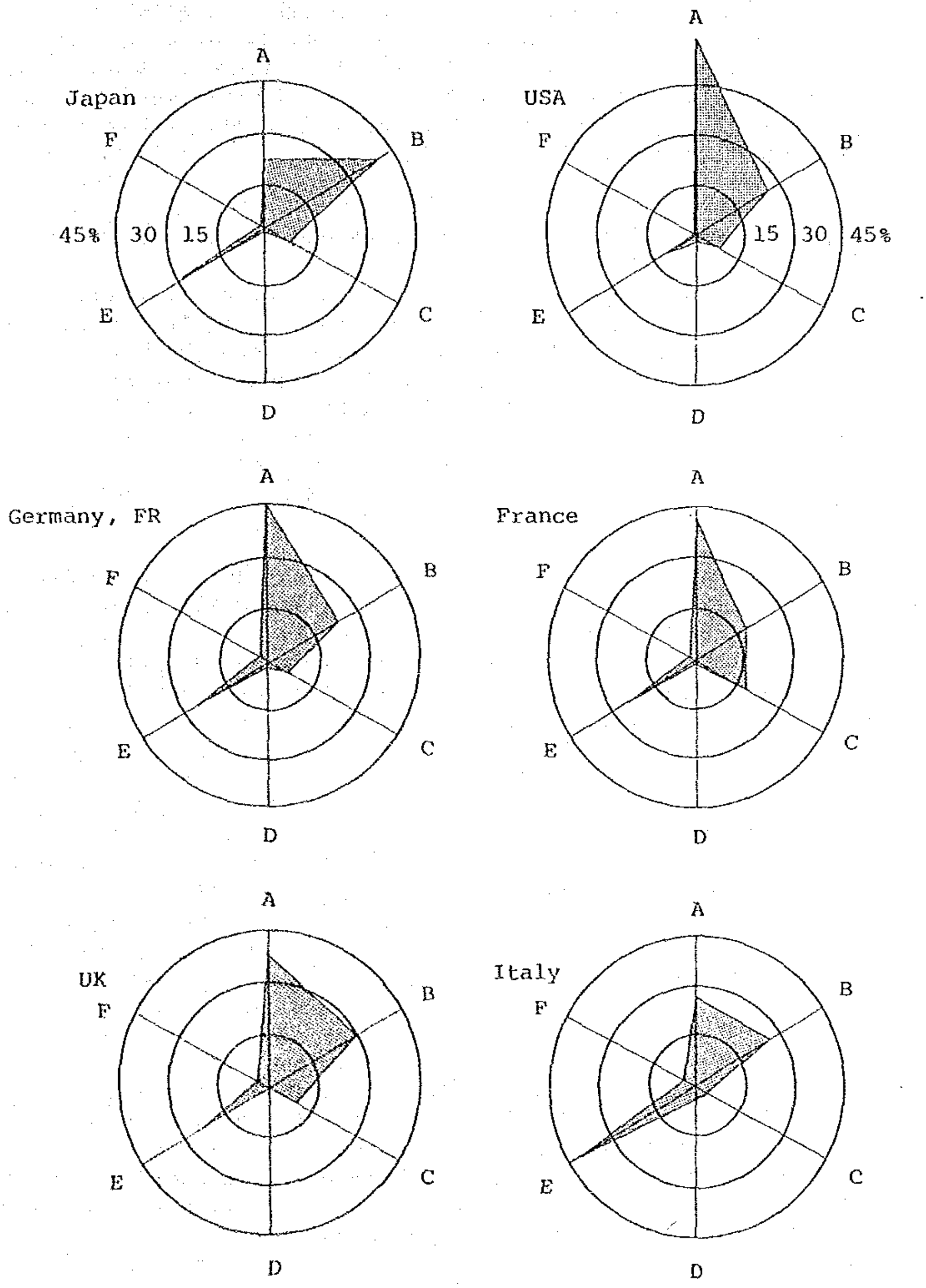
1) Mill products and wire are produced by rolling or extruding primary ingot or scrap metal. Mill products are further divided into rolling and extrusion depending upon the process. Casting and die-casting are the casting products. Aluminum products are divided into these products plus forging and powder. (Slug is a small disc punched from thick plate for drawing tube etc.)
2) 1965 figure included Austria in addition to the six countries.

Fig. C-8 Development of Demand for Aluminum in the 6 Main Countries by Product



Source: Reference Table C-7

Fig. C-9 Comparison of the Demand Structure of Aluminum by Product in the Main Countries (OECD Method)



A: Rolling B: Extrusion C: Electric wire
D: Forging E: Casting F: Powder and paste

broad sense accounted for 79%. In the United States the greatest demand for the rolling comes from beverage cans which is estimated to consume about one third of the rolling products. Also noticeable in the United States is the share of foil which was 12% of the rolling. This quantity is 4.3 times the Japanese counterpart. Relative share of rolling and extrusion in the United States is far larger than in other countries. American demand for aluminum products heavily depends on rolling, especially for consumer goods. The other shares are negligible.

1.2 The Federal Republic of Germany and the United Kingdom

The Federal Republic of Germany is rather similar to the United States. Rolling (45%) and extrusion (24%) total 69%. In addition, casting, with 24%, is very close to the extrusion. The United Kingdom has a more or less intermediate pattern, rolling (39%) and extrusion (29%) totalling 68% and high casting share (20%).

