large difference in growth rates of an increase from 3.8% to 5.0%, France of an increase from 5.9% to 6.5%, and on the other hand the United States of a large decline from 6.6% to 3.6%. Other countries showed no large changes.

According to this UNIDO projection, the total demand for aluminum would maintain the high growth rates and expand up to 1990, but, as of the middle of 1982, this projection seems too optimistic. The reason for this optimism would be firstly because this report compiled projections of main demand sectors and therefore too much emphasis was put on the advantage of aluminum usage, secondly because the GDP growth rates, which were used as bases of projections, were set a little high, and thirdly because the GDP elasticity would be high since actual elasticity up to 1978 was used.

1.3 IPAI's Survey of Primary Aluminum Production Capacity

IPAI publishes twice a year the statistics by area on primary aluminum and alumina production capacity which are received from each member company. The most recent projections based on this information are given in Table F-8. The annual aluminum production capacity as of the middle of 1982 was 13.894 million tonnes and was estimated to increase to 15.115 million tonnes as of the middle of 1985, an increase by 1.221 million tonnes, which represented an annual growth rate of 1.7% for this period, although this projection did not intend to estimate a growth rate.

The annual alumina production capacity was to expand from 30.644 million tonnes to 34.354 million tonnes, giving an annual growth rate for this period of 2.3%, higher than the growth rate for primary aluminum.

1.4 IBA's Projection for Bauxite, Alumina and Aluminum Consumption in the 1980s

IBA published a report concerning aluminum consumption projection in August, 1981 entitled "Bauxite, Alumina and Aluminum - consumption growth or stagnation in the 1980s".

This report studied and analyzed the projections already published by the industry analysts concerning demand for primary aluminum and made the independent projections by IBA for growth rate of demand for primary aluminum.

The projections studied and analyzed by IBA were those 7 as shown in Table F-9. Since projected annual growth rate in those sources varied from 3.5% to 5.6%, the mean rate of 4.1% was

Table F-8 IPAI Primary Aluminum Annual Production Capacity

Situations as of June 30, 1982

(1,000 tonnes)

	AREA							
	1	2	3	4	5	6	7	
	Africa	North America	Latin America	East Asia	South Asia	Europe	Oceania	Total
As of Dec. 31, 1981	502	6,170	911	1,395	737	3,715	530	13,960
As of June 30, 1982	524	6,102	949	1,167	832	3,765	555	13,894
As of Dec. 31, 1982	555	6,235	1,013	1,124	872	3,763	711	14,273
As of June 30, 1983	620	6,235	1,063	1,069	917	3,789	764	14,457
As of Dec. 31, 1983	620	6,235	1,063	1,069	968	3,793	937	14,685
As of June 30, 1984	620	6,235	1,063	1,069	1,016	3,813	972	14,785
As of Dec. 31, 1984	620	6,235	1,123	1,069	1,027	3,795	1,135	15,004
As of June 30, 1985	620	6,235	1,158	1,069	1,027	3,805	1,201	15,115

adopted in this report as the growth rate for primary aluminum demand from 1981 to 1986. The growth rate from 1987 to 1990 was estimated at 5.2%, being the same rate as estimated by USBM for the period until 2000.

As a result, primary aluminum consumption was estimated at 19.070 million tonnes for 1985 and 24.150 million tonnes for 1990. IBA also made projections of bauxite and alumina world demand, which are summarized in Table F-10.

Based on these projections, IBA made the following comments.

It was clear that there would be excess primary aluminum capacity throughout the 1980s. However, if the centrally planned economies continued to import more primary aluminum than it exported and Japanese aluminum industry continued to freeze their capacity, the operation rate in the free world would sooner or later become high.

Table F-9 Projections of Primary Aluminum Consumption Growth Rates referred to in IBA Report

Source	Date of Projections	Period	Average annual growth rate (%)
1. Pechiney Ugine Kuhlmann Group (PUK)* Le Nouveau Journal, Paris*	Feb. 5, '81	1981-1986	4.0
2. "Spector Report", TSAI - Spector Research Report No. 10-81	Aug. 17, '81	1981-1986	5.6
3. Anthony Bird Associates, "Aluminium Analysis"	July '81	1981-1988	3.5
4. Chase Econometrics, T.G. Langton	Aug. 14, '81	1981-1985	4.1
5. The United States Bureau of Mines (USBM), "Mineral Facts and Problems"	1980 Ed.	1978-2000	5.2
6. COMALCO Ltd. 1980 Annual Report	Apr. 1, '81	1981-1990	3 - 4
7. British Aluminium Company (BACO) Ltd. 1980 Annual Report	Mar. 31, '81	1981-1985	4 - 5

* Free world projections

Projections of Annual Growth Rates for Primary Aluminum Consumption by Spector and Bird (1981-1986)

(%)

	1981	1982	1983	1984	1985	1986
Bird	(6.3)	8.5	6.5	4.1	3.4	3.9
Spector	1.1	12.9	8.7	4.9	4.6	1.9

Table F-10 IBA's Projections —— Summary

	Primary Aluminum (1,000 MT)					Alumina (1,000 MT)					Bauxite (1,000,000 MT)			
	Consumption*		Demand	Capacity		Demand			Refining Capacity		Demand		Production	
	World	Growth rates (%)	Free world	Free world	Operation rate (%)	World Metal-lurgical**	Total demand	Free world demand	Free world	Operation rate (%)	Wrold	Free world	World average	Low - High
1980	-		12,606	13,690	92.1	31,740	34,613	28,106	30,574	91.9	82.5	69.5	92.0	92.0
1981	15,185	-7.0	11,879	14,044	84.9	29,611	32,291	27,206	30,637	88.8	80.8	68.1	85.5	80.8- 90.2
1982	16,476	8.5	12,890	14,531	88.7	32,128	35,036	29,518	30,981	95.3	87.7	73.9	92.7	87.7- 97.8
1983	17,546	6.5	13,726	15,000	91.5	34,215	37,312	31,435	31,916	98.5	93.4	78.7	98.8	93.4-104.2
1984	18,336	4.5	14,344	16,606	86.4	35,755	38,991	32,850	33,974	96.7	97.6	82.2	103.2	97.6-108.9
1985	19,070	4.0	14,919	17,974	83.0	37,186	40,552	34,165	36,077	94.7	101.5	85.5	107.3	101.5-113.2
1986	19,718	3.4	15,425	19,298	79.9	38,450	41,930	35,326	40,375	87.5	104.9	88.4	111.0	104.9-117.1
1987	20,743	5.2	16,227	19,760	82.1	40,449	44,110	-	-	-	110.4	93.0	116.8	110.4-123.2
1988	21,822	5.2	17,071	20,670	82.6	42,553	46,405	-	-	-	116.1	97.8	122.9	116.1-129.6
1989	22,957	5.2	-	-	-	44,766	48,818	-	-	-	122.2	102.9	129.2	122.2-136.3
1990	24,150	5.2	-	-	-	47,093	51,356	-	-	-	128.5	108.3	136.0	128.5-143.4

* IBA projections; Baxis data for alumina, bauxite demand

** Alumina/primary aluminum ratio: 1.95; Bauxite/alumina ratio: 2.32

1.5 Chase Econometrics' Projection of Demand for Aluminum up to 1990

Chase Econometrics Associates Inc. forecast in February 1982 the demand for aluminum until 1990.[1] The forecast was made based on economic projections assuming recessions in 1984-1985 and 1990.

Table F-11 is the summary of the projections of total demand for aluminum by the main countries or regions, which was made based on the demand projections by major demand sector.

Demand for primary aluminum was estimated to grow from 12.025 million tonnes in 1980 to 13.444 million tonnes in 1985 and further to 17.509 million tonnes in 1990, which represented an average annual growth rate of 2.3% in the first half of the 1980s and 5.4% in the second half. The reason for lower growth rate in the first half of the decade than the second half was that 1985, being a recession year, was assumed to have low demand.

The growth rates for the various regions in the 1980s were 6.7% for Japan, 6.0% for Canada, 4.3% for Brazil, 3.3% for Europe and 2.4% for the United States. Japan was forecast to have a high growth rate and the United States and Europe were low.

The forecasts of primary aluminum smelting capacity were made based on the existing plants and plans of new smelters until 1986 and were made by estimating up to 1990. The projections for capacity, operation rate and production are shown in Table F-12.

Chase forecasts that the primary aluminum supply and demand balance in the free world, as shown in Table F-13, would show the decline of inventory/consumption ratio from 3.2 months consumption in 1981 to 2.2 months in 1985 and 1.4 months in 1990.

1.6 Mr. Stewart R. Spector's Projection of Medium-Term Supply and Demand

A well known aluminum industry analyst, Mr. Steward R. Spector [2] publishes the research report The Spector Report - Aluminum Industry Service. Based on his two reports,"5-Year Forecast of Aluminum Industry Supply and Demand 1981-1986" published in September 1982 and "Survey of Mid Year Primary Aluminum Capacity 1982-1987" published in August 1982, his projections are analyzed below.

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1) *Light Metals Quarterly*, February 1982

2) President, Tsai-Spector Research Associates Inc.

Table F-11 Chase's Projection of Aluminum Consumption

(1,000 tonnes)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
USA	4,473.00	4,507.43	4,301.03	4,569.34	4,890.28	4,644.20	4,884.83	5,136.96	5,376.20	5,597.48	5,676.23
% change	-10.86	0.77	-4.58	6.24	7.02	-5.03	5.18	5.16	4.66	4.12	1.41
Canada	292.00	295.14	298.60	344.91	386.70	389.96	403.57	437.59	478.76	509.04	521.65
% change	-14.12	1.07	1.17	15.51	12.12	0.84	3.49	8.43	9.41	6.33	2.48
Japan	1,636.80	1,532.96	1,689.53	1,834.17	2,027.70	2,117.82	2,259.74	2,467.12	2,701.05	2,920.03	3,122.59
% change	-9.24	-6.34	10.21	8.56	10.55	4.44	6.70	9.18	9.48	8.11	6.94
Europe	3,857.60	3,589.01	3,727.60	3,968.03	4,235.30	4,197.15	4,371.13	4,623.21	4,919.60	5,151.35	5,318.12
% change	-0.65	-6.96	3.86	6.45	6.74	-0.90	4.15	5.77	6.41	4.71	3.24
Brazil	308.70	309.93	313.34	325.91	346.85	359.60	376.60	398.43	422.41	446.59	469.67
% change	20.07	0.40	1.10	4.01	6.43	3.68	4.73	5.80	6.02	5.72	5.17
Rest of world	1,456.90	1,444.68	1,433.77	1,541.31	1,653.40	1,734.72	1,771.44	1,894.21	2,058.66	2,235.49	2,397.68
% change	13.24	-0.84	-0.76	7.50	7.27	4.92	2.12	6.93	8.68	8.59	7.26
Non-socialist world total	12,025.00	11,679.10	11,763.80	12,584.20	13,539.60	13,444.20	14,066.80	14,957.20	15,956.20	16,859.60	17,508.50
% change	-4.47	-2.88	0.73	6.97	7.59	-0.70	4.63	6.33	6.68	5.66	3.85

Table F-12 Chase's Projections of Aluminum Capacity and Production

(1,000 tonnes)

	1980	1981	1982	1983	1984	1985	1986
USA							
Capacity	4,798.00	4,945.00	5,053.00	5,144.00	5,144.00	5,144.00	5,144.00
Operation rate	0.97	0.91	0.74	0.84	0.89	0.87	0.88
Production	4,653.60	4,480.66	3,758.83	4,314.68	4,561.38	4,457.61	4,517.86
Canada							
Capacity	1,065.00	1,122.00	1,122.00	1,179.00	1,246.00	1,246.00	1,246.00
Operation rate	1.01	0.98	0.92	0.94	0.98	0.98	0.98
Production	1,074.50	1,093.95	1,035.70	1,111.85	1,214.85	1,214.85	1,214.85
Australia							
Capacity	279.00	372.00	475.00	660.00	864.00	1,050.00	1,125.00
Operation rate	1.09	0.99	0.90	0.94	0.96	0.96	1.00
Production	303.50	366.42	427.81	620.37	825.12	1,002.75	1,119.37
Japan							
Capacity	1,157.00	1,136.00	850.00	800.00	750.00	700.00	650.00
Operation rate	0.94	0.68	0.86	0.80	0.90	0.90	0.89
Production	1,091.50	777.15	732.47	642.18	674.90	627.98	578.37
Europe							
Capacity	3,953.00	4,136.00	4,116.00	4,131.00	4,189.00	4,284.00	4,284.00
Operation rate	0.95	0.90	0.81	0.84	0.87	0.84	0.85
Production	3,762.30	3,714.92	3,344.49	3,478.29	3,652.20	3,602.35	3,654.52
Other countries							
Capacity	2,162.00	2,447.00	2,716.00	2,980.00	3,142.00	3,379.00	3,694.00
Operation rate	0.87	0.81	0.72	0.74	0.81	0.79	0.80
Production	1,890.00	1,988.09	1,955.52	2,202.07	2,553.38	2,652.80	2,951.89
World total							
Capacity	13,414.00	14,158.00	14,332.00	14,894.00	15,335.00	15,803.00	16,143.00
Operation rate	0.95	0.88	0.79	0.83	0.88	0.86	0.87
Production	12,775.40	12,421.20	11,254.80	12,369.40	13,481.80	13,558.30	14,036.90

Table F-13 Chase's Projections of Primary Aluminum Supply and Demand Balance

(1,000 tonnes)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Non-socialist world primary consumption	12,025.00	11,679.10	11,763.80	12,584.20	13,539.60	13,444.20	14,066.80	14,957.20	15,956.20	16,859.60	17,508.50
% change	-4.47	-2.88	0.73	6.97	7.59	-0.70	4.63	6.33	6.68	5.66	3.85
Socialist countries, net imports	-124.90	-118.70	-120.00	-130.00	-140.00	-150.00	-160.00	-170.00	-180.00	-190.00	-200.00
GSA, net purchases	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other stockpiles, net purchases	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-socialist world primary demand	11,900.10	11,560.40	11,643.80	12,454.20	13,399.60	13,294.20	13,906.80	14,787.20	15,776.20	16,669.60	17,308.50
% change	-4.48	-2.85	0.72	6.96	7.59	-0.79	4.61	6.33	6.69	5.66	3.83
Non-socialist world primary supply	12,775.40	12,421.20	11,254.80	12,369.40	13,481.80	13,558.30	14,036.90	14,478.90	15,433.30	16,546.90	17,222.00
% change	6.67	-2.77	-9.39	9.90	8.99	0.57	3.53	3.15	6.59	7.22	4.05
Change in commercial inventories	565.00	1,010.74	-539.02	-234.79	-17.78	214.10	280.06	-408.28	-442.93	77.25	63.52
Errors and omissions	310.30	-150.00	150.00	150.00	100.00	50.00	-150.00	100.00	100.00	-200.00	-150.00
Analytical measures:											
EOP commercial inventory level	2,078.00	3,088.74	2,549.72	2,314.94	2,297.16	2,511.26	2,791.32	2,383.04	1,940.11	2,017.36	2,080.87
Months consumption covered by inventory	2.07	3.17	2.60	2.21	2.04	2.24	2.38	1.91	1.46	1.44	1.43

1.6.1 Primary aluminum demand

The demand in the United States, which shares about 30% of free world demand, is in a seriously bad situation as the demand in 1979, 1980 and 1981 fell below the previous year's level for consecutive three years and in 1982, although the degree was slight, it would appear to fall short of the previous year's level again. (Table F-14 showed the forecast that 1982 would exceed previous year, but the most recent forecast by Mr. Spector showed a 3% decrease from the previous year). By 1984, however, the housing and automobile industries were expected to return to the high levels, and hence the demand for aluminum would recover rapidly, exeeding 1978 level. But, in 1985, because the economy would enter an adjustment situation again, demand for aluminum would slow down. Assuming recession continued in 1986, aluminum demand could not be expected to grow but it was forecast to recover again in 1987. It was thus estimated that, from 1980 to 1985, an average annual growth rate would be 4.5% and, from 1982 to 1987, 6.2%. Europe and Japan showed consecutive decline of demand for 1980 and 1981 just as the United States. It was expected that the demand in 1983 would exceed the level of 1979 and then in 1986, it would remain sluggish or even decline due to economic recession.

Total free world aluminum demand was forecast to increase by about 6% in 1982 compared to the previous year, but still lower than 1979 levels. It would then recover rapidly, but, in 1986, the growth rate would decrease due to the recession in Japan, Europe, and the United States. The average annual growth rate from 1980 to 1985 was estimated at 4.9%, 2.8% from 1985 to 1987, and 6.5% during the 5-year period from 1982 to 1987. Table F-14 shows the free world primary aluminum demand forecast by Mr. Spector.

1.6.2 Aluminum smelting capacity

According to the surveys by Mr. Spector at the end of 1981 and in the middle of 1982 as shown in Table F-15, the production capacity as at the middle of 1982 was decreased by nearly 1 million tonnes, although two surveys had only 6 months interval, due to the increase in production cut back caused by decline of demand, the cancellations or delays of expansion programs as well as the permanent shut down of economically obsolete plants. This drastic decrease in capacity was resulted from the reduction of Japan's operation capacity from 700,000 tonnes to 300,000 tonnes, a reduction by 400,000 tonnes, the reduction of Taiwan's capacity from 50,000 tonnes to none, and the decreases in smelting capacity in the United States, and Europe, etc. The capacity at the end of 1987 also showed about 2 million tonnes

Table F-14 Mr. Spector's Projection of Free World Primary Aluminum Demand

(1,000 tonnes)

	USA	Canada	Latin America	Europe	Japan	Others	Totals excluding USA	Free world totals
1978	5,041	317	540	3,294	1,653	1,246	7,050	12,091
1979	4,959	448	595	3,717	1,739	1,179	7,678	12,637
1980	4,324	315	700	3,677	1,658	1,371	7,721	12,045
1981	3,928	325	650	3,500	1,559	1,150	7,184	11,112
1982	4,235	315	675	3,650	1,660	1,250	7,550	11,785
1983	4,960	350	775	4,000	1,870	1,400	8,395	13,355
1984	5,320	400	900	4,300	2,100	1,600	9,300	14,620
1985	5,400	435	1,000	4,400	2,260	1,800	9,895	15,295
1986	5,375	450	1,100	4,400	2,200	1,850	10,000	15,375
1987	5,725	450	1,200	4,500	2,300	2,000	10,450	16,175

* except China, the Democratic Republic of Korea and Eastern Europe

Sources: Various national publications; The Spector Report

Basis for calculation:

Primary aluminum demand = Primary aluminum production ± exports and imports of primary aluminum and mill products ± changes in inventory of producers, customers and London Metal Exchange

Table F-15 Mr. Spector's Survey of Aluminum Smelting Capacity

(1,000 tonnes)

	Timing of survey	
	Middle of 1982	End of 1981
1981		14,370
1982	13,590	14,503
1983	14,050	15,075
1984	14,652	15,620
1985	14,982	15,963
1986	15,614	16,859
1987	15,796	17,757

Source: The Spector Report

reduction from the survey as at the end of 1981 to the one as at the middle of 1982.