1.3 France

In France, rolling (40%) and casting (25%) are dominant. The share of extrusion (17%) is the lowest among all the six countries, showing that the demand for building materials is relatively weak. On the other hand, France has a unique demand structure whereby the share of wire (17%) is the highest among the six countries.

1.4 Italy

The greatest demand in Italy is for casting (37%). Extrusion (28%) and rolling (28%) follow. The high share of casting is a feature not seen in any other country, indicating aluminum consumption heavily depends on capital goods. The share of powder and paste (3%) is also the highest among the six countries.

1.5 Japan

Compared to the United States, Japan has the large share of extrusion (41%) and casting (28%), totalling 69%. Because the extrusion are used mainly as building materials and the casting as components of transportation machinery and scientific equipment the Japanese demand structure is clearly different from the United States. In other words, Japanese demand is capital goods oriented, relying on extrusion and casting. The share of rolling is also large with 23%.

In this way, each country has its own characteristics in the demand structure by product and no common pattern is found. This is, needless to say, due to the differences in industrial structure and way of life among the countries, but the position of competitive material industries seem also greatly responsible. For example, the strong demand for extrusion in Japan (mostly for sash) and the weak demand for the same product in France expresses well the differences in housing structure or housing industries between Japan and France. The extraordinary large demand for beverage can and foil in the United States comes from their unique custom in food.

2. Demand by Usage

The demand structure for aluminum by usage i.e., end market structure is discussed below according to OECD statistics (Reference Table C-8). The end market is divided into the following ten markets: transportation; general machinery; electrical and communication; civil and construction; food, agriculture, refrigeration and chemical industries; packaging; office goods and daily necessities; powder and paste; steel, other metal and others; export.

Fig. C-10 shows the progress of demand for the 10 markets in the six main countries. According to these data, the average annual rate of growth for the 15 years from 1965 to 1980 was 5.3%, quite higher than that for aluminum products. However, if 1970 was made as the starting point, the 10-year average growth rate was 4.3%, being more or less coincident with that of aluminum products. Of these markets, packaging showed the highest growth (8.0% starting from 1970). Civil and construction (4.5%) and transportation (4.1%) followed packaging. As a result, the three fields; transportation, civil and construction and packaging became the main demand area and accounted for 55% of the total demand (except exports) of the six countries for 1980. This pattern is also clear in Fig. C-11, which compares the demand structures of the 3 areas, the United States, Japan and Europe (the Federal Republic of Germany, France, the United Kingdom and Italy). In Japan the share of packaging is still low and the electrical and communication ranks third.

Analysis of the end market structure by region or country shows that, as in the case of the demand pattern of aluminum product, each country has its own characteristics.

Dividing the six countries into three regions, their end market structure is analysed.

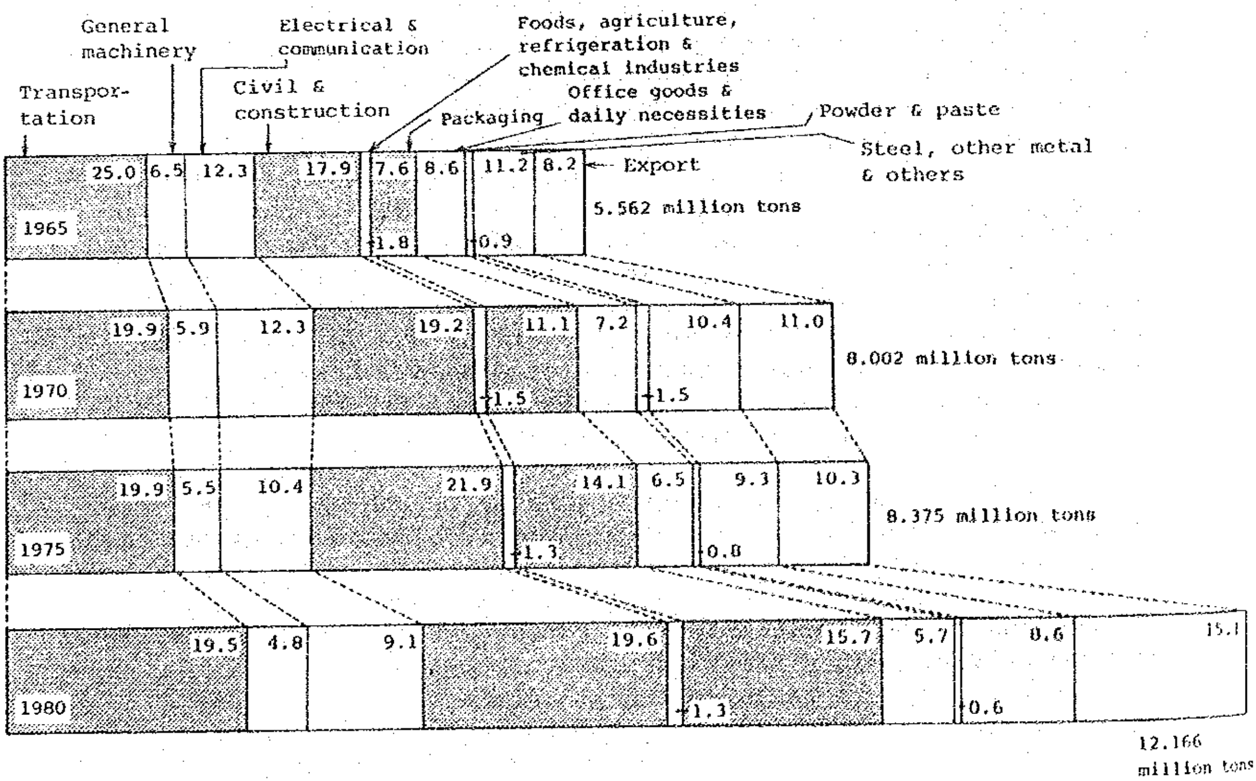
2.1 The United States

In the middle of the 1960s, the three markets, transportation (23.6% share in 1965), civil and construction (22.3%) and electrical and communication (12.6%) totalled 59% of total demand and had large share in the United States end market.

However, the packaging grew very rapidly, reaching at 14.5% share in 1970. During the 1970s it had shown the high annual growth rate of 8.5% and finally became the top market. The growth of the packaging market was tremendous, showing the 15-year annual growth rate of 11.4%, three times as high as the growth rate for total demand of 3.8% starting from 1965. In terms of quantity, packaging market grew to nearly five times of the previous level for 15 years, overwhelming the other markets.

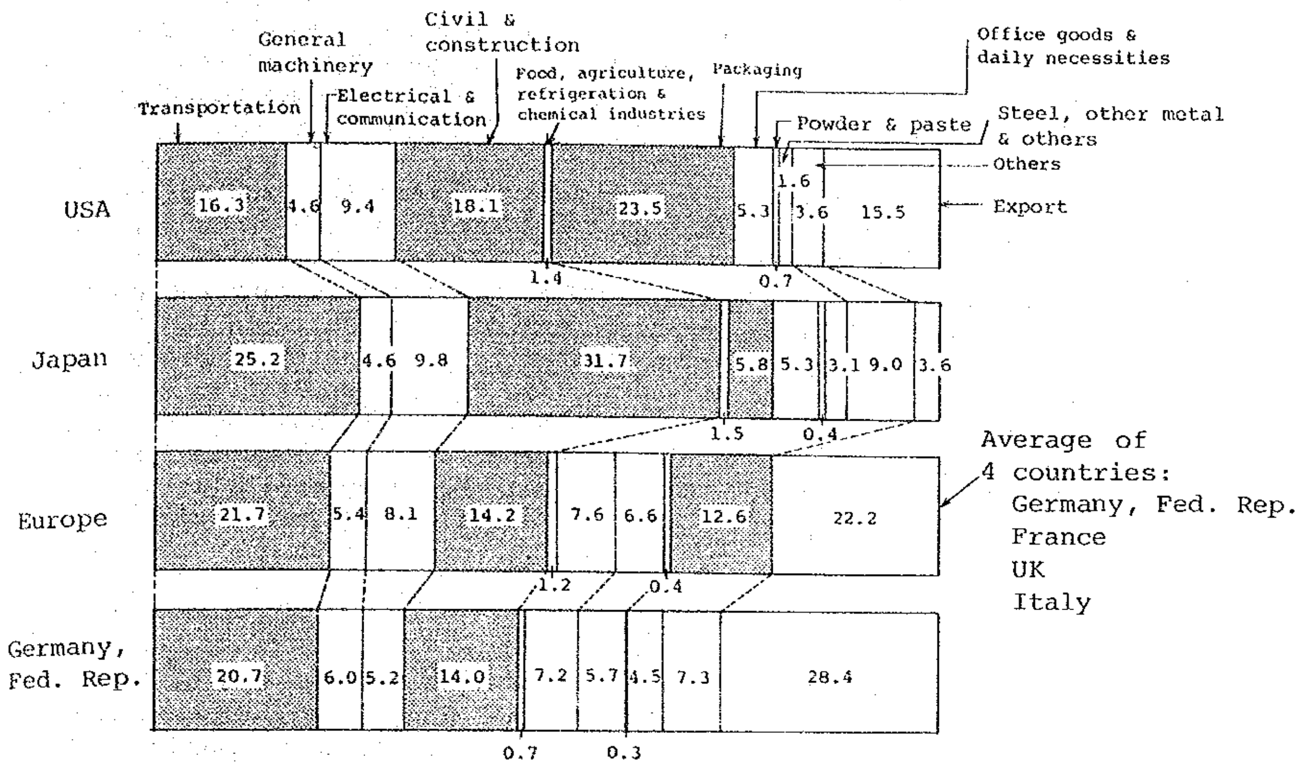
The increase of the demand in the packaging field, though the rapid growth as has been experienced is not anticipated, is

Fig. C-10 Trend in Demand for Aluminum by End Market in the 6 Main Countries



Source: Reference Table C-8

Fig. C-11 Comparison of Demand Structure in the 6 Main Countries (1980)



expected to make it a leading market. The dependence of demand for aluminum in the United States on the packaging field is expected to increase further in the future.

In contrast, the share of the biggest three markets in the past, transportation, civil and construction and electrical and communication relatively decreased and transportation field, which had been the beggiest, was taken over by civil and construction. However, these three big markets remains important and their role as the leader in the capital goods market remains unchanged.