Table F-16 shows the forecast by country of the new or expansion of capacity from 1982 to 1987. The total free world capacity is expected to increase by 2.206 million tonnes for the free world as a whole. Of this, 2.206 million tonnes, consisting of 1.280 million tonnes increase in the developed industrial countries and 0.926 million tonnes in the developing countries. The countries with large capacity increases are Australia, Brazil, Canada, Indonesia, and so forth.

1.6.3 Primary aluminum supply and demand balance

Table F-17 summarizes the supply and demand balance for each year based on Mr Spector's 5-year (1982-1987) supply and demand forecast.

As shown in this table, Mr. Spector forecast that, from 1982 to 1985, the demand would exceed supply and the level of inventory was adjusted, while, during 1986-1987, the inventory would increase as supply exceeded demand.

The current world-wide economic recession is, on the contrary to expectations, even worsening and the above forecast by Mr. Spector may be significantly revised in the future as the capacity survey has already shown major revisions from the one at the end of 1981 to the one at the middle of 1982.

1.7 Mr. James A. Vais's Projection

Mr. James A. Vais [1] made a speech at the Second International Aluminum Congress at Monte Carlo in September 1982, concerning following projections.

As shown in Table F-18, he forecast that the economy would not show a severe zero growth.

Consumption of secondary aluminum which affects primary aluminum consumption would increase from 22% of total aluminum consumption in the free world in 1980, to 24% in 1985 and 26% in 1990.

Consumption of primary aluminum in the free world in 1981 was 11.0 million tonnes, and, although expected to decrease by 3% in

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1) Director, Economic & Marketing Research, Kaiser Aluminum & Chemical Corp.

Table F-16 Mr. Spector's Projections of Free World Primary Aluminum Production Capacity by Country

(1,000 tonnes)

		1982		1983		1984		1985		1986		1987		Average annual growth rate 87/82 (%)	Increased capacity 87-82=A	Rate of contribution to the increase 82 - 87 (%)
Canada		1,234		1,234		1,234		1,291		1,547*		1,547*		4.6	313	14.2
USA		4,998	(5,193)	4,998	(5,193)	4,998	(5,193)	4,998	(5,282)	5,052	(5,366)	5,052	(5,366)	0.2	54	2.4
Argentina	LDC	140		140		140		140		175		175		4.6	35	1.6
Brazil	LDC	364	(384)	401	(396)	519		599*		679*		709	(754)	14.3	345	15.6
Mexico	LDC	45		45		45		45		45		45		0	0	0
Surinam	LDC	60	(66)	60	(66)	60	(66)	60	(66)	60	(66)	60	(66)	0	0	0
Venezuela	LDC	400		400		400		400		400		400		0	0	0
Austria		95		95		95		95		95		95		0	0	0
France		450	(447)	449	(447)	448	(447)	447		447		447		-0.1	-3	-
Greece	LDC	150	(143)	150	(143)	150	(143)	150	(143)	150	(143)	150	(143)	0	0	0
Iceland		88		88		88		88		88		88		0	0	0
Italy		277		277		277		277		277		277		0	0	0
Netherlands		264	(272)	264	(272)	264	(272)	265	(273)	265	(273)	265	(273)	0.1	1	0.0
Norway		770	(774)	770	(783)	829	(842)	829	(845)	829	(845)	829	(845)	1.5	59	2.7
Spain	LDC	407		407		407		407		407		407		0	0	0
Sweden		82	(83)	82	(83)	82	(83)	87	(70)	140	(70)	152	(70)	13.1	70	3.2
Switzerland		86		86		86		86		86		86		0	0	0
UK		285	(387)	285	(387)	285	(387)	285	(387)	285	(387)	285	(387)	0	0	0
Germany, FR		745	(752)	751		768		778		778		778		0.9	33	1.5
Yugoslavia	LDC	327	(367)	377		377	(397)	377	(397)	377	(397)	377	(397)	2.9	50	2.3
Cameroon	LDC	84	(81)	84	(81)	84	(81)	84	(81)	84	(81)	84	(81)	0	0	0
Egypt	LDC	133	(135)	166		166		166		166		166		4.5	33	1.5
Ghana	LDC	200		200		200		200		200		200		0	0	0
Libya	LDC	0		0		0		0		120*		120*		-	120	5.4
S. Africa		130		170		170		170		170		170		5.5	40	1.8
Bahrain	LDC	170		170		170		170		170	(280)	170	(280)	0	0	0
Dubai	LDC	135		135		135		135		135		135		0	0	0
India	LDC	365	(360)	365	(367)	369		369		373		483*		5.8	118	5.3
Indonesia	LDC	75		150		225		225		225		225		24.6	150	6.8
Iran	LDC	50		50		50		50		50		50		0	0	0
Turkey	LDC	45	(60)	60		60		60		90*	(60)	120*	(60)	21.7	75	3.4
Japan		751	(1,111)	727	(1,111)	727	(1,111)	727	(1,111)	727	(1,111)	727	(1,111)	-0.6	-24	-
Operation capacity		300	(700)	300	(700)	300	(700)	400	(700)	400	(700)	400	(700)	5.9	100	4.5

Table F-16 (cont'd.)

(1,000 tonnes)

		1982	1983	1984	1985	1986	1987	Average annual growth rate 87/82 (%)	Increased capacity 87-82=A	Rate of contribution to the increase 82 - 87 (%)
Taiwan	LDC	0 (50)	0 (50)	0 (50)	0 (50)	0 (50)	0 (50)	-	-	-
Korea, Rep. of	LDC	18	18	18	18	18	18	0	0	0
Australia		451 (502)	579 (848)	909 (1,097)	987 (1,213)	987 (1,320)	987 (1,433)	17.0	536	24.3
New Zealand		167 (197)	244 (240)	244 (240)	244 (240)	244 (340)	244 (440)	7.9	77	3.5
Free world total		13,590(14,503)	14,050(15,075)	14,652(15,620)	14,982(15,963)	15,614(16,859)	15,796(17,257)	3.1 (3.5)	2,206(2,754)	100
Developed countries total		10,422	10,672	11,077	11,327	11,690	11,702	3.1	1,280	58.0
LDC totals		3,168	3,378	3,575	3,655	3,924	4,094	5.3	926	42.0
LDC weight		23.3	24.0	24.4	24.4	25.1	25.9	-	-	-
Uncertain capacity		0	0	59 (175)	139 (291)	623 (905)	603 (1,303)	-	-	-
Free world total less uncertain capacity**		13,590(14,503)	14,050(15,075)	14,593(15,445)	14,843(15,672)	14,991(15,954)	15,193(15,954)	2.3 (1.9)	1,603(1,451)	
Average annual capacity for ** above		13,980	13,820	14,322	14,718	14,917	15,092	1.5	1,112	-

* Including uncertain capacity

( ) Figures in brackets are data in the Feb. 26, 1982, report (No figures shown in brackets if no change). Capacity at the end of 1981 was 14,370 according to the same report.

Note: Totalled using Japanese operation capacity

Table F-17 Mr. Spector's Projections of Free World Primary Aluminum Supply and Demand Balance

(1,000 tonnes)

	1979	1980	1981	1982	1983	1984	1985	1986	1987
Supply									
U.S. production	4,557	4,653	4,489	3,638	4,613	4,830	4,920	4,990	5,100
Non-U.S. production	7,417	8,120	7,979	7,769	8,427	9,465	10,207	10,517	11,323
Total production	11,974	12,773	12,468	11,407	13,040	14,295	15,127	15,507	16,423
Imports from Eastern Europe	285	200	175	125	125	175	200	200	200
Total supply (A)	12,259	12,973	12,643	11,532	13,165	14,470	15,327	15,707	16,623
Demand									
U.S. demand	4,959	4,324	3,928	4,235	4,960	5,320	5,400	5,375	5,725
Non-U.S. demand	7,678	7,721	7,184	7,550	8,395	9,300	9,895	10,000	10,450
Demand sub-total	12,637	12,045	11,112	11,785	13,355	14,620	15,295	15,375	16,175
Exports to Eastern Europe	165	250	125	125	125	150	175	225	250
Total demand (B)	12,802	12,295	11,237	11,910	13,480	14,770	15,470	15,600	16,425
Supply and demand balance (A-B)	-543	678	1,406	-378	-315	-300	-143	107	198

Table F-18 Mr. James A. Vais's Projections of Economic Growth by Major Region

(%)

	G.D.P.		I.P.	
	1980-85	1985-90	1980-85	1985-90
USA	2.9	3.3	3.3	4.0
Canada	3.3	4.0	3.5	4.2
Latin America	5.6	6.2	5.5	6.4
Western Europe	3.1	3.5	3.1	3.7
Japan	4.9	5.6	5.0	5.8
Taiwan, Korea, Rep. of and Hong Kong	6.5	7.2	7.0	7.5
Oceania	3.3	4.0	3.4	3.4
Developing countries	5.2	5.7	5.4	5.7

1982, would increase to 13.8 million tonnes in 1985 and in 1990, to 17.1 million tonnes. The annual average growth rate during this period would be 4.6% in the first half, 4.4% in the second half and 4.5% for the entire 1980s.

Primary aluminum production capacity, which was 14.3 million tonnes at the end of 1981, was estimated to increase to 15.7 million tonnes in 1985 and 16 million tonnes in 1987, after considering permanent shut down of existing plants of 1 million tonnes consisting of 0.6 million tonnes in Japan and 0.4 million tonnes elsewhere.

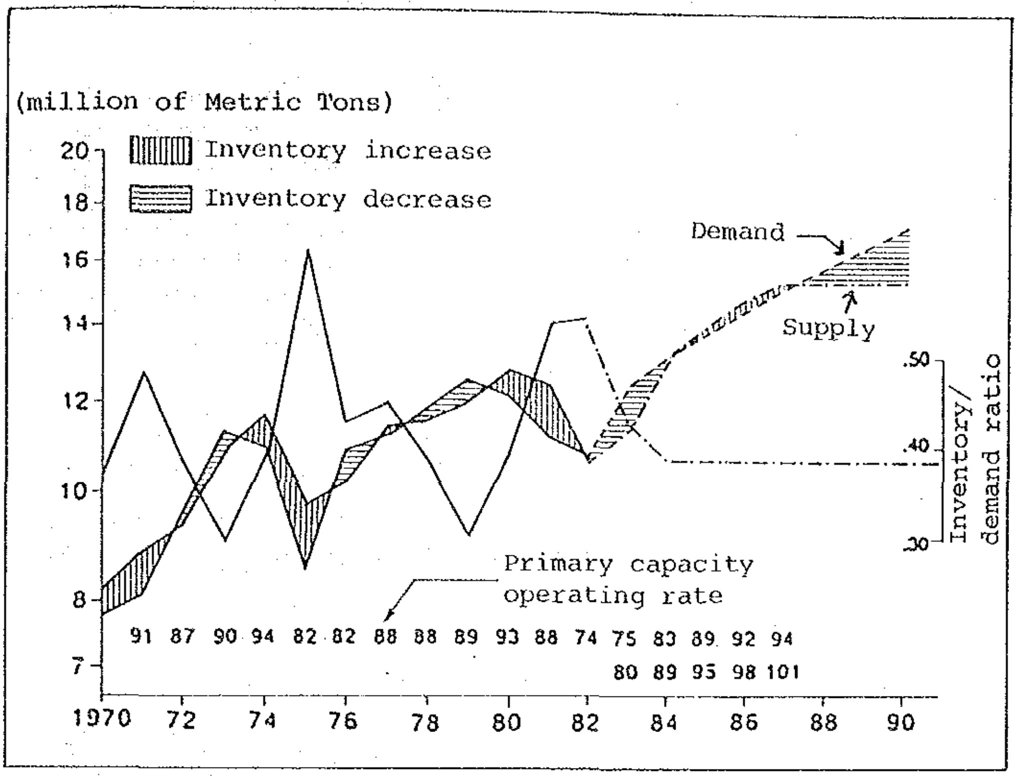
As for the supply and demand balance shown in Fig. F-1, a rather large reduction in inventory was expected in 1983 and 1984. Accordingly, operation rate would be 74% in 1982, 89% in 1985 and, assuming 1 million tonnes capacity mentioned above could not be reopened, it would rise to 95% in 1985 and 98% in 1986. In summary, Mr. Vais forecast that in the second half of 1980s, construction of new plants would be necessary to meet increasing demand.

1.8 Other Projections

a. According to a report from the Chemical Bank (London),[1] demand for primary aluminum would increase at an average annual rate of 4.5% in the world for the next 20 years, due to growth in the can, transportation, and construction fields. And higher

1) Metal Bulletin, Aug. 20, 1982

Fig. F-1 Mr. Vais's Western World Primary Aluminum Supply/Demand Outlook



growth than the economic growth would continue in the developed countries. As a result, supply and demand would be effectively balanced before 1985 and, after that, capacity increases on a scale of 1 million tonnes would be required each year. New capacity would be established in Brazil, Australia, Africa and the Middle East.

b. According to the views of specialists in Billiton,[1] demand for aluminum would grow by 3 to 4% per year in the world over the long term. Although demand would be sluggish in the developed countries such as the United States, the growth in South America and Southeast Asia would make up for it. Since existing world capacity was on the level of 14 million tonnes, increase in capacity of about 0.5 million tonnes would be necessary each year, if supply and demand were balanced.

c. According to the latest report by Chase Econometrics Associates

1) International Billiton Newspaper, June 28, 1982

as quoted in Metals Week,[1] the U.S. aluminum industry would pass through a two-year growth period in 1983 and 1984, then enter recession period from around 1985 with another inventory increase. Afterwards, the annual growth rate until 1987 would be from 4 to 6.5%.

d. According to Messrs. Hargreaves and Williamson,[2] aluminum demand was currently sluggish, but it would maintain stable growth on the level of 3 to 4% over the long term.

e. According to an analyst at Martin Marietta,[3] demand would grow at an annual rate of 4.6% for 10 years between 1980 and 1990. The demand sectors for which rapid growth was expected were machinery and durable consumer goods.

2. Comparison of Published Projections

Table F-19 summarizes the published projections discussed above. Based on comparison of these projections, following remarks can be made.

2.1 Aluminum Demand or Consumption

Fig. F-2 summarizes the projections of annual growth rates for aluminum demand or consumption for the first and second half of the 1980s. Six projections shown in this Figure have a large variation from 2.3% to 7.6% for the first half of the 1980s, from 4.4% to 6.1% for the second half of the 1980s, and from 3.8% to 6.9% for the entire 1980s.

The average of these projected growth rates is 4.8% for the first half of the 1980s, 4.7% for the second half and 4.8% for the decade, which is close to other recent projections of the 3-5% level.[4] It should be noted that this average is a little higher than otherwise because of a signicantly high projection made by UNIDO.

UNIDO expected the highest growth rate of 6.9% for the entire 1980s and 7.6%, particularly high, for the first half of the decade. The lowest growth rate was Chase projection of 2.3% for the first half of the 1980s. Even this projection showed a relatively high rate of 5.4% for the second half. Only Mr. Vais's

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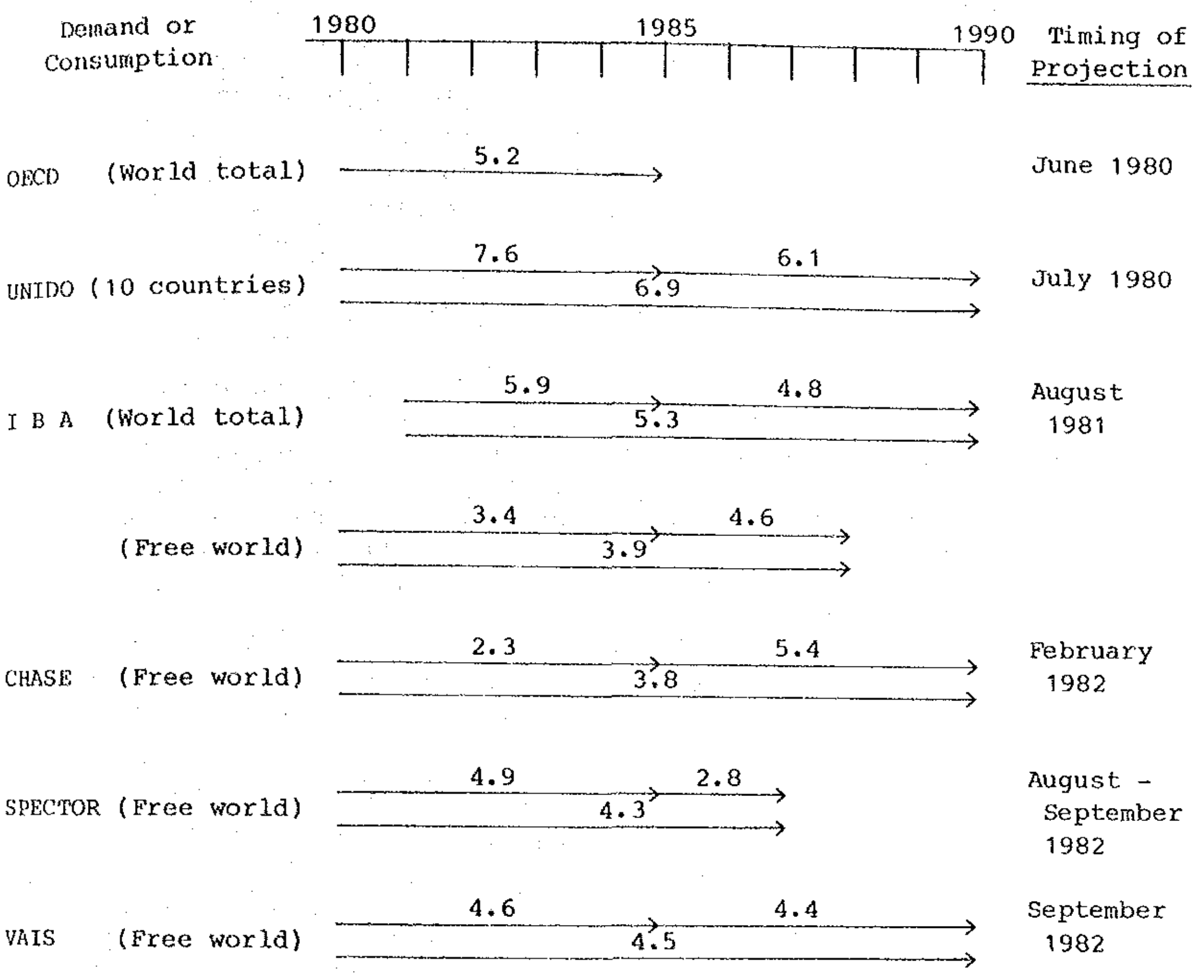
1) Metals Week, April 5, 1982
2) Reuters, Feb. 25, 1982
3) AMM, March 16, 1982
4) cf. Chapter II, Section 1, Sub-section 1.8

Fig. F-2 Comparison of Various Published Projections for Primary Aluminum Growth Rates (%)



projection showed comparatively stable growth rates in the first and second half of the 1980s, 4.6% and 4.4% respectively.

Following is a comparison of the quantity of aluminum consumption or demand.

		1985	1990
		(million tonnes)	
OECD	Total world	20.100	-
IBA	Total world	19.070	24.150
"	Free world	14.919	-
CHASE	"	13.444	17.509
SPECTOR	"	15.295	-
VAIS	"	13.800	17.100

While projections for total world in 1985 showed similar quantity of 19-20 million tonnes in OECD and IBA reports, those for the free world had a wide variation from 13 million tonnes in Chase report to 15 million tonnes in Spector report. This is probably because of the different timing of projections and the different views on economic recession in 1985-1986. In particular, the projections by Spector and IBA are considered too optimistic under the current situation.

The projections in 1990 were about 17 million tonnes both in Chase and Vais report. These two projections for 1985 were rather on the low side.

2.2 Primary Aluminum Smelting Capacity

Due to stagnant demand, excessive inventory and low prices, the United States, Japan and Europe at present cut down their primary aluminum production intensely and some plants were even scrapped down permanently due to high energy cost. Uncertainty in the timing of re-start of these idle capacity and operation commencement of new plants makes it very difficult to forecast the smelting capacity in the future.

Though various projections for capacity are listed in Table F-19, forecasts for 1985 and 1987 are summarized below for comparison.

		1985	1987
		(million tonnes)	
OECD	Total world	21.800	-
IPAI	Free world	15.115	-
IBA	"	17.974	19.760
CHASE	"	15.803	-

Table F-19 Summary of Various Published Projections for Aluminum Demand and Supply

(1,000 tonnes)

	OECD Primary aluminum			UNIDO Total	IPAI Primary aluminum	IBA Primary aluminum			CHASE Primary aluminum			Spector Primary aluminum				Vais Primary aluminum		
	World			Demand 10	Mid-year	Consumption		Free	Free world			Free world				Free world		Opera-
	Demand	Produc- tion	Capacity	coun- tries	free world capacity	World	Free world	world capacity	Consump- tion	Produc- tion	Capacity	Demand	Produc- tion	Capacity (end of 81)	Capacity (mid-82)	Consump- tion	Capacity	tion rate (%)
1980	15,600	15,600	17,500 (89.1%)	11,251	(13,544)	(15,321)	12,606	13,690	12,025	12,775	13,414 (95%)	12,045	12,773	(14,189)	(14,189)			93
1981	16,400	16,500	18,000 (91.7%)			15,185	11,879	14,044	11,679	12,421	14,158 (88%)	11,112	12,468	14,370 (86.8%)		11,000	14,300	88
1982	17,200	17,300	18,800 (92.0%)		13,894	16,476	12,890	14,531	11,764	11,255	14,332 (79%)	11,785	11,407	14,503 (78.7%)	13,590			74
1983	18,500	18,700	19,800 (94.4%)		14,457	17,546	13,726	15,000	12,584	12,369	14,894 (83%)	13,355	13,040	15,075 (86.5%)	14,050			75
1984	19,400	19,500	20,700 (94.2%)		14,785	18,336	14,344	16,606	13,540	13,482	15,335 (88%)	14,620	14,295	15,620 (91.5%)	14,652			83
1985	20,100	20,200	21,800 (92.7%)	16,229	15,115	19,070	14,919	17,974	13,444	13,558	15,803 (86%)	15,295	15,127	15,963 (94.8%)	14,982	13,800	15,700	89-95
1986						19,718	15,425	19,298	14,067	14,037	16,143 (87%)	15,375	15,507	16,859 (92.0%)	15,614			98
1987						20,743	16,227	19,760	14,957			16,175	16,423	17,957 (92.5%)	15,796		16,000	101
1988						21,822	17,071	20,670	15,956									
1989						22,957			16,860									
1990				21,870		24,150			17,509							17,100		
Growth rates (annual %)																		
1980-1985	5.2	5.3	4.5	7.6	2.2	(4.5)	3.4(4.4)	5.6	2.3	1.2	3.3	4.9	3.4	2.4	1.1	4.6	2.4	
1980-1990	-	-	-	6.9	-	(4.7)	3.9	5.3	3.8	1.6	3.1	4.3	3.7	3.3	1.5	4.5	1.9	
1985-1990	-	-	-	6.1	-	(4.8)	-	-	5.4	-	-	-	-	-	-	4.4	-	

		1985	1987
		(million tonnes)	
SPECTOR (1981 end Survey)	"	15.963	17.757
SPECTOR (Mid 1982 Survey)	"	14.982	15.796
VAIS	"	15.700	16.000

As shown above, the 1985 free world primary aluminum production capacity forecasts range from 14.982 to 17.974 million tonnes, and average 15.4 million tonnes if two of the highest forecasts by IBA and Mr. Spector (Survey at the end of 1981) are excluded. The capacity growth rate forecasts for 1980-1985 are in the range from 2.2% to 2.4% except 5.6% by IBA and 3.3% by Chase.

2.3 Primary Aluminum Supply and Demand Balance

According to the OECD's forecast, supply and demand balance would remain tight until 1985 and the seller's market would continue for the next 5 years. According to IBA, there would be excess capacity throughout the 1980s, but if the centrally planned economies imported more aluminum and Japan's plants were frozen, the operation rate in the free world would become rather high. Chase's view was that the supply and demand balance would be tight for 1983 and 1984 and become loose again in 1985 and 1986. According to Mr. Spector's forecast, the inventory adjustment would continue from 1982 to 1985 and after that, supply would exceed demand. Mr. Vais's projection, the latest one, forecast that demand would exceed supply from 1982 to 1984 with inventory adjustment proceeding, while operation rate would remain below 90%. From 1985, supply and demand would balance, but from 1988 onward, demand would exceed supply.

Summarizing those projections, it seems that until about 1985, the supply and demand balance will improve with inventory adjustment progressing although operation rate remains low. From about 1987, operation rate will go up and supply and demand balance will be desirable.

3. Projection of Primary Aluminum Demand in 1990 and 2000

Taking into account various projections above, an projection of free-world demand for primary aluminum in 1990 and 2000 is made as follows.

Two different methods are used for a projection.

The first method forecasts GDP growth rate [1] until 2000 by the major region in the world, calculates the growth rate of demand by multiplying it by GDP elasticity of primary aluminum demand and then estimates the quantity of demand.

The second method is to apply the Gompertz growth curve to the past movement of free world aluminum demand and forecasts demand until 2000.

Total of 3 cases, a standard case (II), an high case (I) and a low case (III), are estimated.

GDP growth rate from 1985 to 2000 used in the projections are, as shown in Table F-20, in the developed countries such as North America, Europe and Japan 2.1% in the low case (III), 3.1% in the standard case (II) and 3.7% in the high case (I). The highest rate of 6% for Middle East used in the high case and the lowest is 2% for Europe in the low case.

3.1 Projection Based on GDP Elasticity

As discussed in Subsection 4, Secion I, Chapter C, GDP elasticity of aluminum consumption in 1960s reached a high level of 1.7, because annual growth rate of aluminum consumption was 9.2% while annual growth rate of GDP was 5.3%. In the 1970s after oil crisis aluminum consumption growth rate significantly dropped by about 5% to 4.3% from the previous period, while GDP growth rate dropped to 4.0% by only 1%, which resulted in the reduction of GDP elasticity to 1.1. Especially, during 5 year period from 1975 to 1980 after oil crisis, aluminum consumption growth rate of 3.0% (adjusted value [2]) fell below GDP growth rate of 3.9% and hence GDP elasticity dropped to 0.8, below 1.0 level.

As the quantity of consumption increases, GDP elasticity tends to decline both in the developed countries and the developing countries. In the developed countries such as the United States, Europe and Japan, in particular, aluminum consumption growth fell below GDP growth rate due to sluggish industrial activities affected by stagnant economy and energy cost increase caused by oil crisis.

In this projection, estimates are made for GDP elasticity for main areas until 2000, consisting of a medium term estimate from 1980 to 1985 and a long term estimate from 1985 to 2000.

As for 5 year period until 1985, comparison is made for each area between elasticity for the 1960s and elasticity for the 1970s

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1) Refer to Volume 1, Chapter 2.

2) cf. Part C, Reference Table C-2

and a declining tendency of elasticity during those period is applied to the estimate for 1980-1985 period.

In North America and the centrally planned economies, GDP elasticity was 0.9 in 1970s, already below 1.0, and, in Japan, Middle East and Asia, if the declining trend of elasticity for the past 20 years is applied, elasticity estimate may fall well below 1.0. This lower elasticity than 1.0 in North America and the centrally planned economies was caused, as analyzed in Chapter C, by substantial reduction in aluminum consumption in 1975 and 1980 due to oil crisis. However, although economic recession continued until 1981, there was a sign of economic recovery in the second half of 1982 in the United States and Japan and increase in housing construction and consumption was expected. It can be therefore expected that the growth rate of aluminum consumption will recover towards 1985 as the economic and industrial activities become active again. Accordingly, GDP elasticity for those areas as North America, Japan and the centrally planned economies, etc., as mentioned above is estimated at 1.0 until 1985. As for GDP elasticity for 15 years from 1985 to 2000, considerations are given to the consumption trend in long term including the change in demand structure and the competition with other materials.

With respect to demand structure, 4 main demand sectors of construction, transportation, packaging and electrical share more than 70% of total domestic market in all the developed countries, the United States, Europe and Japan and they are expected to keep the major shares in aluminum demand in the future. In the developing countries, particularly in newly industrializing countries, utilization of aluminum as basic materials is expected to expand as well as steel while the industrialization progresses along with the economic and industrial development and the improvement of standard of living.

In relation to the competition with other materials, it is expected that aluminum demand grows with competing with other basic materials, since the increase in energy cost after oil crisis affected not only aluminum but also other basic materials. Even if new materials are produced by future technical innovation, it is hardly expected that aluminum is completely replaced by such new materials before 2000.

In summary, some changes in demand structure and competion with other materials are not expected to change an industrial and economic role of aluminum as useful materials and it is natural to expect that aluminum consumption increases along with increase in GDP growth in the long term.

Accordingly, GDP elasticity of aluminum consumption is estimated at 1.0 from 1985 to 2000 for all areas.

The elasticity values and GDP growth rates estimated are shown in Table F-20.

As a result of estimate, the free world demand for primary aluminum is as follows:

	1985	1990	2000
	(million tonnes)		
High case	14.09	17.09	25.20
Standard case	14.09	16.56	23.09
Low case	14.09	15.87	20.21

Demand in 1985 is estimated at about 14 million tonnes, mid point of the 13.4 - 15.3 million tonnes range of the various projections mentioned above. For 1990, the various projections estimate 17 million tonnes which is roughly equal to the high case above. It appears that this projection based on elasticity is not very different from most of other projections. It should be noted that, because this projection estimates the demand for main regions in 1985 based on very rough assumption of elasticity, such estimate is not necessarily close to other various projections and is not regarded as accurate regional estimate.

Free world demand in 2000 is estimated at 20.2 million tonnes in the low case, 23.1 million tonnes in the standard case and 25.2 million tonnes in the high case. Comparison of these cases with the 1980 figure of 12.0 million tonnes, gives an annual growth rate of 2.6%, 3.3%, and 3.8% respectively. In conclusion, the demand for primary aluminum is estimated to grow at more or less 3% a year until 2000.

3.2 Projection Based on Growth Curve

Process of growth, for example, population increase, spread of cars and growth of human being, usually starts slowly, gradually increases its growth rate and reaches expansion period. But its growth rate starts to decrease at a certain point and, after mature period, growth stops. Growth curve shows this process statistically.

Out of various growth curves, Logistic curve and Gompertz curve are well known. As shown in the figure below, a turning point in the center of the curve represents the point where growth goes into mature stage from expansion stage.

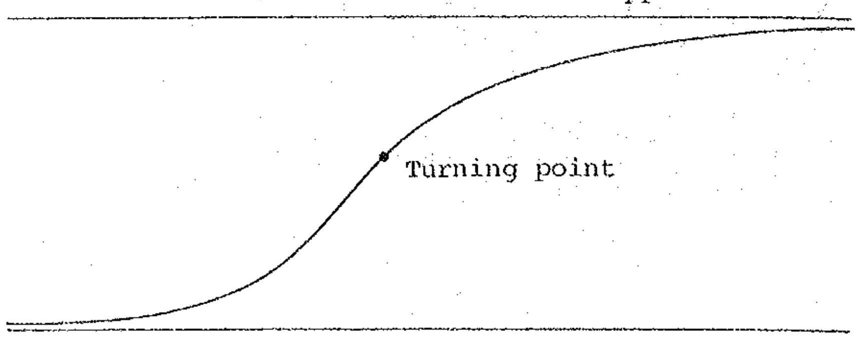
Table F-20 Long-Term Projection of Demand for Primary Aluminum

	Elasticity				GDP Growth rate (%)				Demand for aluminum (1,000 tonnes)					Growth rate (%)	
	1960→1970	1970→1980	1980→1985 (Estimate)	1985→2000 (Estimate)	1980→1985	1985→2000 Cases I	II	III	1980 (Actual)	1985		1990 (Estimate)	2000 (Estimate)	1980→1985	1985→1990
World total	1.74	1.08							15,320	17,930	I	21,620	31,450	3.2	3.8
											II	20,980	28,970		3.2
											III	20,210	25,770		2.4
Free world	1.84	1.15							12,011	14,090		17,090	25,200	3.2	3.9
												16,560	23,090		3.3
												15,870	20,210		2.4
Developed countries	1.80	1.11							10,576	12,080		14,520	20,990	2.7	3.7
												14,050	19,190		3.1
												13,430	16,640		2.1
North America	2.14	0.85	1.0	1.0	2.1	3.7	3.1	2.1	4,765	5,290		6,350	9,140	2.1	3.7
												6,140	8,350		3.0
												5,870	7,220		2.1
Europe	1.52	1.35	1.2	1.0	2.0	3.7	3.1	2.0	3,853	4,350		5,220	7,520	2.5	3.7
												5,050	6,870		3.0
												4,790	5,840		1.9
Japan	1.77	1.14	1.0	1.0	4.7	3.7	3.1	2.5	1,637	2,060		2,470	3,560	4.7	3.7
												2,390	3,250		2.0
												2,330	2,980		2.5
Oceania, S. Africa	2.40	1.73	1.1	1.0	3.1	4.9	4.4	3.1	321	380		480	770	3.4	4.8
												470	720		4.3
												440	600		3.0

Table F-20 (cont'd.)

	Elasticity				GDP Growth rate (%)				Demand for aluminum (1,000 tonnes)					Growth rate (%)	
	1960→ 1970	1970→ 1980	1980→ 1985 (Estimate)	1985→ 2000 (Estimate)	1980→ 1985	1985 → 2000 Cases I	II	III	1980 (Actual)	1985	1990 (Estimate)		2000	1980→ 1985	1985→ 1990
Developing countries	2.93	1.89							1,435	2,010	I	2,570	4,210	7.0	5.0
											II	2,510	3,900		4.5
											III	2,440	3,570		4.0
Africa	4.76	3.43	2.1	1.0	3.3	5.2	4.5	3.3	101	140		180	300	6.7	5.2
												180	280		5.2
												170	230		4.0
Middle East	–	1.66	1.0	1.0	4.4	6.0	5.1	4.2	125	160		210	380	5.1	5.6
												200	330		4.6
												200	300		4.6
Asia	3.85	1.77	1.0	1.0	5.1	4.9	4.4	3.9	606	780		990	1,590	5.2	4.9
												970	1,490		4.5
												940	1,380		3.8
Latin America	2.11	2.03	2.0	1.0	4.5	5.0	4.5	3.9	603	930		1,190	1,940	9.1	5.1
												1,160	1,800		4.5
												1,130	1,660		4.0
C.P. Economies	1.40	0.89	1.0	1.0	3.0	3.3	2.9	2.5	3,309	3,840		4,530	6,250	3.0	3.4
												4,420	5,880		2.9
												4,340	5,560		2.5

Model of Gompertz Curve



Aluminum consumption, as already shown in Fig. C-1 in Chapter C, although showing wide fluctuation after oil crisis, tends to decrease its growth rate and is considered to have already passed a turning point and reached at a mature stage in the growth curve. Actual data of aluminum consumption in the free world from 1950 to 1980 are applied to a formula for Gompertz curve, $y = Ka^{b^t}$, and estimates of aluminum consumption for 1985, 1990 and 2000 are made based on this formula.

In order to analyze the relation between the extension of actual trend and estimated curve, and the effect on the upper limit of the gradient of estimated curve, three cases are estimated with different upper limit, i.e. 30 million tonnes, being an approximately double of actual consumption in 1980, 40 millions tonnes and 50 million tonnes.

Results of estimates are:

	1985	1990	2000
	(million tonnes)		
Case I 1)	14.52	17.26	22.80
Case II 1)	14.20	16.67	21.40
Case III 1)	13.74	15.80	19.50

The projections above for 1985 and 1990 are similar to the projections based on elasticity and the various other projections. The annual growth rates from 1980 to 2000 for above projections are 3.3% for case I, 2.9% for case II, and 2.5% for case III, lower than projections based on elasticity in the previous sub-section.

1) Case I assumes the upper limit of 50 million tonnes; case II, 40 million tonnes; case III, 30 million tonnes.

Taking into consideration, however, that aluminum continues to be an attractive metal in the future, it hard to believe that the growth rate of demand for alumium drops to the 2% level in 2000. on the contrary, if similar projection is made based on the growth curve in 1990, the estimate for 2000 will be changed upwards because the upper limit is lifted up compared to that used in the above projection.

3.3 Summary of Projections

The projections of demand for primary aluminum made in the previous sub-sections with two methods are summarized in Fig. F-3.

Considering that the demand for primary aluminum in the free world decreased by 6.3% in 1981 compared to 1980 and that the recovery is weak in 1982, it is likely that the demand for aluminum will follow the lower line of the projections in the medium term.