In 1980 in the end market, four big markets, packaging (24% share), civil and construction (18%), transportation (16%) and electrical and communication (9%), shared 67% total demand. The consumption trends in these fields are determining aluminum demand. In recent years, the export market has been growing (16% in 1980) to be a market that cannot be ignored, but the demand in the United States, in general, depends on the domestic market. The other fields do not show any significance. Trends in the shares of these markets are shown in Fig. C-12.

Table C-1 gives interesting data showing the relationship between these end markets and the aluminum products discussed earlier. These data are compiled by AA method which is different from the OECD method [1], but no major difference is found between them.

The biggest usage in the packaging market, which is the largest market, is can material made from rolling product which consumes about 1.20 million tonnes per year. This amount is so giant that it is equal to the 1980 total primary aluminum consumption in Latin America and Asia (excluding Japan). In the construction market, the second largest, the majority of product are made from rolling and extrusion. In the transportation market, the third largest, casting is used for product such as car engine, but almost other product is made from rolling. This analysis of end market also proves the fact that the demand for aluminum product in the United States heavily relies on mill product.

2.2 Europe

In 1965, the largest market for aluminum was transportation (29% share), as in the United States. The second largest market was electrical and communication (12%), followed by exports (11%). These three big markets accounted for 52% of the total.

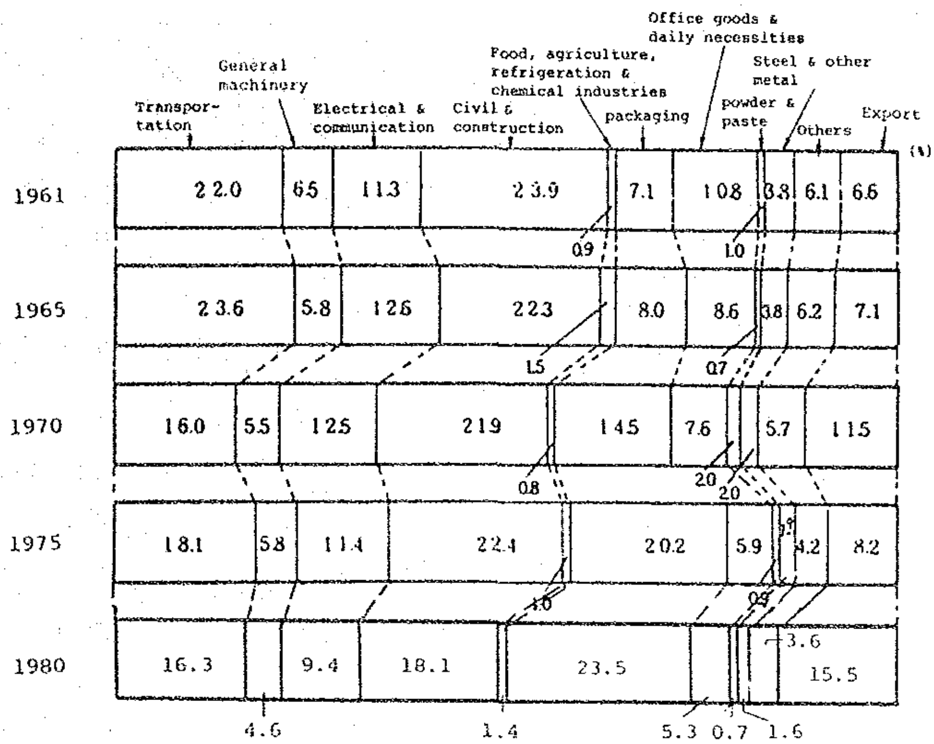
However, since the beginning of the 1970s, civil and construction joined this group (11% share in 1970), leading the growth of demand. The 10 year average annual growth rates for the 1970s showed the export enjoyed the highest growth rate (9.7%), followed by civil and construction (7.5%).

In contrast, electrical and communication showed a particularly low growth of only 0.7%. In 1980, it held a small share of 8% and dropped out of the leading markets.

In summary, in Europe, unlike the United States, the major markets were export (22% share in 1980), transportation (22%) and

1) According to the OECD statistics, the demand for foil in the United States in 1980 was 377,000 tonnes (Reference Table C-7), but according to the AA Statistical Review, it was no more than 128,000 tonnes. However, according to another A.A. data aggregating the figures from the A.A. members' weekly new order reports, the demand for foil was 385,000 tonnes, being nearly equal to the OECD statistics.

Fig. C-12 Trend in Demand Structure in the United States



1980/1965	Average annual growth rate(%)	1980/1965	Average annual growth rate(%)
Transportation	1.3	Office goods & daily necessities	0.5
General machinery	2.3	Powder & paste	3.9
Electrical & communication	1.7	Steel & other metal	-1.6
Civil & construction	2.3	Others	0
Food, agriculture, refrigeration & chemical industries	3.1	Export	9.2
packaging	11.4	Total	3.8

Source: OECD NFMS for each year

Table C-1 Trend in the Four Main End Markets in the United States (A.A. Method)

		1970		1975		1980	
		(1,000 tonnes)	(%)	(1,000 tonnes)	(%)	(1,000 tonnes)	(%)
Building & Construction (Rolling, extrusion, some casting)	Window, Door	286	42.8	312	46.5	387	52.4
	Awning, Canopy	53	7.9	42	6.3	65	8.8
	House siding	149	22.3	178	26.6	171	23.1
	Mobile home	126	18.8	89	13.3	71	9.6
	Bridge, road & highway	55	8.2	49	7.3	45	6.1
	Subtotal	669	100	670	100	739	100
Transportation (Rolling, casting)	Truck, bus	75	15.0	73	13.8	130	18.2
	Passenger car	324	64.7	390	73.7	475	66.4
	Trailer, Semi-trailer	102	20.3	66	14.5	110	15.4
	Subtotal	501	100	529	100	715	100
Consumer durables (Rolling)	Air conditioner, Freezer, Refrigerator	127	57.2	83	50.3	112	53.3
	Portable appliance	29	13.1	21	12.7	25	11.9
	Kitchen utensil	66	29.7	61	37.0	73	34.8
	Subtotal	222	100	165	100	210	100
Container & packaging (Rolling)	Household & other foil, etc.	84	15.3	105	12.9	128	9.3
	Can	398	72.8	640	78.7	1,172	85.4
	Semi-rigid can	65	11.9	68	8.4	73	5.3
	Subtotal	547	100	813	100	1,373	100
	Total	1,939		2,177		3,037	

Source: A.A. Statistical Review 1980 (Pounds converted to kilograms) civil and construction (14%), the three big markets totalling 58% and having decisive influence on the demand structure. If the fourth market of electrical and communication (8%) was added, the total share of the markets reached at 66% of total demand. High dependence on export is characteristic, not seen in the United States and Japan. The Federal Republic of Germany, particularly, had a much high export share of 28%. (See Fig. C-11). In the Federal Republic of Germany, dependence on the limited markets, export and transportation, was unusually high, those two markets totalling about 50% share of the total demand.

Another characteristic in Europe, compared to the United States, is low share of packaging field (8% of the 1980 total demand). The average annual rate of growth in the packaging for the 1970s was not high, only at 3.8%, and this field was not influential in the total demand. Fig. C-13 shows the demand structure and its trend in Europe.

2.3 Japan

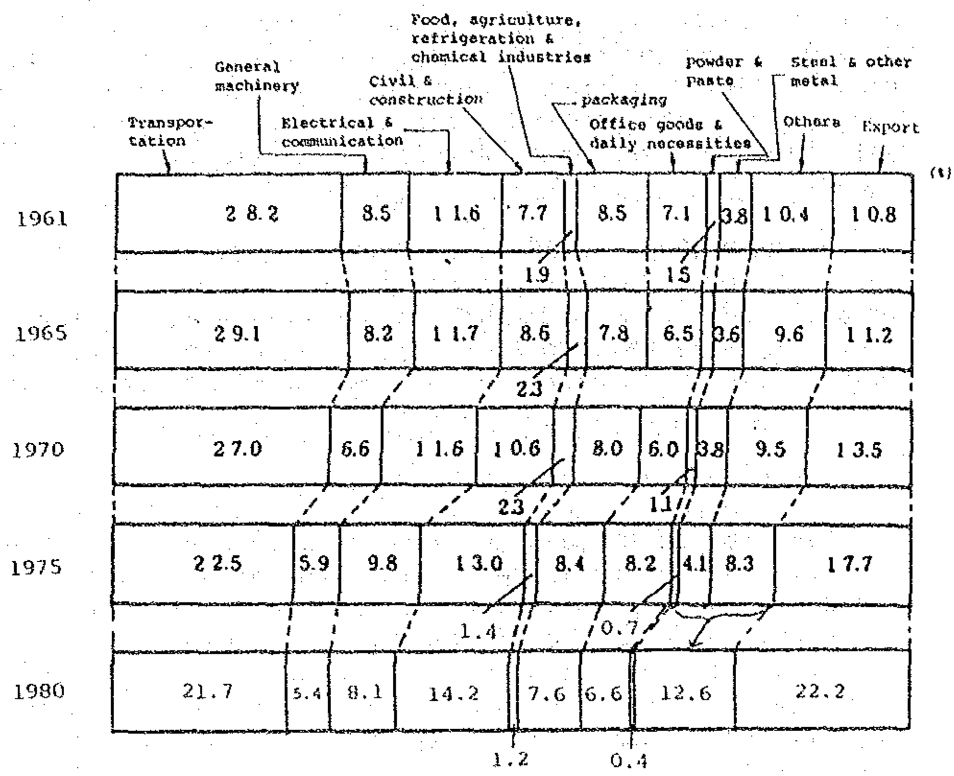
Compared to the demand structures in Europe and the United States, the demand structure in Japan has experienced radical change. In the United States, transportation, civil and construction, electrical and communication and packaging have been the leading fields since 1965, even if their rankings sometimes changed. Also in Europe, though the share of electrical and communication fell off, transportation, export and civil and construction have continued holding their leading position.

The demand structure in Japan in 1965 was relatively well balanced, with the transportation field in the first place (23% share of total demand), office goods and daily necessities in the second place (18% share), electrical and communication (12%) and civil and construction (12%). Noteworthy was the very high share of office goods and daily necessities as compared to the United States and Europe (in 1965, Japan, 18%; the United States, 9%; Europe, 7%).

However, since the beginning of the 1970s, the civil and construction field has grown rapidly (10-year average annual growth rate during the 1970s of 8.9%). In the second half of the 1970s, this single field kept the level of 30% share. The transportation field also showed the similar growth (average annual growth rate for the same period of 8.5%). In 1980, these two leading fields alone accounted for a 57% share of total demand.