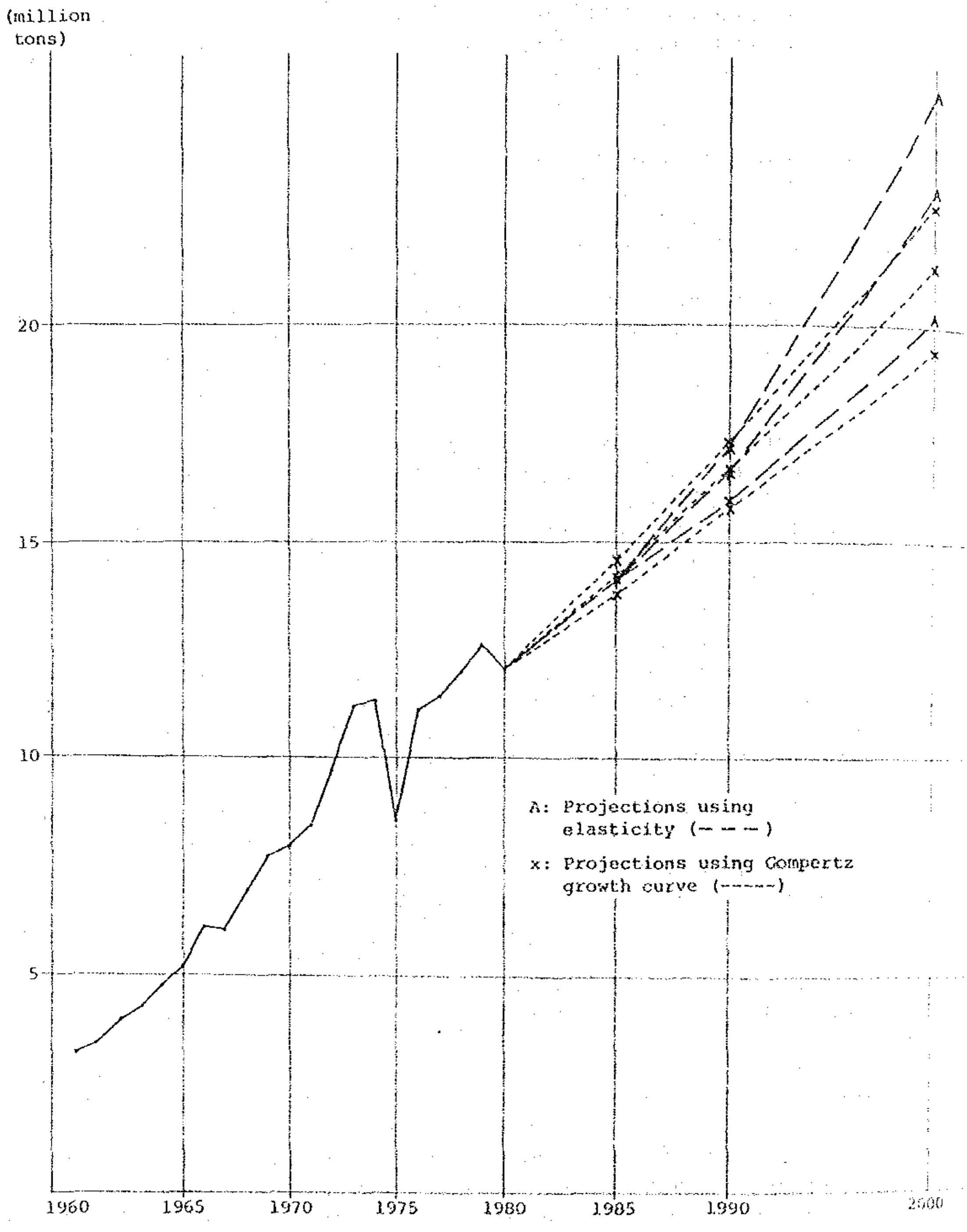
Based on the results above, it may conclude that demand will be slightly under 14 million tonnes in 1985, about 16-17 million tonnes in 1990 and on the level of 20-25 million tonnes in 2000. The average annual growth rate is estimated at 3.1% from 1980 to 1985, 2.7% to 4.0% from 1985 to 1990 and from 2.3% to 3.9% from 1990 to 2000.

It is very difficult to make projection of supply and demand balance at present based on the demand projection above. As discussed in Section I, the possibility of realizing the development plans in various countries become remote and even existing capacity varies depending upon the timing of survey.

It may be, however, possible to make a brief conclusion that, assuming that the free world smelting capacity as at the end of 1982 was 14 million tonnes and the various development plans already announced with approximately 3 million tonnes of total capacity are realized in 1987-1990, total free world capacity will reach about 17 million tonnes in 1987-1990. While the demand for aluminum in 1990 is estimated at 16-17 million tonnes, the supply and demand in macro economy will finally balance around 1990.

It is of course possible that, if the demand growth follows a low case estimate, it becomes difficult to realize some of the development plans. On the contrary, if the demand grows more than expected, the realization of development plans are accelerated. It is very clear at this moment that the development plans already announced are sufficient enough to cover the demand growth until around 1990. In other words, the investigation of possible new projects must be started with the analysis of actual demand in the second half of 1980s or in the first half of 1990s as well as the supply and demand projection at that time.

Fig. F-3 Trends and Projections of Demand for Primary Aluminum



G. COMMENT ON POSSIBILITY OF EXPORTING ALUMINUM FROM CARAJAS

The aluminum industry has now entered a period of low growth along with the recent worldwide recession and the period in which the aluminum company could automatically sell all it produced has clearly ended.

Now that many aluminum smelters were scrapped or mothballed in the developed countries due to energy cost hike, it may be a good opportunity to study the possibility of realizing a new smelter in the Carajas region with many desirable conditions for development.

Appendix Table 1 Production Capacities for Bauxite, Alumina and Primary Aluminum in 1982

Area	Country	Aluminum	Alumina	Bauxite
Africa	Cameroon	80		
	Egypt	166		
	Ghana	200		420
	South Africa	169		
	Guinea		691	13,700
	Sierra Leone			800
	Subtotal	615	691	14,920
North America	Canada	1,234	1,225	
	USA	5,146	7,282	2,000
	Subtotal	6,380	8,507	2,000
Latin America	Argentina	140		
	Brazil	414	480	4,975
	Surinam	66	1,330	7,500
	Venezuela	405	500	
	Mexico	45		
	Guyana		315	4,450
	Jamaica		2,994	14,170
	Dominican Rep.			1,425
	Subtotal	1,070	5,619	32,520
East Asia	Taiwan	83	100	
	Japan	615	2,635	
	Korea, Rep. of	18		
	Subtotal	716	2,735	0
South Asia	Indonesia	75		1,260
	Iran	50		
	India	353	682	1,950
	Turkey	60	200	550
	United Arab Emirates	135		
	Bahrain	170		
	Malaysia			750
	Subtotal	843	882	4,510
Europe	Austria	92		
	France	453	1,320	1,800
	Germany, Fed. Rep.	736	1,640	
	Greece	145	500	5,390
	Iceland	87		
	Italy	276	800	30
	Sweden	83		
	Netherlands	266		

Appendix Table 1 (cont'd.)

Area	Country	Aluminum	Alumina	Bauxite
(Europe - cont'd.)	Norway	802		
	Spain	398	800	10
	Switzerland	93		
	UK	388	130	
	Subtotal	3,819	5,190	7,230
Oceania	Australia	475	7,338	32,970
	New Zealand	244		
	Subtotal	719	7,338	32,970
The centrally planned economies	Czechoslovakia	60	100	
	German Dem. Rep.	85	60	
	Hungary	71	905	3,350
	Poland	55		
	Romania	250	500	1,500
	Yugoslavia	385	1,540	4,210
	USSR	3,130	4,790	12,530
	Korea, Dem. Rep.	20		
	China	363	850	1,800
	Subtotal	4,419	8,745	23,390
Free world Subtotal		14,162	30,962	94,150
TOTAL		18,581	39,707	117,540

Appendix Table 2 Bauxite Mining Companies in the World, 1982

Area	Country	Company/Plant	Location	Capa-city (1,000 MT/year)	Start-up date	Mining method	Reserves/Grade (mill. tons)	Sales outlets	Ownership
Africa	Ghana	Ghana Bauxite Co.	Awaso	420	1941	Open-pit	20 Al_2O_3 52% SiO_2 2.5%	UK, Spain Germany, FR	Govt. 55% British Aluminium 45%
	Guinea	Cie. des Bauxites de Guinée (CBG)	Sangaredi Plateau	9,000	1973	Open-pit	2,000 Al_2O_3 60% SiO_2 3%	Exported	Govt. 49% Halco Mining Inc. 51%
		Friguia Consortium	Fria-Kimbo	2,200	1960	Open-pit	2,500 Al_2O_3 48% SiO_2 3%	Associated Friguia refinery	Govt. 49% Frialco 51%
		Office de Bauxite de Kindia (OBK)	Debele Kindia	2,500	1974	Open-pit	200 Al_2O_3 52% SiO_2 3%	Exports mainly to USSR	Govt. 100%
	Sierra Leone	Sierra Leone Ore & Metal Co. Ltd.	Mokanji	800	1963	Open-pit		W. Europe N. America	Alusuisse 100%
North America	USA	ALCOA Mining Co.	Arkansas	800		Open-pit	40	Company refinery	ALCOA 100%
		Reynolds Mining Co.	Arkansas	950		Open-pit		Company refinery	Reynolds 100%
		Other small mines		250					
Latin America	Brazil	ALCAN Aluminio do Brasil SA	Ouro Preto	350		Open-pit	17	Company's Saramenha refinery	ALCAN 100%
		Cia. Brasileira de Aluminio (CBA)	Pocos de Caldas	625		Open-pit	100	Company's Sorocaba refinery	Votorantim 80% Govt. 20%
		ALCOA Aluminio SA	Pocos de Caldas	650		Open-pit		Company's Pocos de Caldas refinery	ALCOA 50% Hanna Mining 32% Minas Gerais Bank 15% Private interest 3%
		Mineracao Rio do Norte SA	Trombetas	3,350	1979	Open-pit	600 Al_2O_3 50% SiO_2 7%	Initially exported Supply to ALUNORTE and ALCOA Aluminio refineries	CVRD(Govt.) 51% CBA 10% ALCAN 19% Reynolds 5% Alumina Espanol 5% Billiton 5% Norsk Hydro 5%
	Dominican Republic	ALCOA Exploration Co. Ltd.	Cabo Rojo	1,425	1959	Open-pit	32.4 Al_2O_3 50%	ALCOA, USA (Point Comfort, etc.)	ALCOA 100%
	Guyana	Guyana Mining Enterprise Ltd. (GUYMINE)	Karakara & Utuni mines	2,100				Local alumina refinery plus export to	Bauxite Industry Development Co.
			East Montgomery mine	1,250	1979	Open-pit	500 Al_2O_3 65%	N. America & Europe	(=Govt.)(BIDCO) 100%
			Kwakwani-Everton area	1,100	1952				

Appendix Table 2 (cont'd.)

Area	Country	Company/Plant	Location	Capacity (1,000 MT/year)	Start-up date	Mining method	Reserves/Grade (mill. tons)	Sales outlets	Ownership
(Latin America - cont'd.)	Jamaica	Alumina Partners of Jamaica (ALPART)	Nain	2,700	1969	Open-pit		ALPART refinery, Nain	Kaiser 36.5% Reynolds 36.5% Anaconda 27.0%
		Jamaican Joint Venture	Swallenburg	1,370	1953	Open-pit	Al_2O_3 43.8%	Jamaican's Ewarton refinery	ALCAN 93% Govt. 7%
			Kirkvine	1,550	1959	-	Al_2O_3 45%	Jamaican's Kirkvine refinery	
		Jamalco Joint Venture	Clarendon	1,350	1963	Open-pit	Al_2O_3 45% SiO_2 1%	Jamalco's Clarendon refinery	ALCOA 94% Govt. 6%
		Kaiser Jamaica Bauxite Company	Discovery Bay	3,700	1953	Open-pit	Al_2O_3 45%	Kaiser's US refineries in Louisiana	Kaiser 49% Govt. 51%
		Jamaica Reynolds Bauxite Partnership	Lyford	3,500	1952	Open-pit	Al_2O_3 42.5% SiO_2 5%	Reynolds US smelter	Govt. 51% Reynolds 49%
	Surinam	N.V. Billiton Maatschappij Surinam	Onverdacht	3,000		Open-pit	Al_2O_3 55.8%	Partly exported, partly toll-refined by SURALCO	Royal Dutch Shell 100%
		Surinam Aluminum Co. (SURALCO)	Moengo Lelydorp	4,500	1922 1969	Open-pit		SURALCO Paranam refinery plus exported mainly to USA & Canada	ALCOA 100%
Asia	India	Bharat Aluminium Co. Ltd.	Amarkantak Phutkaphur	250		Open-pit		Company refinery at Korba	Govt. 100%
		Hindustan Aluminium Corp. Ltd.	Palamau, Bihar	400		Open-pit		Company refinery at Renkoot, Uttar Pradesh	Birla Group 73% Indian banks & institutions 27%
		Indian Aluminium Corp. Ltd. (INDAL)	Chanqdad Maharashtra Lohardaga, Bihar Others	400 200 300		Open-pit		Company refinery at Belgaum, Karnataka	ALCAN 55% Private interests 45%
		Madras Aluminium Co. (MALCO)	Shevroy, Tamil Nadu	150				Company refinery at Mettur, Tamil Nadu	Madras State 73% Montecatini-Edison SpA 27%
		Gujarat State & others	Gujarat	250					
	Indonesia	P.T. Aneka Tambang	Bintan Islands	1,260		Open-pit		Exported to Japan	Govt. 100%
	Malaysia	South East Asia Bauxite Co.	Johore	750		Open-pit		Esported to Japan & Taiwan	ALCAN 100%
	Turkey	Etibank	Mortas Milas	550		Open-pit	50	Mainly Etibank refinery at Seydisehir	Govt. 100%
Europe	France	Aluminium Pechiney	Brignoles Var Dept.	890		Underground	Al_2O_3 51% SiO_2 4%	Pechiney alumina refineries in France	Pechiney 100%
			Mèze, Hérault Dept.	200		Underground	Al_2O_3 54% SiO_2 4%		
		Société des Bauxites de France	Brignoles, Var Dept.	200		Underground	Al_2O_3 54% SiO_2 6%		ALUSUISSE 100%
		Société Anonyme des Bauxites et Alumines (SABAP)	Brignoles, Var Dept.	450		Underground	Al_2O_3 51% SiO_2 7%	Exported	ALCAN 100%
		Union des Bauxites de France	Var Dept.	60		Underground	Al_2O_3 51% SiO_2 7%	Mostly to Pechiney alumina refineries in France	British Aluminium 88%

Appendix Table 2 (cont'd.)

Area	Country	Company/Plant	Location	Capacity (1,000 MT/year)	Start-up date	Mining method	Reserves/Grade (mill. tons)	Sales outlets	Ownership
(Europe - cont'd.)	Greece	Bauxites Delphi SA	Elaion	250		Open-pit & Underground			Aluminium de Grèce 100%
		Bauxites Helleniques de Distomon Ltd.	Distomon	440		Underground			Pechiney 53% Other 47%
		Bauxites Elikonos	Elikon Mts.	400					G. Barlos Group 100%
		Bauxites Eleusis Mines	Eleusis, Itea Lamia, Kymi	800		Open-pit & Underground	Al_2O_3 54% SiO_2 4%		Skalistiri Group 100%
		Bauxites Parnasse Mining SA	Parnassus-Chiona-Oeti	3,500		Open-pit & Underground	580		Eliopoulos-Kyriakopoulos Group
Italy				30					
Spain				10					
Oceania	Australia	ALCOA of Australia Australia Ltd.	Jarrahdale WA	5,500	1963	Open-pit	Al_2O_3 32%	Company refinery at Kwinana, WA	ALCOA 51%
			Del Park WA Huntly WA	9,250	1972 1976			Company refinery at Pinjarra, WA	Western Mining Corp. 20%
			Willowdale WA	1,870	1982				North Broken Hill 12%
								Company refinery at Wagerup, WA	Broken Hill South 13.1% Aust. Institutes & Nominees 3.9%
		Comalco Ltd.	Weipa Andoom	11,000 250	1963 1975	Open-pit	Al_2O_3 56% SiO_2 9-12%	QAL refinery and exported to Italy, Japan, etc.	Conzinc Riotinto of Aust. 45% Kaiser 45% Aust Institutions & public 10%
		Nabalco Pty Ltd.	Gove, NT	5,100	1971	Open-pit	Al_2O_3 50% SiO_2 4%	Associated Gove refinery plus exported to Japan and Europe	Austrasuisse 70% Gove Alumina 30%
The centrally planned economies	Yugoslavia	Energoinvest	Vlasenica	1,500	1960			Zvornik refinery	Govt. 100%
			Mostar	500	1937			Mostar refinery	
			Jace	40	1950				
			Krupa	150					
			Roving	150	1922				
		Jadral	Jesenice, Krusevo & Drnis	800	1930				Govt. 100%
		Kombinat Aluminijuma	Niksic	820	1947				Govt. 100%
		Enterprise Thermoenergetic	Grebnik, Kosovo	200	1959				Govt. 100%
		Pomgrad-Split	near Imotski	50					Govt. 100%
	Romania	Bihor Mountains Sosia & Dubresti		1,500					Govt. 100%

Appendix Table 2 (cont'd.)