On the other hand, the field of office goods and daily necessities, which formerly had the second biggest share, showed a low average growth of only 2.9%. The electrical and communication field also grew at a relatively low rate (3.8%). As a result, the share of office goods and daily necessities has declined to 5% and the share of the electrical and communication field to 10%.

Fig. C-13 Trend in Demand Structure in Europe



1980/1965	Average annual growth rate(%)	1980/1965	Average annual growth rate(%)
Transportation	3.7	Office goods & daily necessities	5.8
General machinery	2.7	Powder & paste	-2.3
Electrical & communication	3.2	Steel & other metal industries	5.4
Civil & construction	9.3	Others	
Food, agriculture, refrigeration & chemical industries	1.2	Export	10.6
Packaging	5.5	Total	5.7

Note: Average of 4 countries; the Federal Republic of Germany, France, the United Kingdom, Italy

The change in demand structure in Japan was so drastic as above, showing sharp contrast with those of the United States and Europe. In particular, the large share of civil and construction (32% in 1980) was outstanding. Combined with the transportation field (25%), the two fields accounted for about 60% of the total. This is a unique structure, not seen in any other nation. If the share of the third biggest market, electrical and communication, is added, the total share of the three markets reached about 70%. It was stated earlier that the Federal Republic of Germany has a demand structure that is overreliant on export and transportation (combined share 50%). However, Japan is more overreliant on limited fields than the Federal Republic of Germany.

The civil and construction, the largest market in Japan, showed a rapid growth up to the middle of 1970s, but has shown a declining trend since the oil crisis, especially coupled with the decreased housing construction in recent years. The stagnated civil and construction market might be a sign of major change in the demand structure in Japan and future trends should be very interesting.

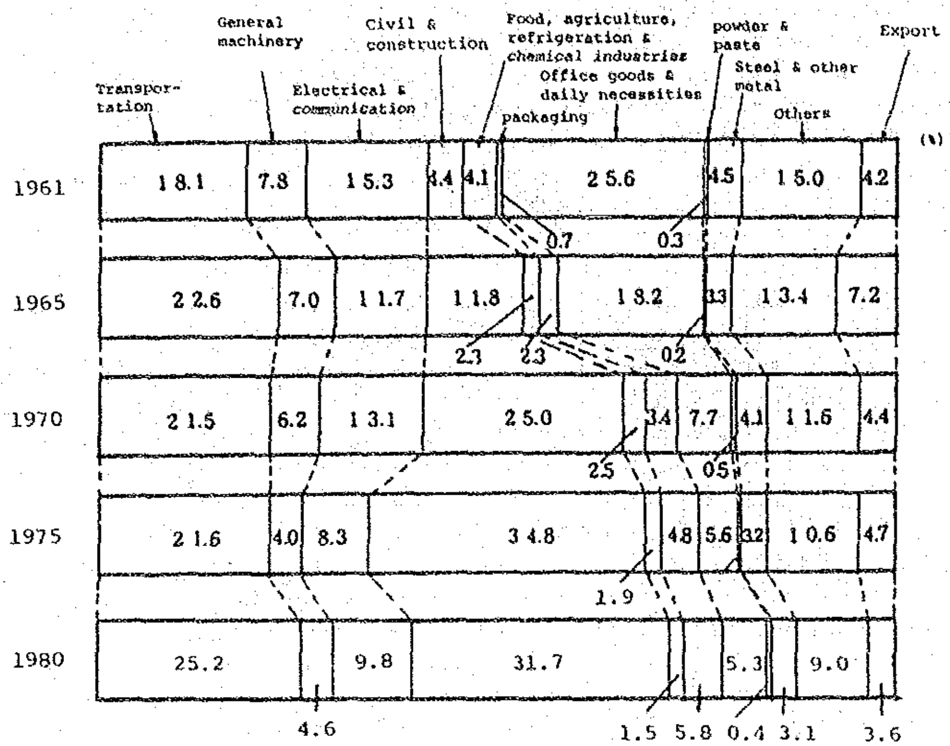
The field that showed the highest growth in the end markets in Japan in 1970s, however, was not civil and construction, but packaging. Its average annual growth rate was quite high at 12.6% (15-year average annual growth rate of 17.4% starting from 1965). Such a rapid growth surpassed even that in the United States packaging market and has not been found in other fields and in other countries. The rapid growth of the packaging field is due to the great increased in aluminum beverage cans, but the volume used in this field is still small, accounting for only 6% of the total demand in 1980. Comparing with the giant share of the United States counterpart (24%) already mentioned and that of the European counterpart (8%), this field may be one of the promising field in Japan in the future.

The export field in Japan was low in its share (4% in 1980) and has not shown any sign of increase. Japan is dependent on the domestic demand and contrasts with Europe which depends much on export. Fig. C-14 shows Japan's demand structure and its trned. Fig. C-15 shows the demand structures in the main countries and their trends in circle graphs.