Area	Country	Company/Plant	Location	Capacity (1,000 MT/year)	Start-up date	Mining method	Reserves/Grade (mill. tons)	Sales outlets	Ownership
(The centrally planned economies - cont'd.)	China	Shantung Shanxi Shenxi Liaoning Kweichow Hoöei Yunnan Henan Guangxi Other provinces		1,800			1,300,000 Al_2O_3 59.9% (Guangxi)	China	Govt. 100%
	Hungary	Bakony Bauxite Mining Company	Halimba Basin	600		Underground	20	Local refineries and exports	Govt. 100%
		Nyirad-Darvasto Area	Deaki, Dultnyires Iza, etc.	1,350		Underground	8		Govt. 100%
		Tharkut Area & others		200					Govt. 100%
		Bauxite Mining Co.	Rakhegy II	600					Govt. 100%
		Kincesbanya & others		400					Govt. 100%
		Others		200					Govt. 100%
	USSR	Tikhvin Region		1,800		Open-pit & Underground	250 Al_2O_3 52%	USSR	Govt. 100%
		North Urals		230		"		"	Govt. 100%
		N. Kazakhstan & Bilinsk		2,600		"		"	Govt. 100%
		Nepheline Production	Kola Peninsula	3,500		Open-pit		USSR	Govt. 100%
			Belogorsk	3,000		Open-pit		USSR	Govt. 100%
		Alunite Production	Zaglik	1,400				USSR	Govt. 100%

Appendix Table 3 Alumina Manufacturing Companies in the World, 1982

Area	Country	Company/Plant	Location	Capacity (1,000 MT/year)	Start-up date	Ownership	Bauxite source	Alumina type	Sales outlets
Africa	Guinea	Friquia Société d'Economie Mixte	Kimbo	691	1960	Govt. 49% Frialco 51%	Guinea - company source	Floury converting to Sandy	USA Europe & Egypt
North America	Canada	ALCAN Aluminium Ltd.	Vaudreuil Jonquière (Quebec)	1,225		ALCAN 100%	Guinea (CBG) Brazil (Trombetas)	Sandy	ALCAN smelters in Quebec Prov., Canada
	USA	Aluminum Company of America (ALCOA)	Bauxite, Arkansas Mobile, Alabama Point Comfort, Texas	340 913 1,332 2,585	before 1950 " 1950	ALCOA 100%	Company sources in Arkansas (USA), Jamaica, Surinam, & Dominican Rep.	Sandy	ALCOA smelters in USA
		Kaiser Aluminum & Chemical Corp.	Baton Rouge, Louisiana Gramercy, Louisiana	930 725 1,655		Kaiser 100%	Company sources in Jamaica	Sandy	Kaiser smelters in USA
		Martin Marietta Aluminum Inc.	St. Croix, Virgin Islands	500		Martin Marietta 87% Private interests 13%	Guinea (Boké) Guyana	Sandy	Company smelters in USA; also Norway
		Ormet Corporation	Burnside (Ascension), Louisiana	525		Conalco 66% Revere Copper & Brass 34%	Surinam (SURALCO)	Sandy	Company smelters in Ohio, USA
		Reynolds Metals Company	Hurricane Creek, Arkansas Corpus Christi, Texas	760 1,257 2,017		Reynolds 100%	Arkansas (USA), & imported from Jamaica	Sandy	Company smelters in USA
Latin America	Brazil	ALCAN Aluminio do Brasil SA	Saramenha, Ouro Preto	120	1944	ALCAN 100%	Company source in Minas Gerais (Brazil)		ALCAN's Brazilian smelters at Saramenha & Aratu
		Cia. Brasileira de Aluminio (CBA)	Sorocaba, Sao Paulo	180		Votorantim 80% Govt. 20%	Brazil - company source		CBA smelter at Sorocaba
		ALCOA Aluminio SA	Pocos de Caldas, Minas Gerais	180	1972	ALCOA 50% Hanna Mining 32% Minas Gerais Bank 15% Private interests 3%	Brazil - company source		Company smelter at Pocos de Caldas
	Guyana	Guyana Mining Enterprise (GUYMINE)	Mackenzie	315	1961	Bidco (Govt-owned) 100%	Guyana - company source	Sandy	Exported
	Jamaica	Revere Jamaica Alumina Ltd.	Maggoty	219		Revere Copper & Brass 100%	Jamaica - company source		Revere smelter (USA) until 1975
		Jamaican Joint Venture	Ewarton Kirkvine	545 550 1,095	1953 1959	ALCAN 93% Govt. 7%	Jamaica - company source	Sandy	Exported to ALCAN smelter interests in Canada, Norway, Spain, UK, etc.
		Jamalco Joint Venture	Woodside (Halse Hall, Clarendon)	500	1972	ALCOA 94% Govt. 6%	Jamaica - company source	Sandy	ALCOA smelters in USA

Appendix Table 3 (cont'd.)

Area	Country	Company/Plant	Location	Capa-city (1,000 MT/year)	Start-up date	Ownership	Bauxite source	Alumina type	Sales outlets
(Latan America - cont'd.)	(Guinea - cont'd)	Alumina Partners of Jamaica Ltd. (ALPART)	Nain, St. Elizabeth	1,180	1969	Kaiser 36.5% Reynolds 36.5% Anaconda 27%	Jamaica - company source	Sandy	Exported to partners smelter interests in USA, UK, etc.
	Surinam	Surinam Aluminum Co. (SURALCO)	Paranam	1,330	1965	ALCOA 100%	Surinam (SURALCO & Billiton)	Sandy	SURALCO smelters and exported to USA, Venuzuela, etc.
	Vene-zuela	Interamericana de Alumina SA (INTERALUMINA)	Puerto Ordaz	500	1982	Govt. 88.75% ALUSUISSE 11.25%	Surinam	Sandy	Mainly local smelters; balance for export
East Asia	Japan	Mitsui Alumina Co., Ltd.	Wakamatsu (Kyushu)	400		Mitsui Group 90% CSR Ltd. 10%	Australia (Gove)	Sandy 50% Floury 50%	Mitsui smelter in Japan
		Nippon Light Metal Co., Ltd. (NLM)	Shimizu Tomakomai	515 360 875		ALCAN 50% Private interests 50%	Australia (Weipa & Gove) Malaysia, Indonesia	Sandy	NLM smelters in Japan and exported to Canada for toll smelting Also exported to Indonesia
		Showa Aluminum Industries KK	Yokohama	620		Showa Denko 50% Private interests 50%	Australia (Weipa & Gove), Indonesia	Floury	Showa smelter in Japan and exported to Indonesia
		Sumitomo Aluminium Smelting Co., Ltd.	Kikumoto	740		Sumitomo Chemical 50% Private interests 50%	Indonesia Australia (Weipa & Gove), Indonesia	Floury Sandy	Sumitomo smelters in Japan and exported to Indonesia
	Taiwan	Taiwan Aluminum Corp. (TALCO)	Kaohsiung	100		Govt. 100%	Australia (Weipa) Malaysia		Local smelter
South Asia	India	Bharat Aluminium Corp. Ltd.	Korba, Bharat State	200		Govt. 100%	India	Floury	Local smelter, also exported to USSR
		Hindustan Aluminium Corp. Ltd. (HINDALCO)	Renukoot, Uttar Pradesh	190		Birla Group 73% Indian banks & Institutions 27%	India	Floury	Local smelter
		Indian Aluminium Co. Ltd. (INDAL)	Belgaum, Mysore Muri, Bihar	160 72		ALCAN 55% Private interests 45%	India	Floury	Company smelters in India
		Madras Aluminium Co. Ltd. (MALCO)	Mettur, Tami Nadu	60		Madras State 73% Montecatini Edison SpA 27%	India	Floury	Local company smelter
	Turkey	Etibank	Seydisehir	200		Govt. 100%	Turkey	Floury	Associated smelter
Oceania	Austra-lia	ALCOA of Australia Ltd. (AA)	Kwinana, WA Pinjarra, WA	1,400 2,400 3,800	1963 1972	ALCOA 51% Western Mining 20% Broken Hill South 13.1% North Broken Hill 12% Aust. institutions 3.9%	Australia	Sandy	AA's smelters and exports
		Nabalco Pty Ltd.	Gove, NT	1,100	1972	Austrasuisse 70% Gove Alumina 30%	Australia (Gove)	Sandy	Exported
		Queensland Alumina Ltd. (QAL)	Gladstone Qld.	2,438	1967	COMALCO Ltd. 30.3% Kaiser 28.3% ALCAN 21.4% Pechiney 20%	Australia (Weipa)	Sandy	Australian smelters and exported to NZ, USA, Canada, etc.

Appendix Table 3 (cont'd.)

Area	Country	Company/Plant	Location	Capa-city (1,000 MT/year)	Start-up date	Ownership	Bauxite source	Alumina type	Sales outlets
Western Europe	France	Aluminium Pechiney	Cardanne La Barasse Salindres	720 350 250 1,320		Pechiney 100%	France & Imports	Floury " "	Mainly French smelters
	Germany, Fed. Rep.	Aluminium-Oxid State GmbH	Stade	600		Reynolds 50% VAW 50%	Imported	Sandy	Germany, FR Austria
		Giulini-Chemie GmbH	Ludwigshafen	130		Gebr, Guilini 100%	Imported	Sandy	Ludwigshafen smelter and exported to Austria
		Martinswerk GmbH	Bergheim	360		ALUSUISSE 100%	Imported	Floury	Rheinfelden smelter; also exported to Austria
		Vereinigte Aluminium Werke AG (VAW)	Lunen Schwandorf	430 120 550		Govt. 100%	Imported	Sandy	VAW smelters in Germany, FR, some exported to ? Spain
	Greece	Aluminium de Grèce	Distomon	500		Pechiney 70% Govt. & other interests 30%	Greece	Floury	Company smelter in Greece; also some exported
	Italy	Aluminio Italia SpA	Porto Marghera	200		Govt. 100%	Imports (Australia, Yugoslavia, Guinea, etc.)	Floury	Italian smelters
		Eurallumina SpA	Porto Vesme, Sardinia	600	1973	Alsar (Govt. owned) 41.7% Aluminio Italia (Alumetal) 20.8% COMALCO 20% Metallgesellshaft 17.5%	Australia (Weipa)	Sandy 60% Floury 40%	Italy & exported
	Spain	Alumina Español SA	San Ciprian, Lugo	800	1980	ENDASA 55% ALUGASA 20% Banks 25%	Boké, Guinea (CBG mine)	Sandy	Spanish smelters
	UK	British Aluminium Co. Ltd.	Burntisland	130		Tube Investments 58% Institutions 42%	Imported mainly from Ghana; also from Greece		
The centrally planned economies	Yugoslavia	Energoinvest	Mostar Birac	280 600	1975 1978	Govt. 100%	Yugoslavia	Floury	Mainly exported to Germany, FR, Italy, Poland, etc.
		Kombinat Aluminijuma Titograd (KAT)	Titograd	200		Govt. 100%	Yugoslavia	Floury	Titograd smelter and some exported
		Boris Kidric Tovarna Glinice in Aluminija	Kidricevo	160		Govt. 100%	Yugoslavia	Floury	Kidriveco smelter
		Jadral	Obrovac	300	1978	Govt. 100%	Yugoslavia	Floury	Yugoslav smelters and exported

Appendix Table 3 (cont'd.)

Area	Country	Company/Plant	Location	Capa-city (1,000 MT/year)	Start-up date	Ownership	Bauxite source	Alumina type	Sales outlets
(The centrally planned economies - cont'd.)	USSR	Bogoslovsk	Krasnoturinsk	535					
		Uralsk Kamensk	Urals	350					
		Kandalaksha	Kola Peninsula	80					
		Novokuznetsk		250					
		Tikhvin	Boksitogorsk	350		Govt. 100%	USSR & Imports	Floury	USSR
		Volgograd	Stalingrad	60					
		Pavlodar I	Kazakhstan	225					
		Zaporzhye	Ukraine	300					
		Nikolayev, nr. Odessa	Black Sea coast	1,000	1980				
				3,150					
		Sumgait-Kirovobad	Azerbaydzhan	200	1965	Govt. 100%	USSR		USSR
		Achinsk	Siberia	800	1969	Govt. 100%	USSR		USSR
		Pikalevo	Kandalaksha	500		"	"		"
		Volkhov	Kola Peninsula	140		"	"		"
				1,440					
	Czechoslovakia	Z.S.N.P. Kovohute Praha	Ziar nad Hronom	100		Govt. 100%		Floury	Local smelter
	German DR	Lauta Werke	Lauta	60		Govt. 100%		"	"
	Hungary	Hungalu	Ajka I & II plants	470		Govt. 100%	Hungary	Floury	Local smelter and exported
			Almas Fuzito	325					
			Maygarovar	110					
				905					
	Romania	Alumina Enterprise	Crisana	250		Govt. 100%	Romania	Floury	Romanian smelters
			Tulcea	250					
				500					
	China	Nanting	Shantung						
		Sian	Shanxi						
		Kweiyang	Kweicho	850		Govt. 100%	China	Floury	Chinese smelters
		Fushun	Liaoning						
		Wenchang	Hainan Is.						
		Zhengshou	Henan						

Appendix Table 4 Aluminum Smelters in the World, 1982

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina (Country/Company)	Source of Bauxite (Country/Company)	Method of Production*	Ownership	(%)	Share of product (%)
AFRICA											
Cameroon	Co. Camerounaise de l'Aluminium (=ALCAM)	Edea	80	1957	Hydro 100%	Guinea	———	SAF	Pechiney Govt. Others	48 25 27	
Egypt	Aluminium Co. of Egypt	Nag Hammadi	166	1975	Hydro 100%	Australia USSR	Australia	SAF	United Arab Republic (Govt.) USSR Government	100 0	70 30
Ghana	Volta Aluminium Co., Ltd. (VALCO)	Tema	200	1967	Hydro 100%	Gladstone, Australia (QAL) Jamaica (Nain)	Australia, Jamaica (Alumina Partners of Jamaica)	PAF	Kaiser Reynolds	90 10	90 10
South Africa	Alusaf (Pty.) Ltd.	Richards Bay	169	1971	Coal 100%	ALCOA of Australia	Australia	PAF	Industrial Development Corp. (Govt.) ALUSUISSE Others	66 22 12	66 22 12
SOUTH ASIA											
Bahrain	Aluminium Bahrain	Knuff	170	1971	Natural gas 100%	ALCOA of Australia (KWINANA) COMALCO of Australia (QAL)	Australia	PAF	Govt. Saudi Arabia Govt. Kaiser Alum. Breton Investments	57.9 20 17 5.1	57.9 20 17 5.1
India	Madras Aluminium Co., Ltd.	Mettur	25	1967	Hydro 100%	Company source (Mettur)	India	SAF	Madras State Govt. Montecatini-Edison, SpA	73 27	73 27
	Bharat Aluminium Co., Ltd.	Korba, Madhya Pradesh	100	1975	Thermal 100%	Company source (Korba)	"	SAF	Bharat State Govt.	100	100
	Hindustan Aluminium Corp. Ltd.	Renukoot, Uttar Pradesh	100	1962	Hydro 55% Thermal 45%	Company source (Renukoot)	"	PAF	BIRLA Group Kaiser	73 17	100
	Indian Aluminium Corp. Ltd. (INDAL)	Belgaum, Karnataka	73	1969	Hydro 100%	Company source (Belgaum)	"	PAF	ALCAN Private interests	55 45	55 45
		Alupuram, Kerala	21	1943	Hydro 100%	Company source (Belgaum)	"	PAF			
		Hirakud, Orissa	25	1959	Hydro 100%	" (Muri)	"	PAF			

* SAF: Soderberg; PAF: Prebaked

Appendix Table 4 (cont'd.)

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina (Country/Company)	Source of Bauxite (Country/Company)	Method of Production*	Ownership	(%)	Share of product (%)
(India - cont'd.)	Aluminium Corp. of India (ALCOIN)	Jaykaynagar	9		Thermal 100%			SAF	ALCOIN	100	
Indonesia	Indonesia Asahan Aluminium (INALUM)	Kuala Tanjung, Sumatera	75 (225)	1982	Hydro 100%	Japan Australia		PAF	Nippon Asahan Aluminium Co. Ltd. Govt.	75 25	75 25
Iran	Iran Aluminium Co. (IRALCO)	Arak	50	1972		Australia (ALCOA of Australia)		PAF	Govt. Reynolds Pakistani Government	95 4 1	95 4 1
Turkey	ETIBANK	Seydisehir Konya	60	1972		Turkey (Company source)	Turkey	probably SAF	Govt.	100	100
Dubai - United Arab Emirates	Dubai Aluminium Co., Ltd.	Jebel Ali	135	1979	Natural gas 100%	Australia (ALCOA of Australia		PAF	Govt. Nissho-Iwai Southwire Local interest	80 7 8 5	
OCEANIA											
Australia	ALCAN Australia Ltd.	Kurri-Kurri Newcastle, NSW	90	1969	Thermal Coal 100%	Australia (Queensland Alumina Ltd.)	Australia (Weipa)	PAF	ALCAN Aust. institutions	70 30	70 30
	ALCOA of Australia Ltd.	Point Henry Geelong Victoria	165	1963	Thermal Brown Coal 100%	Company refineries in Western Australia (Kwinana, Pinjarra)	Australia	PAF	ALCOA Western Mining Corp. Broken Hill South Ltd. North Broken Hill Ltd. Aust. institutions	51 20 13.1 12 3.9	100
	COMALCO Ltd.	Bell Bay, Tasmania	117	1955	Hydro 100%	Australia (Queensland Alumina Ltd.)	Australia (Weipa)	PAF	KAISER Conzinc Rio Tinto Private interest COMALCO	45 45 10	 100
	Boyne Smelters Ltd.	Boyne Island, Gladstone	103 (206)	1982	Thermal Coal 100%	Australia (Queensland Alumina Ltd.)	Australia (Weipa)	PAF	KAISER COMALCO Japanese investors	20 30 50	20 30 50
New Zealand	New Zealand Aluminium Smelters Ltd.	Tiwai Point (Bluff)	244	1971	Hydro 100%	Australia (Queensland Alumina Ltd.)	Australia (Weipa)	PAF	Sumitomo Aluminium Showa Aluminium COMALCO	20.64 20.64 58.72	20.64 20.64 58.72
EUROPE											
Austria	Salzburger Aluminium GmbH	Lend, Salzburg	12	1899	Hydro 100%	Guinea (Friquia) German, FR, and Australia (NABALCO)	Guinea Australia (Gove)	SAF	ALUSUISSE	100	100

* SAF: Soderberg; PAF: Prebaked

Appendix Table 4 (cont'd.)

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina (Country/Company)	Source of Bauxite (Country/Company)	Method of Production*	Ownership	(%)	Share of product (%)
(Austria - cont'd.)	Vereinigte Metallwerke Ranshofen-Berndorf	Ranshofen	80	1941	Hydro 100%	Germany, Fed. Rep. and Hungary	Hungary	SAF	Govt.	100	100
Czecho-slovakia	Z.S.N.P. Kovohute Praha	Ziaron River Hron	60	1953	Hydro 100%	Ziar refinery		probably SAF	Govt.	100	100
France	Aluminium Pechiney	Auzat (Ariège)	44	1914		France (company source) and imported		SAF	Pechiny Ugine Kuhlmann Group	100	100
		La Praz (Savoie)	4	1893	Hydro 100%	"		PAF			
		L'Argentière (Hautes Alpes)	40	1910	Hydro 100%	"		PAF			
		La Saussaz (Savoie)	12	1905	Hydro 100%	"		PAF			
		Noguères (Bas Pyrenées)	113	1960	Thermal Natural gas 100%	"		SAF			
		Riouperoux (Isère)	24	1926	Hydro 100%	"		PAF			
		St. Jean de Maurienne (Savoie)	100	1907	Hydro 100%	"		PAF 50% SAF 50%			
		Sabart (Ariège)	24	1929		"		PAF			
		Lannemézan (Hautes Pyrenées)	63	1939		"		SAF			
		Venthon	29		Hydro 100%	"		PAF 36% SAF 64%			
German Dem. Rep.	Elektro-chemisches Kombinat	Bitterfeld	55			Mainly Hungary		probably SAF	Govt.	100	100
		Lauta Werke	30			Associated Lauta refinery also Hungary		SAF			
Germany, Fed. Rep.	ALCAN Aluminium Werke GmbH	Ludwigshafen	44	1964		Germany, Fed. Rep.		PAF	ALCAN	100	100
	Aluminium-Hütte Rheinfelden GmbH	Rheinfelden (Baden)	64	1897		ALUSUISSE sources in Germany, Fed. Rep.	Guinea (Friguia) Australia (Gove)	SAF	ALUSUISSE	100	100
	Kaiser-Aluminum Europe Inc. (KAPAL)	Voerde	72	1971				PAF	Kaiser Preussag	50 50	100
	Leichmetall GmbH	Essen-Borbeck	126	1970		Italy (Eurallumina) and Australia (Gove)	Australia	PAF	ALUSUISSE Others	98 2	98 2

* SAF: Soderberg; PAF: Prebaked

Appendix Table 4 (cont'd.)

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina (Country/Company)	Source of Bauxite (Country/Company)	Method of Production*	Ownership	(%)	Share of product (%)
(Germany, Fed. Rep. - cont'd.)	Hamburger Aluminium Werke GmbH	Hamburg	100	1973		Germany, FR (VAW)		PAF	City of Hamburg	100	
									VAW		34
									Reynolds		33
									Ranshofen-Berndorf		33
	Vereinigte Aluminium Werke A.G. (VAW)	Töging (Innwerk)	77	1925	Hydro	Germany, FR (company sources)		PAF 53% SAF 47%	Govt.	100	100
		Lünen (Lippenwerk)	33	1938		"		PAF 50% SAF 50%			
		Norf (Rheinwerke)	155	1963		"		PAF 50%			
		Elbewerk Stade	65	1973	Thermal nuclear 100%	"					
Greece	Aluminium de Greece S.A.	Distomon	145	1966	Hydro 100%	(Company source)	Parmassua & Elikon Greece	PAF	Pechiney Ugine Kuhlmann Group	70	70
							Hellenic Bauxites of Distomon Ltd.		Govt.	30	30
							Bauxite Parmasse Mining Co.				
							Eleusis Bauxite Mines Inc.				
Hungary	Hungarian Aluminium Corporation	Ajka	25	1943		Hungarian refineries	Hungary	SAF	Hungarian Govt.	100	100
		Inota	30	1950		"	"	SAF			
		Tatabanya	16	1940		"	"	SAF			
Iceland	Icelandic Aluminium Co.	Straumsvik Hafnarfjordur	87	1969	Hydro 100%	Gove (Northern Territory, Australia, NABALCO Pty. Ltd.) Mackenzie (Guyana, Guyana Bauxite Co.) Parnam (Surinam Aluminium Co.)	Gove (Northern Territory, Australia) Paranam (Méngo Mines, Surinam) Three Friend Maria (Guyana)		Swiss Aluminum Ltd. (ALUSUISSE)	100	100
Italy	Aluminio Italia SpA	Bolzano	35	1937	Hydro 100%	Italy (Eurallumina)	Australia (Weipa)	SAF	Italian Govt. (EFIM-MCS)	100	100
		Fusina	35	1971	Thermal 100%	Porto Vesme Italy (Euralumina)	"	PAF			
		Mori (Trento)	21	1928	Hydro 100%	Porto Marghera Italy Montecatini-Edison SpA	Australia (Weipa)	SAF			
	Soc. Aluminio Veneto per Azioni SpA	Fusina	30	1962	Hydro 50% Thermal 50%	Italy (Montecatini-Edison, Eurallumina)	Australia (Weipa)	PAF	Italian Govt.	50	50
									Alusuisse	50	50
	"	Porto Marghera	30	1928	Hydro 100%	Italy	Australia (Weipa)	PAF 34% SAF 66%			
	Alsar SpA	Porto Vesme (Sardinia)	125	1973	Thermal 100%	Italy (Eurallumina)	Australia (Weipa)	SAF	Italian Govt.	100	100

* SAF: Soderberg; PAF: Prebaked

Appendix Table 4 (cont'd.)

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina (Country/Company)	Source of Bauxite (Country/Company)	Method of Production*	Ownership	(%)	Share of product (%)
Sweden	Granges Aluminium AB	Sundsvall (Kubikenborg)	83	1943	Hydro 100%	Jamaica and Surinam		SAF	Granges AB	100	100
Netherlands	Aluminium Delfzijl BV	Delfzijl	96	1966	Thermal natural gas 100%	Surinam (Billiton sources)	Surinam	PAF	Hoogovens Ijmuiden (Holland Aluminium)	100	100
	Pechiney Nederland N.V.	Vlissingen	170	1971	Thermal nuclear 100%	France (Pechiney source) and Greece	France	PAF	Pechiney Hunter Douglas	85 15	85 15
Norway	Det Norske Nitridaktieselskap	Tyssedal	24	1916	Hydro 100%	Brazil (Aluminio Minas Gerais)	Brazil (Aluminio Minas Gerais)	SAF	Govt.	100	100
	Mosal Aluminium Elkem-Spigeverket A/S	Mosjoen	95	1958	Hydro 100%	Surinam	Surinam	SAF	ALCOA ELKEM	45 55	45 55
	"	Lista	82	1971	Hydro 100%	"	"	SAF			
	Norsk Hydro A/S	Karmøy Island	157	1967	Hydro 100%	Virgin Islands and Australia	Guinea Jamaica and Guyana	SAF	Govt. Norsk Hydro	51 49	51 49
	A/S Ardal og Sunndal Verk	Ardal	182	1946	Hydro 100%	Jamaica and Guyana		PAF 47% SAF 53%	Govt.	100	100
		Høyanger	68	1915	Hydro 100%	"	"	SAF			
		Sunndal	122	1954	Hydro 100%	"	"	PAF 10% SAF 90%			
	Sør-Norge Aluminium A/S	Husnes	72	1965	Hydro 100%	Guinea	Guinea	PAF 50% SAF 50%	Alusuisse Compadec & private interest	74.8 25.2	74.8 25.2
Poland	Centrozap	Malniec, Konin	55	1965	Thermal (lignite) 100%	Mainly Hungary & Yugoslavia; also Guinea	Guinea	SAF 100%	Govt.	100	100
Romania	Slatina Aluminium Complex	Slatina	250	1964	Thermal (lignite) 50% Hydro 50%	Romanian refineries	Romania	PAF	Govt.	100	100
Spain	Aluminio de Galicia SA (ALUGASA)	La Coruña	78	1961		Spain (San Ciprian)	Guinea	SAF	Pechiney Spanish banks Other interests	67.5 25.4 7.1	
		Sabiñanigo (Huesca)	14	1928		Spain (San Ciprian)	-	SAF			

* SAF: Soderberg; PAF: Prebaked

Appendix Table 4 (cont'd.)

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina (Country/Company)	Source of Bauxite (Country/Company)	Method of Production*	Ownership	(%)	Share of product (%)
(Spain - cont'd.)	Empresa Nacional Del Aluminio SA (ENDASA)	Avilés	101	1959	Hydro 50% Thermal 50%	Spain (San Ciprian)	Guinea	SAF	Govt. ALCAN Private interests	56.8 41.5 1.7	
		Valladolid	25	1949	Hydro 50% Thermal 50%	"	"	SAF	"	"	
	Aluminio Español SA	San Cipriano Lugo	180	1978	Thermal (lignite) 100%	Associated San Ciprian (Spain) refinery	"	PAF	ENDASA Banks ALUGASA	55 25 20	
Switzer-land	Swiss Aluminium Ltd. (ALUSUISSE)	Chippis	35	1908	Hydro 100%	Surinam, Guinea & Australia (Gove)		PAF 70% SAF 30%	ALUSUISSE	100	100
		Steg	48	1962	Hydro 100%	"		PAF 100%			
	Usine D'Aluminium Martigny SA	Martigny	10	1938	Hydro 100%			SAF 100%	Usine D'Aluminium Martigny SA	100	100
UK	ALCAN Aluminium (UK) Ltd.	Lynemouth, Northumberland	127	1972	Thermal (incl. coal 50%)	ALCAN Jamaica Ltd.	Jamaica	PAF	ALCAN UK private investors	78 22	
	British Aluminium Co., Ltd. (BACO)	Kinlochleven, Scotland	10	1909	Hydro 100%			SAF	Tube Investments (BACO)	58	58
		Fort William (Lochaber), Scotland	37	1929	Hydro 100%			PAF	Private interests (BACO)	42	42
		Invergordon, Scotland	101	1971	Thermal (nuclear) 100%	Jamaica (ALPART)	Jamaica	PAF			
	Anglesey Aluminium Ltd.	Holyhead, Wales	113	1971	Thermal (nuclear) 100%	Jamaica (ALPART) and Australia (QAL)	Australia (Weipa) and Jamaica		Rio Tinto Zinc Corp. Kaiser	33 67	33 48
Yugo-slavia	Tovarna Glinice in Aluminijuma (Boris Kidric)	Kidricevo, Slovenia	75	1954		Yugoslavia	Yugoslavia	SAF 100%	Govt.	100	100
	Kombinat Aluminijuma Titograd	Titograd, Montenegro	110	1972	Hydro 50% Thermal 50%	Yugoslavia (Titograd) refinery	"	PAF 100%			
	Tvornica Lakih Metala (Boris Kidric)	Sibenik, Dalmatia	110	1973		Yugoslavia (Obrovac) refinery	"	SAF 100%			
	Energoinvest	Mostar	90	1981	Hydro 100%	Yugoslavia (Mostar) refinery	"	PAF			
USSR	USSR Govt.	Bogoslovsk	150	1945	Thermal (lignite) 100%	Bogoslovsk refinery	Local mine	SAF	Govt.	100	100
		Bratsk	600	1966	Hydro 100%	USSR sources	"	SAF			

* SAF: Soderberg; PAF: Prebaked

Appendix Table 4 (cont'd.)

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina	Source of Bauxite (Country/Company)	Method of Production*	Ownership	(%)	Share of product (%)
(USSR - cont'd.)	(USSR Govt. - cont'd.)	Shielikhovo	280	1962	Hydro 100%	USSR sources		SAF			
		Kamensk-Uralsk	150	1939	Thermal (lignite) 100%	Kamensk refinery		SAF			
		Kanaker (Yerevan)	100	1950	Hydro 100%	Probably USSR source; also from Hungary		SAF			
		Kandalaksha (Murmansk)	60	1951	Hydro 100%	Kandalaksha refinery		SAF			
		Krasnoyarsk	430	1964	Hydro 50% Thermal (coal) 50%	Achinsk refinery & other USSR sources		SAF			
		Nadvoitsy	60	1954	Hydro 100%	Probably Kandalaksha refinery		Probably SAF			
		Novokuznetsk (Stalinsk)	200	1943	Thermal (coal) 100%	Mainly from Siberian sources (Achinsk)		SAF			
		Sumgait (Kirovabad)	120	1955	Hydro 50% Thermal (natural gas) 50%	Azerbaydzhan refinery	Local mine	SAF			
		Volgograd (Stalingrad)	300	1959	Hydro 100%	Refinery in Volgograd		SAF	Govt.	100	100
		Volkhov (near Leningrad)	60	1932	Hydro 100%	Refinery in Volkhov		SAF			
		Zaporozhye (on Dneiper River, Ukraine)	120	1934	Hydro 100%	Zaporozhye refinery and Hungary		SAF			
		Regar (Dushanbe, Tadzikstan)	500	1975	Hydro 100%	Imports					
EAST ASIA											
Korea, Dem. Rep.	Government	Chinampo	20						Govt.	100	100
China		Fushun (Liaoning)	100	1937		Mainly from Chinese sources		SAF	Chinese Govt.	100	100
		Taiyuan (Shanxi)	18								
		Lanzhou (Gansu)	25								
		Hofie (Anhui)	16								
		Changling (Jilin)	16								
		Qingdao (Shandong)	16								
		Jiaozuo (Henan)	16								
		Wuhan (Hubei)	16								
		Kunming (Yunnan)	15								
		Changshai (Hunan)	15								
		Sanmenxia (Henan)	30	1974							
		Guiyang (Guizhou)	80	1981				PAF			

* SAF: Soderberg; PAF: Prebaked

Appendix Table 4 (cont'd.)

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina (Country/Company)	Source of Bauxite (Country/Company)	Method of Production*	Ownership	Share of Ownership (%)	Share of product (%)
Korea, Rep. of	Aluminium of Korea, Ltd. (KORALU)	Ulsan	18	1973	Thermal 100%	Japan		SAF	Hyundai Industries/ Korean Develop. Bank	50	50
									Pechiney	50	50
Taiwan	Taiwan Aluminum Corp. (TALCO)	Kaohsiung I	33	1935	Thermal 100% (incl. approx. 25% nuclear & 30% diesel oil)	Associated Kaohsiung refinery	Australia (Weipa) Malaysia	PAF 50% SAF 50%	Govt.	100	100
		Kaohsiung II	50					PAF			
Japan	Mitsui Aluminium Co., Ltd.	Omuta, Miike (Kyushu Island)	144	1970	Thermal coal 100%	Mitsui Alumina Co., Ltd. (Wakamatsu, Kyushu)	Australia (Gove)	PAF	Mitsui group	80	100
									Private interests	20	
	Sumitomo Aluminium Smelting Co., Ltd.	Toyama	83	1967	Thermal (oil) 100%	Company source (Kikumoto)	Indonesia (Bintan) Australia (Gove, Weipa)	SAF	Sumitomo Chemical	50	
									Private interests	50	
		Toyo (Shikoku)	100	1975	Thermal (oil) 90% Hydro 10%	Imported from Australia (Alcoa of Australia)		PAF			
	Showa Aluminum Industries K.K.	Chiba	76	1962	Thermal (oil) 100%	Company source (Yokohama)	Australia (Gove, Weipa) Indonesia (Bintan)	PAF & SAF	Showa Denko K.K.	50	
									Private interests	50	
	Nippon Light Metal Co., Ltd.	Kambara	64	1940	Hydro 100%	Company source (Shimizu)	Australia (Gove, Weipa)	SAF	ALCAN	50	
									Private interests	50	
		Tomakomai (Hokkaido)	72	1969	Thermal (oil) 100%	Company source (Tomakomai)	Malaysia, Indonesia	PAF			
	Mitsubishi Light Metal Industries Ltd.	Sakaide (Shikoku)	76	1972	Thermal (oil) 100%	Imported from Australia (Alcoa of Australia)		PAF	Mitsubishi Chemical Industries, Ltd.	90	90
									Nippon Steel	10	10
LATIN AMERICA											
Argentina	Aluar Aluminio Argentino (ALUAR)	Puerto Madryn	140	1975	Hydro 100%	Australia (Pinjarra Alcoa of Australia)	Australia	PAF	Fate	51	
									Private interests	49	
Brazil	ALCAN Aluminio do Brasil SA	Saramenha	60	1945	Hydro 100%	Company refinery in Brazil (Saramenha, Ouro Petro)	Company source in Brazil (Minas Gerais)	SAF	ALCAN	100	100
	Aluminio do Brasil Nordeste SA	Aratu (Bahia)	28 +30	1972 1983	Hydro 100%	Company refinery in Brazil (Saramenha Ouro Preto)	"	SAF	ALCAN	100	100
	Cia. Brasileira de Aluminio (CBA)	Sorocaba (Sao Paulo)	120	1955	Hydro 100%	Company refinery in Brazil (Sorocaba)	Company source in Brazil	SAF	Votorantim	80	80
									Govt.	20	20

* SAF: Soderberg; PAF: Prebaked

Note) Japan — The capacity of facilities not in operation is excluded. (Total production is limited to 700,000 tonnes.)

Appendix Table 4 (cont'd.)

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina (Country/Company)	Source of Bauxite (Country/Company)	Method of Production*	Ownership	(%)	Share of product (%)
(Brazil - cont'd.)	ALCOA Alumino SA	Pocos de Caldas (Minas Gerais)	90	1970	Hydro 100%	Company refinery in Brazil (Pocos de Caldas)	Company source in Brazil	SAF	ALCOA	50	50
									Hanna Mining Co.	32	24
									Minas Gerais Bank	15	26
									Private interests	3	
	Valesul Alumino SA	Santa Cruz	86	1982	Hydro 100%	Import (Surinam)	Surinam	PAF	Shell Brasil	35	
									CVRD (Govt.)	49	
									Brazilian interests	11	
									Reynolds	5	
Surinam	Surinam Aluminum Co. (SURALCO)	Paranam	66	1965	Hydro 100%	Surinam (company sources)	Surinam (company source)	SAF	ALCOA	100	100
Vene-zuela	Aluminio del Caroni SA (ALCASA)	Puerto Ordaz	125	1967	Hydro 100%	Imported from USA (Reynolds' refinery in Texas)	Arkansas (USA) and imports from Jamaica	PAF	Corporation Venezolana de Guyana (CVG Govt. owned)	14.6	
									Fondo de Inversiones de Venezuela (FIV, Govt. owned)	57.5	
									Reynolds	27.9	
	Industria Venezolana de Aluminio (VENALUM)	San Felix, Guyana	280	1978	Hydro 100%	Imported mainly from Jamaica	Jamaica	PAF	CVG	18.8	43
									FIV	61.2	
									Japanese investors	20	57
Mexico	Aluminio SA	Veracruz	45	1963	Thermal (oil) 50% Hydro 50%	Imported from USA (ALCOA, Texas)	Company sources in Jamaica, Surinam and Dominican Republic	SAF	ALCOA	44	44
									Intercontinental	26	26
									Private interests	30	30
NORTH AMERICA											
Canada	Canadian Reynolds Metals Co., Ltd.	Baie Comeau (Quebec)	159	1957	Hydro 100%	Reynolds (Texas)	Arkansas (USA) and imported from Jamaica	SAF	Reynolds	100	100
	ALCAN Aluminium Ltd.	Arvida (Quebec)	432	1926	Hydro 100%	Mainly from ALCAN's Quebec refinery; also some from Guyana, Jamaica, etc.	Guinea (CBG) Brazil (Trombetas)	PAF 25% SAF 75%	ALCAN	100	100
		Isle Maligne (Quebec)	75	1943	Hydro 100%	"	Guinea (CBG) Brazil (Trombetas)	SAF			
		Kitimat (B.C.)	268	1954	Hydro 100%	Australia (QAL), Jamaica (Jamalcan), and Japan (NLM)	Australia (Weipa), Indonesia (Bintan), Jamaica	SAF			
		Beauharnois (Quebec)	46	1943	Hydro 100%	Mainly from ALCAN's Quebec refinery; also some from Guyana, Jamaica, etc.	Guinea (CBG) Brazil (Trombetas)	SAF			
		Shawinigan (Quebec)	83	1900	Hydro 100%	"	"	SAF			
		Grande Baie (Quebec)	171	1980	Hydro 100%	ALCAN sources - mainly imports		PAF			

* SAF: Soderberg; PAF: Prebaked

Appendix Table 4 (cont'd.)