3. Demand Structure in Japan and its Movement

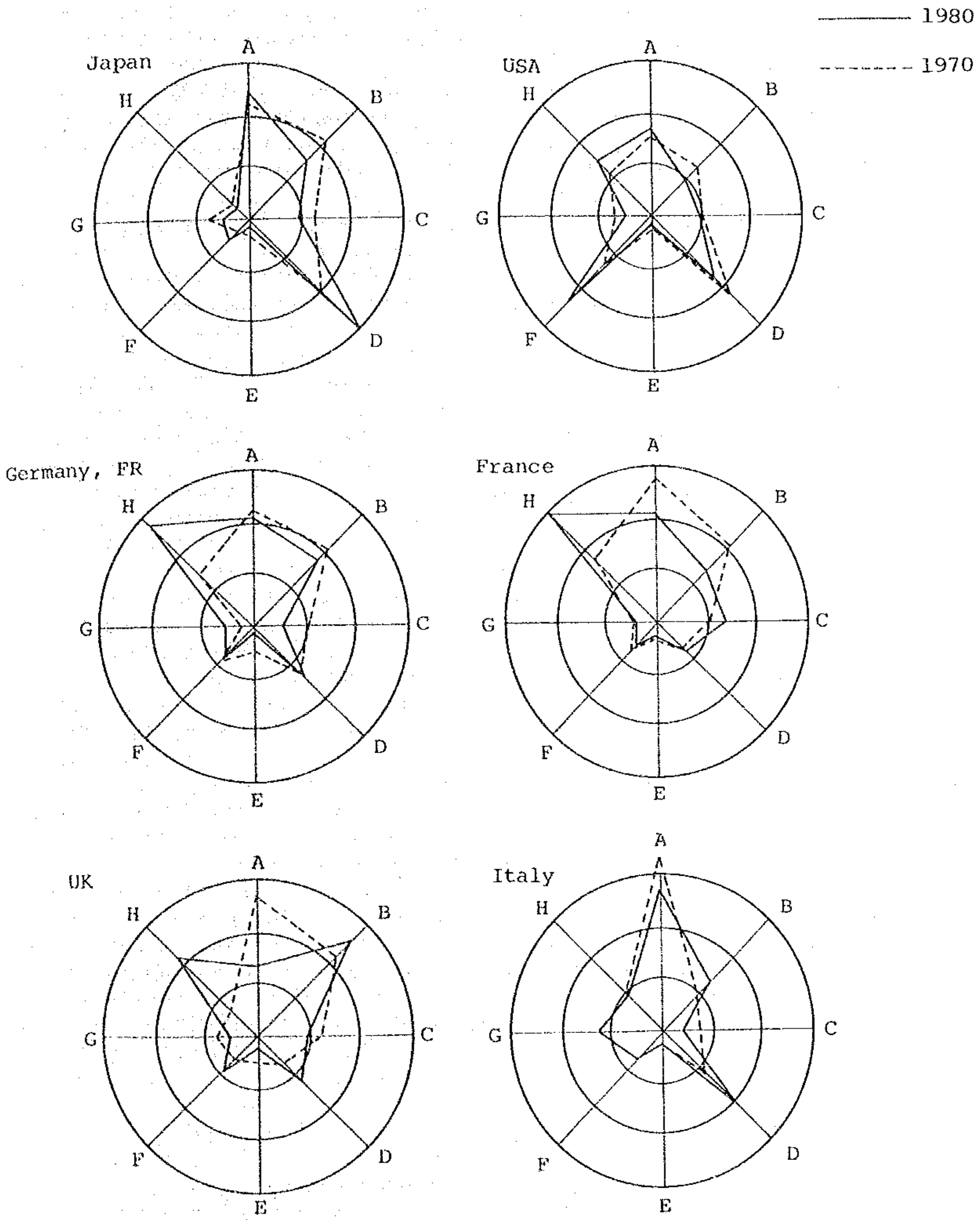
As explained above, the demand structure in each country has its own special pattern corresponding to its industrial structure and way of life and each pattern is not always common. Therefore countries which expect a large aluminum demand in the future are to develop their own demand structure free from the patterns of the developed countries.

Fig. C-14 Trend in Demand Structure in Japan



1980/1965	Average annual growth rate(%)	1980/1965	Average annual growth rate(%)
Transportation	13.6	Office goods & daily necessities	4.5
General machinery	9.5	Powder & paste	16.9
Electrical & communication	11.4	Steel & other metal	10.1
Civil & construction	20.4	Others	
Food, agriculture, refrigeration & chemical industries	7.1	Export	7.6
Packaging	17.4	Total	12.8

Fig. C-15 Comparison of Change in Demand Structure in the Main Countries (1970, 1980) (OECD Method)



A: Transportation
B: General machinery
C: Electrical & communication
D: Civil & construction
E: Chemical industries, powder
F: Packaging
G: Daily necessities
H: Export

However, for countries expecting the development of their aluminum industries in the future, it is not meaningless to learn the development process of some other countries. This section discusses in more detail the development process of Japanese aluminum industry, from the point of how its demand structure has developed.

Before the Second World War, aluminum was widely used for daily necessities and utensils such as lunchbox, washbowl and was also used for the aircraft as a lightweight industrial material, automobile engine, electric wire, firework and explosive.

During the Second World War, aluminum was intensively used as the most important material for aircraft and the other market was mainly the light industry for daily necessities and utensils such as pot, kettle, washbowl and lunch box as before the war.

After the Second World War, the aluminum market for aircraft was lost. On top of this, the use of aluminum other than household utensils, some machinery parts and electric wire was prohibited by the Major Materials Usage Restriction Regulation and the development of new market was difficult. Until the second half of the 1940s, the demand structure for aluminum remained unchanged, generally dependent on domestic demand such as the daily necessities and utensils as before the war.