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina (Country/Company)	Source of Bauxite (Country/Company)	Method of Production*	Ownership	Share of product (%)	(%)
USA	Alumax Inc.	Mt. Holly S. Carolina	179	1980	Thermal 100%	Mainly from Australia	Australia	PAF	AMAX Mitsui & Co. Nippon Steel	50 45 5	50 45 5
	Aluminum Company of America (ALCOA)	ALCOA, Tennessee	199	1914	Hydro 20% Thermal 80%	ALCOA sources in USA (Alabama, Texas); Jamaica, Surinam		PAF 84% SAF 16%	ALCOA	100	100
		Palestine, Texas	14	1976	Thermal 100%						
		Badin, N. Carolina	163	1916	Hydro 60% Thermal 40% (coal & nuclear)	ALCOA sources in USA; Jamaica, Surinam		PAF			
		Evansville, Indiana	263	1960	Thermal 100% (coal)	"	Company sources in USA, Surinam and Jamaica	PAF			
		Massena, N.Y.	195	1903	Hydro 50% Thermal 50% (nuclear)	ALCOA sources in USA		PAF			
		Point Comfort, Texas	168	1949	Thermal 100% (natural gas)	ALCOA's Texas plant		SAF			
		Rockdale, Texas	295	1952	Thermal 100% (lignite)	ALCOA plants in Alabama and Texas		PAF			
		Vancouver, Washington	104	1940	Hydro 100%	Mainly from Australia (ALCOA of Australia); also Jamaica	Australia (Alcoa of Australia)	PAF			
		Wenatchee, Washington	191	1952	Hydro 100%	"	"	PAF			
	Anaconda Aluminum Co., Ltd. (ARCO Metals)	Columbia Falls, Montana	163	1955	Hydro 100%	Jamaica (ALPART)	Jamaica	SAF	Atlantic Richfield	100	100
		Sebree, Kentucky	163	1973	Hydro 100%	"	"	PAF			
	Consolidated Aluminum Corp. (CONALCO)	Lake Charles, Louisiana	30	1971	Thermal 100% (natural gas)	Australia (Nabalco), Surinam (SURALCO) and USA (Ormet)	Australia, Surinam	PAF	ALUSUISSE Phelps Dodge/ ALUSUISSE (Approx. one-half of Phelps Dodge's share sold to ALUSUISSE)	60 40	
		New Johnson-ville, Tennessee	125	1963	Hydro 20% Thermal 80%	"	"	PAF			
	Eastalco Aluminum Co., Ltd.	Frederick, Maryland	160	1970	Thermal 100%	Mainly Australia (ALCOA of Australia); also Jamaica and Greece	Australia, Jamaica and Greece	PAF	Alumax Howmet (Howmet owned 100% by Pechiney)	50 50	
	Intalco Aluminum Corp.	Ferndale, Washington	236	1966	Hydro 100%	Australia (ALCOA of Australia & QAL)	Australia	PAF	Alumax Howmet (Howmet owned 100% by Pechiney)	50 50	
	National South-wire Aluminum Co., Ltd.	Hawesville, Kentucky	163	1969	Thermal 100%	USA (ALCOA, Kaiser)		PAF	National Steel Southwire	50 50	50 50

* SAF: Soderberg; PAF: Prebaked

Appendix Table 4 (cont'd.)

Area/ Country	Company/Plant	Plant Location	Capacity (1,000 MT/year)	Start up	Type of power	Source of Alumina (Country/Company)	Source of Bauxite (Country/Company)	Method of Production*	Ownership	Share of (%)	product (%)
(USA - cont'd.)	Noranda Aluminum Inc.	New Madrid, Missouri	204	1971	Thermal 100%	USA (Kaiser) and Guinea (Friguia)	Guinea	PAF	Noranda Mines	100	100
	Ormet Corporation	Hannibal, Ohio	236	1958	Thermal 100% (coal)	Ormet's Louisiana plant	Surinam (SURALCO)	PAF	CONALCO Revere	66 34	66 34
	Revere Copper & Brass Inc.	Scottsbor, Alabama	104	1971	Thermal 100% (nuclear)			PAF	Revere	100	100
	Kaiser Aluminum & Chemical Corp.	Chalmette, Louisiana	236	1951	Thermal 100% (natural gas)	Kaiser's Louisiana plants	Company sources in Jamaica	SAF	Kaiser	100	100
		Ravenswood, W. Virginia	148	1957	Thermal 100% (coal)	"	"	PAF			
		Mead, Washington	200	1942	Hydro 100%	Australia (QAL)	Australia (Weipa)	PAF			
		Tacoma, Washington	73	1942	Hydro 100%	"	"	SAF			
	Martin Marietta Aluminum Inc.	The Dalles, Oregon	82	1958	Hydro 100%	Company source (Virgin Is.)	Guyana	SAF	Martin Marietta Private interests	87 13	87 13
		Goldendale, Washington	168	1971	Hydro 100%	"	"	SAF			
	Reynolds Metals Company	Arkadelphia, Arkansas	62	1954	Hydro 32% Thermal 68%	Reynolds' Arkansas plant	Company sources in USA (Arkansas) and Jamaica	SAF 75% PAF 25%	Reynolds	100	100
		Jones Mills, Arkansas	113	1942	Thermal 100% (incl. 40% natural gas)	"	"	PAF			
		Listerhill, Alabama	183	1940	Hydro 20% Thermal 80%	"	"	SAF			
		Corpus Christi, Texas	103	1952	Thermal 100% (90% natural gas 10% other thermal)	Reynolds' Texas plant	"	SAF			
		Longview, Washington	191	1941	Hydro 100%	Jamaica (ALPART)	Jamaica	SAF			
		Massena, N.Y.	114	1953	Hydro 90% Thermal 10% (nuclear)	Reynolds' plants in USA	Company sources in USA (Arkansas) and Jamaica	SAF			
		Troutdale, Oregon	118	1942	Hydro 100%	Jamaica (ALPART), Surinam (SURALCO) and Australia	Jamaica, Surinam and Australia	PAF			

* SAF: Soderberg; PAF: Prebaked

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[2] NICKEL AND FERRO-NICKEL

[2] NICKEL AND FERRO-NICKEL

CONTENTS

[2] NICKEL AND FERRO-NICKEL

A. OUTLINE

I. Properties of Nickel

Nickel is a lustrous, silvery-gray metal with a specific gravity of 8.9, a melting point of 1453°C and a hardness of 3.8. Like iron, it is quite malleable and ductile and can be forged and welded. Furthermore, it can take an extremely good polish.

As for its chemical properties, nickel is highly resistant to corrosion by distilled water, natural water and sea water, and also by neutral or alkaline salt solutions. At room temperature, in air, masses of nickel are stable, but finely powdered nickel may ignite spontaneously in air. Nickel combines with phosphorus, arsenic, antimony and other elements, and forms mixed alloys with iron, copper, manganese, aluminum, chromium, zinc, and other metals. Nickel dissolves in dilute acids but is much less soluble than iron. It dissolves readily in dilute nitric acid but, like iron, it enters a passive state and does not dissolve in undiluted nitric acid.

The ability of nickel to increase the elastic limit and strength of steel is quite large. Not only is it used to strengthen ferrites, but due to its ability to facilitate quenching, it is also an indispensible element in special structural steel, which must have high strength. The corrosion resistance of nickel, in particular its resistance to acids, is made use of in making special steels, such as stainless steels, that are not easily corroded by acids or other chemicals. Furthermore, by adding 18% chromium and 8% nickel to iron, as in 18-8 stainless steel, its heat resistance can also be improved.

II. The History of Nickel

The use of nickel goes back to prehistoric times. It is believed that it began with the fashioning of swords and tools from meteoric iron containing nickel. It is known that a natural alloy of nickel and copper called 'Packfong' was used in China.

Nickel was first extracted as an element in 1751 by the Swedish chemist Cronstedt, who gave the element its name. In 1756, another Swede, Engestrom, discovered that Packfong was made of copper, nickel and zinc, and soon after that, a similar alloy was being made all over Europe. It was called German silver or, after the First World War, nickel silver. This nickel silver was the first use of nickel as an industrial raw material.

In 1775, 24 years after Cronstedt extracted elemental nickel, a German, Begmann, recognized that nickel was a simple substance and verified that it was an element.

In 1865, the Frenchman Garnier discovered the garnierite nickel deposit in New Caledonia, mining of which began in 1877, and nickel ore was discovered in a copper mine in the Sudbury region of Canada. Then Thomson in 1890, discovered a method for separating nickel from copper, and this became the starting point for the prosperity of the Canadian nickel industry.

Today's stainless steel, the first of the chromium steels, was invented after the turn of the century. In 1914, an Englishman, Brearley, acquired a British patent on a practical stainless steel with 0.7% or less carbon and from 14% to 16% chromium. The first combination of nickel with stainless steel was made by Friedrich Krupp in Germany, which discovered in 1912 that steel with up to 1.0% carbon, from 15% to 40% chromium, and 4% to 20% nickel, or with up to 1.0% carbon, 7% to 25% chromium, and 5% to 20% nickel, has superior corrosion resistance and acquired a German patent on it. The Friedrich Krupp Huttenwerke A.G. commercialized stainless steel under this patent under the names V1M (chromium 12-14%; nickel 0.5-2.0%) and V2A (chromium 20%, nickel 7%), and the latter was the first industrially produced 18-8 austenitic stainless steel. After this, the consumption of nickel grew rapidly along with the development of the special steel field.

III. Nickel Ores

Nickel is widely distributed in the earth's crust in the form of a variety of minerals, but the locations where it is concentrated enough to be economically mineable are much unevenly distributed. The nickel content of the earth's crust is 35-80 ppm. Like cobalt, nickel tends to be concentrated in basic rocks and especially in ultrabasic rocks, where its concentration reaches an average of 2000 ppm.

Nickel ores can be classified into sulfide minerals and oxide silicate minerals (called laterite nickel). Generally, the sulfide minerals are a raw material for electrolytic nickel, and the silicate minerals for ferronickel. The major economic sulfide mineral is pentlandite, while the major economic silicate minerals are garnierite and nickeliferous limonite. Deep-sea manganese nodules, which contain nickel, are attracting attention as a future resource. Reference Table A-1 lists the main nickel minerals.

IV. Extraction Metallurgy of Nickel

The nickel extraction processes currently in use are outlined in Reference Fig. A-1. The main ones are detailed below.

1. Nickel Metal

1.1 Extraction from Sulfide Ores

1.1.1 Ore dressing and smelting

First, nickel sulfide ore is concentrated by dressing to give nickel sulfide concentrates, e.g. nickel 6.5%, copper 0.3%, iron 40%, sulfur 27%. At the Thompson factory of INCO, this nickel concentrate is roasted in a fluidized bed roaster and about half the sulfur is eliminated. Next, it is smelted in an electric furnace, and the matte (e.g., nickel 17%, iron 47%, sulfur 26%) and the slag (e.g., iron 38%, silicon dioxide 36%, magnesium oxide 5%) are separated. The molten matte is blowed in a converter to eliminate the iron by oxidizing it. This gives nickel matte.

The Western Mining Corporation Ltd. of Australia smelts nickel concentrates (e.g., nickel 12%, copper 1.1%, iron 35%, sulphur 30%) in a flash furnace.

1.1.2 Refining

(1) Electrolytic methods

There are two electrolytic methods: the matte anode process and the metal anode process. The matte anode process directly melts nickel matte to give matte anode, while the metal anode process oxidation-roasts nickel matte to give nickel oxide, and then obtains the metal anode by reduction metling. Thus, the matte anode process has the advantage over the metal anode process of being able to eliminate the roasting and reduction steps. However, the matte anode process has the disadvantages of a high decomposition voltage and the need to make up the deficiency of nickel ions caused by the anode current efficienty being less efficient than the cathode one.

The electrolytic cell has the cathode in a box with a stretched filter cloth of synthetic fiber. Electrolyte from which impurities have been eliminated is supplied to this cathode box. The anolyte containing impurities is removed from the electrolytic cell, and copper, cobalt, iron, etc., are eliminated in the purification stage. When the matte anode process is used, nickel ion compensation is necessary. The nickel ions are made up either with nickel hydroxide produced by electrolysis of matte anodes in a sodium chloride solution or with nickel metal from pulverized matte anode scrap.

The copper is removed by either cementation with nickel powder or sulfide precipitation using H_2S. Cobalt and iron removal is accomplished by oxidation with chlorine. The pH of the electrolyte from which impurities have been removed is adjusted and used to supply the cathode box in the electrolytic cell. The current density is 1.5-2.5 A/dm2. The cathode is taken out of the electrolytic cell when it reaches a thickness of about 10mm. This is the nickel end-product. Reference Figs. A-2 and A-3 are the flowsheets for these processes.

(2) Carbonyl method

The fundamental carbonyl process is based on the historic discoveries of Carl Langer and Ludwing Mond. Carbon monoxide reacts with nickel at normal pressures and at temperatures up to 90°C to form a colorless gas, nickel carbonyl. This reaction can be reversed easily by raising the temperature. At 200°C, nickel carbonyl decomposes into pure nickel and carbon monoxide. At normal pressures, the impurities in crude metallic nickel do not enter the gas phase. The process is extremely selective. Nickel carbonyl is highly toxic, but it was this process that first made commercial production possible.

INCO Metal Company's Clydach plant in Wales in the United Kingdom began production based on this process in 1902. As a result of the many improvements made over the years, Inco's newly constructed plant at Copper Cliff, Canada, accelerates the nickel carbonyl reaction rate by using high pressure. Reference Fig. A-4 is a flowsheet for this process.

(3) Ammonia leaching - hydrogen reduction method (Sherritt process)

The nickel refining process used at the Fort Saskatchewan plant of Sherritt Gordon Mines Ltd. is known as the Sherritt process. After nickel concentrate or nickel matte is ground, it is leached with ammonia, the leaching residue and the solution are separated and some of the copper is removed. After filtration, the rest of the copper is eliminated from the solution with a copper strip autoclave. Then the purified solution is oxidized and hydrogen-reduced to obtain nickel powder. Some of this powder is made into briquettes. After reduction, a small amount of nickel (about 1 g/l) is left in the solution so as not to allow precipitation of cobalt, but is then removed as mixed cobalt nickel sulfide by blowing H_2S through the solution. After purification, this mixture is fed to a cobalt plant. The remaining solution after the cobalt and nickel have been removed is concentrated and crystallized as ammonium sulfate in an ammonium sulfate plant. Reference Fig. A-5 ia a flow sheet for this process.

(4) Solvent extraction method

At the Kristiansand plant of Falconbridge Ltd., high-purity nickel pellets are produced from nickel-copper matte with a solvent extraction process. Reference Fig. A-6 is a flowsheet for this process.

1.2 Extraction from Oxide Ores

1.2.1 Reduction - ammonia leaching method

This extraction method is based on the Nicaro process, which leaches nickel from laterite ore with an ammoniacal solution. The Marinduque Mining and Industrial Corporation combines this process with the Sherritt process to produce nickel briquettes. Reference Fig. A-7 is a flowsheet for this process.

1.2.2 Production of nickel matte

Nickel matte is produced from nickel oxide ore at the Soroako plant of P.T. International Nickel Indonesia (P.T. INCO) in Indonesia. After the ore is selectively reduced and sulfurized in a rotary kiln, it is smelted in an electric furnace, and separated into matte and slag. The matte is then blown with a converter to produce high-grade nickel matte. Reference Fig. A-8 is a flowsheet for this process.

1.2.3 Sulfuric acid leaching of laterite

This extraction method is used to process laterite ore at Moa Bay in Cuba. It is appropriate because this ore contains little MgO. Reference Fig. A-9 is a flowsheet for this process.

2. Nickel Oxide Sinter

2.1 Nicaro Process

This is the method of processing laterite by ammonia leaching to produce nickel oxide, as used at Cuba's Nicaro refinery. Reference Fig. A-10 is a flowsheet for this process.

2.2 Matte Roasting Process

In this process, after nickel matte is ground, it is subjected to fluidized-bed roasting to produce nickel oxide. Reference Fig. A-11 is a flowsheet for this process.

3. Ferro-nickel

3.1 Rotary Kiln - Electric Furnace Process

Ore is dried and crushed with a rotary dryer and an impact dryer and then sieved. After anthracite or coal is blended as a reductant, the ore is pelletized and fed into a rotary kiln.

The calcined ore discharged from the rotary kiln at around 800-900°C is fed continuously into the electric furnace, where it is rapidly melted and reduced in the vicinity of the electrodes. Metallic fine particles of nickel, cobalt and some of the iron aggregate and cause the slag layer to settle down to the bottom of the furnace. The crude ferro-nickel tapped from the electric furnace is desulfurized with calcium carbide and soda ash.

Depending on the usage intended, the desulfurized crude ferro-nickel, whose phosphorus content is usually 0.030% or less, may be cast into high-carbon ferro-nickel as it is, or be converted into low-carbon ferro-nickel by complete removal of the impurities by oxidizing blowing in an LD converter or a shaking converter. Reference Fig. A-12 is a flowsheet for this process.

3.2 Shaft Furnace - Electric Furnace Process (Selective Reduction)

This is the method employed by Falconbridge Dominicana C. por A. Briquettes are pre-reduced in the shaft furnace with the dry briquetting method and hot-charged into the electric furnace, where high-nickel-content crude ferro-nickel is produced by selective reduction. Reference Fig. A-13 is a flowsheet for this process.

3.3 Other Processes

Besides the above processes, the Krupp-Renn process (in use at Nippon Yakin's Oeyama plant), the Ugine process (formerly used at the Hanna Nickel Smelting Company's Riddle plant), and the blast furnace process (in use at Nippon Mining's Saganoseki plant) also exist in practiced application.

V. Nickel Product Standards

Nickel products take the form of nickel metal, ferro-nickel and nickel oxide sinter. Nickel metal is produced as briquettes, cathodes, granules, pellets, powder, rondelle, and shot. Ferro-nickel takes the shape of ingots and shot. The standards for nickel products include international standards, national standards in the major countries, and the standards of the leading producers. Reference Tables A-2 through A-4 show the details of these standards. However, the international standards cover only nickel metal. Furthermore, since not much time has passed since these standards were established (in 1979), various national standards, such as those of the American Society for Testing and Materials (ASTM), the British Standards Institute's standards (BS) and the Japanese Industrial Standards (JIS), are employed in transactions.

The leading producers' standards are shown in Reference Table A-4. Reference Table A-4-1 gives the Class I [1] standards, those for ordinary nickel metal, and reference Table A-4-2 gives the Class II [2] standards. This category covers ferro-nickel and nickel oxide sinter. Reference Table A-4-3 gives the standards for intermediate products.

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1) This is nickel metal of a purity of 99.8% or higher and includes cathode, briquettes, and pellets.