After 1950, the technological developments to enhance the use of aluminum as a basic material such as the improvement of high-strength aluminum alloys which started during the war and the development of corrosion resistant alloys, ternary alloys and building structural materials began to produce their fruits.[1] This opened new markets in a variety of manufacturing industries, especially for the machinery industry and the demand started to increase in transportation such as motorcycle, household electric appliances such as washing machine and electric fan and various parts for industrial machinery.

Since the second half of the 1950s when Japanese economy moved into a period of high growth based on the development of the heavy chemical industry, the technical development of new usages, especially in the machinery industry, to which the aluminum industry had been devoting all its energy, drastically increased the demand for aluminum, accelerated by the household electric appliance boom, the motorcycle boom, the camera boom and the drastic demand increase for sewing machine.

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1) High-strength aluminum alloy = Al + Cu + Mg (Duralmin is one variety. Possible to reinforce by adding zinc.)
Corrosion-resistant alloy = Al + Mg (+ Si)
Ternary alloy = Al + Zn + Mg

In summary, from the second half of the 1950s to the first half of the 1960s, the demand structure for aluminum in Japan experienced a major change from the light-industry-oriented structure in which the main markets were daily necessities and utensils to the heavy-industry-oriented structure in which machinery and chemical industries were major markets for aluminum. This drastic change is well illustrated in the movement of demand structure from 1955 to 1965 shown in Reference Fig. C-1, Development of Demand Structure by Aluminum Usage.

From the second half of the 1960s, while the development and popularization of ready-made aluminum sash rapidly increased the demand for extruded shape for construction in rolling products, the demand structure for aluminum again began to change rapidly to the one in which the main market was the civil and construction. At the same time, quality of demand changed in the market; for example, demand for television set shifted from black and white set to color set, demand for automobile shifted from 2-wheeled vehicle to 4-wheeled vehicle and demand for aluminum electric wire increased rapidly because of the soaring price of copper in 1965.

This changed the demand structure by aluminum product; In mill product, rolling product enjoyed a predominant position in the market from the 1950s to the first half of the 1960s, but from around 1970, extrusion took over the position of rolling product. In casting, casting product predominated up to the first half of the 1960s, but from the first half of the 1970s die-casting became popular in the market.[1] These trends are also shown in Reference Fig. C-2, Development of Demand Structure by Aluminum Product.

During the 1970s, the demand for aluminum in civil and construction had expanded with the rapid growth of demand for houses and buildings and the demand for transportation, electrical and communication, machinery and metal became stable. The present demand structure was almost established in this period; Mill product (especially extrusions) and casting (especially die-casting) were the two major markets in demand structure by aluminum product, and civil and construction and transportation were two major markets in demand structure by usage.

It was during the 1970s that all-aluminum can was first developed. As already mentioned, the rapid increase in demand for beverage can using aluminum as the end or body material resulted in the amazing growth of demand for aluminum in the packaging market.

From the second half of the 1970s new markets for aluminum have been developed one after another; the progress of aluminum use in

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1) Casting product is produced one by one by small quantity, but die-casting allows mass production of the same product.

exterior products such as balcony, gate, fence etc, aluminum bat and aluminum wheel, aluminum-made LNG tank, aluminum train for Tohoku and Joetsu bullet lines and small-sized aluminum barrel for beer.

Reference Fig. C-3 summarizes the relationship of the rapid development of aluminum demand and general economic conditions in Japan.

As explained above, the aluminum industry in Japan, over these 25 years, changed its demand structure from light industry oriented depending upon daily necessities and utensils to heavy chemical and machinery industry and construction industry oriented and established and strengthened its position as the material industry. In other words, the aluminum industry moved from the period when it depended on mass consumption of daily necessities to the period in which it depended greatly on the indirect demand for durable consumer goods produced by machinery and construction industry. This trend was made clear by the fact that 70% of the total aluminum product demand was for construction material and durable consumer goods. As almost all aluminum durable consumer goods were connected to daily life, it was basically unchanged that demand structure of aluminum was daily-life-oriented probably because of its characteristics. However, aluminum products were sophisticated and diversed more than before and gained solid ground in the Japanese lifestyle and industrial structure.

The amount of total shipment of the aluminum industry [1] was 296.5 billion yen in 1965, exceeded 1,000 billion yen in 1972 and doubled to about 3,400 billion yen in 1980. Compared to 1965, this level was 10 times larger and the average annual growth rate during this period reached 16.8%. Reference Fig. C-4 shows the demand structure in Japan by end market in 1980.

With the recent decreasing trend in the number of housing construction, it has become hard to expect that the demand for aluminum for civil and construction, which was leading the aluminum end markets since the second half of the 1960s, would grow in the future as has been before. Therefore, it was also expected that the share of extruded shapes in demand of mill products would decline. Furthermore, the demand for the aluminum electric wire which achieved high growth since the second half of 1960s was not expected to grow until around 1985 since the demand for electric wire for distribution was saturated. Thus, there emerged recently another sign of change in aluminum demand structure.

Though the Japanese aluminum industry has gained firm ground in

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1) The total amount of shipment from primary aluminum and secondary aluminum to all the processed products including rolling, casting, foil, sash, door, daily necessities, etc.