2) these are items that fall outside Class I because their purity is not high enough for it, e.g. ferronickel, nickel oxide sinter, utility shot, and Inco's Incomet.

VI. Usages of Nickel

Because of the corrosion resistance of nickel and the many properties it contributes to alloys, nickel is used in the production of capital goods and consumer goods in a wide range of fields. The main field that uses pure metallic nickel is nickel plating, which is responsible, for example, for the nickel crucibles used in laboratories.

However, the main uses for nickel are as an important material in the production of various metal alloys, particularly stainless steels and special steels. Nickel alloys are used in the following fields:

a. Chemical industry and petroleum refining

Because stainless, heat-resistant steel alloys with a nickel content of 8% or more are highly corrosion-resistant, they are used as plant materials and materials for components to be exposed to corrosive chemicals. Wrought cast nickel alloys containing 90-95% nickel are used for parts requiring resistance to strong caustic solutions.

b. Ships and desalination plants

Copper-nickel alloys are used for their resistance to salt corrosion in condenser tubes in ships and thermal power plants, in desalination plants, etc.

c. Storage tanks and tankers

Invar and 9% nickel alloy steel are used for gas storage tanks and LNG tankers.

d. Aircraft and nuclear power plants

Heat-resistant nickel-based alloys are used in gas turbines and jet engines. They are also used in tubes and heat exchangers for nuclear power plants.

e. Electronic materials and electric appliances

Alloys of nickel, cobalt, and iron are used in integrated circuit lead frames, etc. Also, nickel-iron alloys are used in tape recorder heads, high frequency iron cores, transistor vacuum tubes, etc. High permeability nickel alloys (cast magnets) are used in loudspeakers for televisions, radios, stereos, etc., and in various types of motors.

Besides these uses, nickel alloys are used in diverse fields such as general construction, household goods and coins. Other uses for nickel include catalysts and chemical applications.

Reference Table A-1 Main Nickel-bearing Minerals

Mineral	Chemical formula	Ni %	SG	Notes
Sulfides				
vaesite	NiS_2	47.8		Ni analog or pyrite, named by Kerr (1945).
pentlandite	$(Ni,Fe)_9S_8$	34.0~35.0	4.6~6.0	Most important Ni mineral; Canada (Sudbury), Australia
bravaite	$(Ni,Fe)S_2$	17.0~25.0	4.7	Germany, FR, Spain
millerite	NiS	64.7	5.5	Low temperature mineral; Canada (Sudbury), USA, Germany, FR
polydymite	Ni_3S_4	54.0~58.0	4.8	Rare mineral; Germany, FR
gersdorffite	$NiAsS$	35.4	5.9	Rare mineral; Canada, Sweden, Zimbabwe
violarite	Ni_2FeS_4	34.0~43.0	4.8	Rare mineral; Canada (Sudbury), USA
siegenite	$(Ni,Co)_3S_4$	30.0~32.0	4.8	Rare mineral; Canada (Sudbury), Zimbabwe
heazlewoodite	Ni_3S_2	72.4		Product of pentlandite reduction resulting from serpentinization of mafic rocks
godlevskite	Ni_7S_6	68.1		Texmont Mine, Ontario (Naldrett, 1972)
Arsenides				
niccolite	$NiAs$	40.0~44.0	7.8	USA, Canada (Sudbury); found in norite related deposits
maucherite	$Ni_{11}As_8$	49.0~54.0	8.0	Canada, Spain
rammelsbergite	$NiAs_2$	26.0~28.1	7.1	Germany, FR, Canada
arite	$Ni(As,Sb)$			Product of replacement of part of As in noccolite by Sb
Antimonides				
breithauptite	$NiSb$	30.0~32.5	8.2	Canada, Italy
Oxides, Silicates and Arsenates				
garnierite	$(NiMg)_6Si_4O_{10}(OH)_8$	up to 47.0		Secondary mineral after ultrabasic rocks. New Caledonia, Cuba, Indonesia
nickeliferrous limonite	$(Fe,Ni)O(OH)nH_2O$	low but variable		Secondary mineral after ultrabasic rocks. New Caledonia, Cuba, Indonesia
zaratite	$NiCO_3 \cdot 2Ni(OH)_2 \cdot 4H_2O$	44.2~46.8	2.6	Secondary mineral; Spain, USA
annabergite	$Ni_3As_2O_8 \cdot 8H_2O$	13.5~26.6	3.1	Secondary mineral
erythrite	$(Co,Ni)_3(AsO_4)_2 \cdot 8H_2O$	~9.0	3.1	Secondary mineral
Others				
nickel-iron	Fe-Ni	24.0~77.0	7.8~8.2	Common in gold mashings, awaruite ($\doteqdot FeNi_2$) jesephinite ($\doteqdot FeNi_3$)
pyrrhotite	$(Fe,Ni,Co)_{1-x}S$	max.5.0	4.6~4.8	Associated with pentlandite; Canada (Sudbury)
pyrite	$(Fe,Ni)S_2$	~16.0	4.8~5.0	Low Ni content of bravaite

Reference Table A-2   International Standards for Nickel

Composition \ Type	Ni 9900	Ni 9950	Ni 9990	Ni 9995
Ni + Co min.	99	99,5	99,9[1]	99,95[1]
Co max.	1,5	1,0	0,5	0,1
Ag max.				0,000 5
As max.				0,001
Bi max.			0,002	0,000 5
C max.	0,05	0,05	0,03	0,015
Cu max.	0,3	0,1	0,03	0,005
Fe max.	0,1	0,1	0,03	0,02
P max.				0,002
Pb max.		0,005	0,005	0,001 0
S max.	0,05	0,03	0,03	0,002 5
Sb max.			0,002	0,001
Se max.				0,001
Sn max.				0,000 5
Te max.				0,000 5
Tl max.				0,000 5
Zn max.				0,002

Reference Table A-3 Standards of the Main Nations

Standard	Product	Specification (%)														
		Ni	Co	Fe	Cu	Pb	Mn	C	S	Si	P	As	Sb	Bi	Sn	Zn
USA ASTM B39-67	Nickel	99.80 min	0.15 max	0.02 max	0.02 max	0.005 max	0.005 max	0.03 max	0.01 max	0.005 max	0.0005 max	0.0005 max	0.0005 max	0.0005 max	0.0005 max	0.0005 max
A636	Nickel Oxide Sinter															
	Grade 75	75.00	1.00	0.50	0.90	-	-	-	0.02	-	-	-	-	-	-	-
	Grade 90	89.0	1.20	0.60	0.30	-	-	-	0.02	-	-	-	-	-	-	-
UK BS 375-1930	Refined Nickel	Ni+Co 99.5 min	Ni 99.0 min	0.10	-	-	-	-	0.20	SiO_2 0.02 min	-	-	0.0005	0.0005	-	0.0005
Japan JIS H2104	Nickel Ingots Special	Ni+Co 99.95	0.30	0.02	0.005	0.001	0.002	0.02	0.001	0.005						
	1	99.95	-	0.02	0.005	0.0015	0.002	0.02	0.001	0.005						
	2	99.85	-	0.04	0.03	0.005	-	0.02	0.005	-						
	3	98.00	-	1.00	0.30	-	-	0.25	0.05	-						
G2316	Ferronickel (High carbon)															
	FNiH1	16.0	Ni×0.05 max.	-	0.10	-	0.3	3.0	0.03	3.0	0.05	Cr max. 2.0				
	FNiH2	16.0	Ni×0.05 max.	-	0.10	-	0.3	3.0	min. less than 0.03	5.0	0.05	2.5				
	(Low carbons) FNiL1	28.0		-	0.10	-	-	0.02 max.	0.03	0.3	0.02	0.3				
	FNiL2	17.0 min. less than 28.0	Ni×0.05 max. Ni×0.05 max.	-	0.08	-	-	0.02 max.	0.03	0.3	0.02	0.3				

Reference Table A-4-1 Quality Standards of the Major Producers

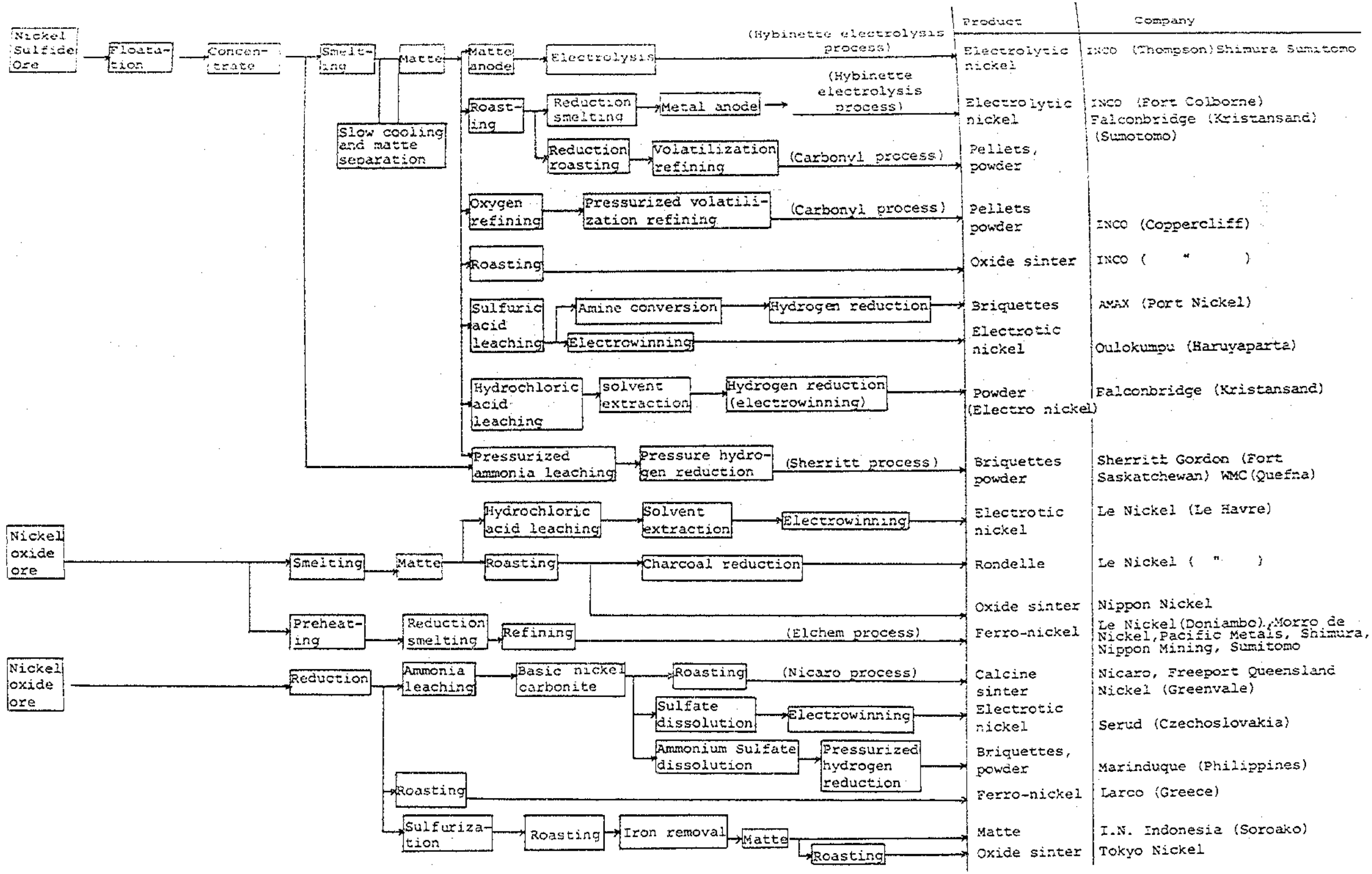
Company	Nation	Type	Specification								(%)
			Ni+CO min.	Co max.	Fe max.	Cu max.	Pb max.	Mn max.	C max.	S max	Si max.
INCO	Canada	Cathode (Typical)	99.97		0.01	0.01			0.01	0.001	
		" (Low-Co)	Ni 99.96	0.01	0.002	0.001	0.0001		0.01	0.001	
		" (Corborne)	Ni 99.93	0.05	0.002	0.005	0.002		0.01	0.001	
		S.Rounds	99.95		0.01	0.01			0.01	0.02	
		Pellets	Ni 99.97	0.0005	0.01	0.001	0.0001		0.01	0.001	
		Utility	Ni 96.6	1.3	0.4	0.9			0.4	0.1	0.3
		INCOMET	Ni 95	1.3	0.4	0.4			0.02	0.003	
FALCON	Canada	Cathode (Typical)	99.95	0.009	0.0009	0.0015	0.0007		0.003	0.0007	
SUMITOMO	Japan	L	99.95	0.02	0.02	0.005	0.001	0.002	0.02	0.001	0.005
		A	99.95	0.3	0.02	0.005	0.001	0.002	0.02	0.001	0.005
SHIMURA	Japan	HS	99.95	0.03	0.005	0.005	0.001	0.002	0.02	0.001	0.005
SLN	New Caledonia	Rondelles	99.60	0.4	0.12	0.03			0.050	0.005	
		Electro	99.97	0.003	0.0015	0.0005			0.004	0.001	
SHERRITT	Canada	Briquette	99.7	0.1	0.015	0.006			0.008	0.005	
W.M.C.	Australia	Briquette	Ni 99.8	0.06	0.008	0.006			0.012	0.006	
Marinduque	Philippines	Briquette	99.8	0.08	0.01	0.007		0.001	0.006		
Amax	U.S.A.	Briquette	99.9	0.03	0.002	0.001			0.01		

Reference Table A-4-2 Quality Standards of the Major Producers

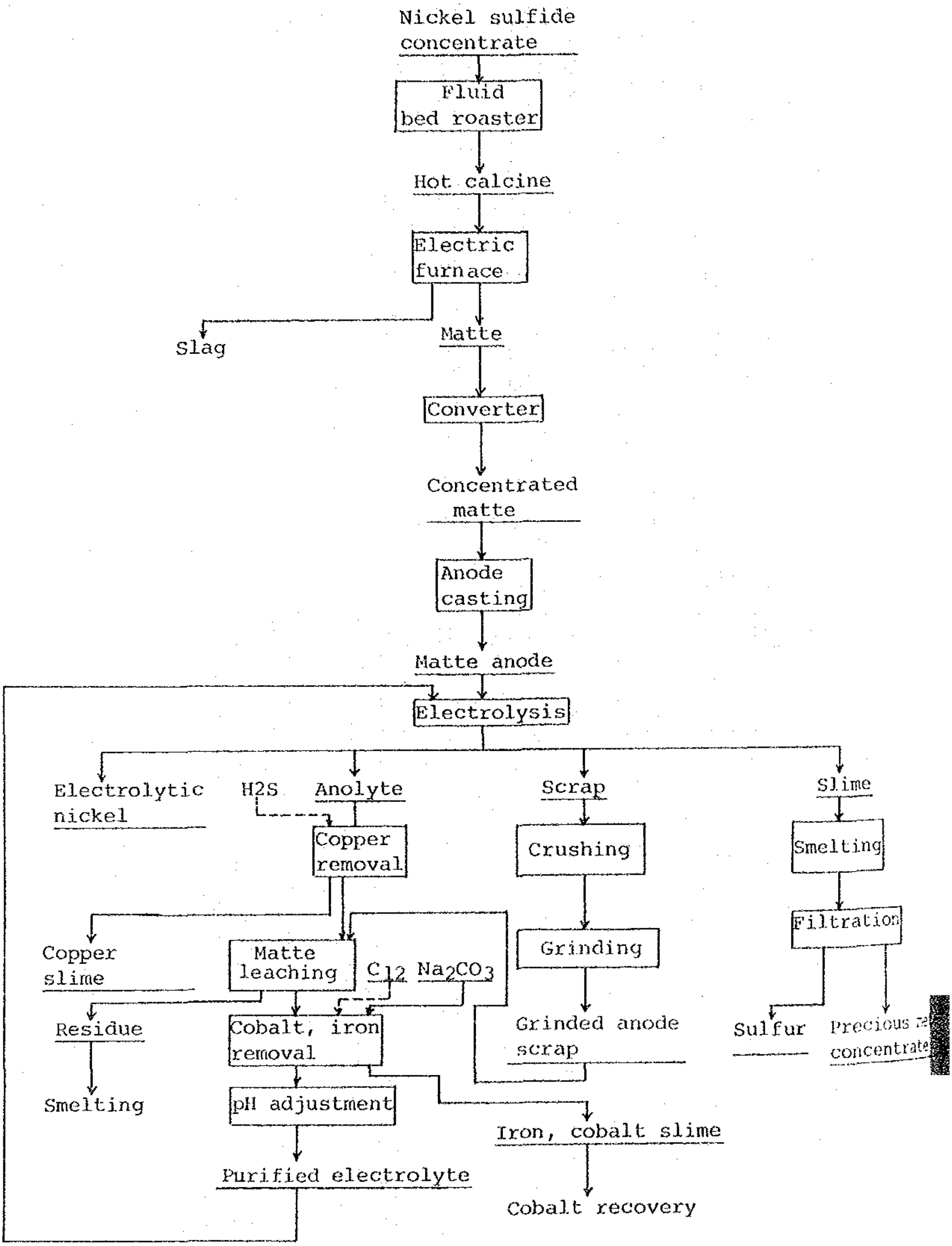
Company	Nation	Type	Specification									(%)	
			Ni	C	Si	Mn	P	S	Cr	Cu	Co	Fe	
Falcon	Canada	(Typical)	32 or 38	0.06	0.4		0.01	0.06		0.08	Nix0.025 max.		
SLN	New Caledonia	FN1	24 ∿ 30	0.03	0.030		0.016	0.030	0.030		Nix1/30 max.		
		FN3	22 ∿ 28	1.20∿1.80	0.50∿2.00		0.016	0.030	1.20∿1.80		"		
		FNC	22 ∿ 28	1.20∿1.80	0.50∿2.50		0.016	0.040	1.20∿1.80		"		
		FN4 max. (Typical)	22 ∿ 28	1.20∿1.90	1.00∿3.00		0.016	0.230	1.20∿1.80		"		
ANTAM	Indonesia	H.C.	20.0 min.	2.50 max.	3.00 max.	0.20 max.	0.030 max.	0.030 max.	2.5 max.	0.10 max.	Nix1/30 max.		
		L.C.	20.0 min.	0.020 max.	0.30 max.	0.10 max.	0.020 max.	0.030 max.	0.20 max.	0.08 max.	" max.		
INCO	Canada	Sinter 75	76					0.006		0.75	1.0	0.3	
		(Typical)	NiCo 77.63	0.005		0.0006	0.0005	0.01				0.38	
		(Typical)	NiCo 78.10	1.20		0.0008	0.000n	0.01		0.04		0.22	

Reference Table A-4-3 Producer Standards for the Main Intermediate Nickel Products

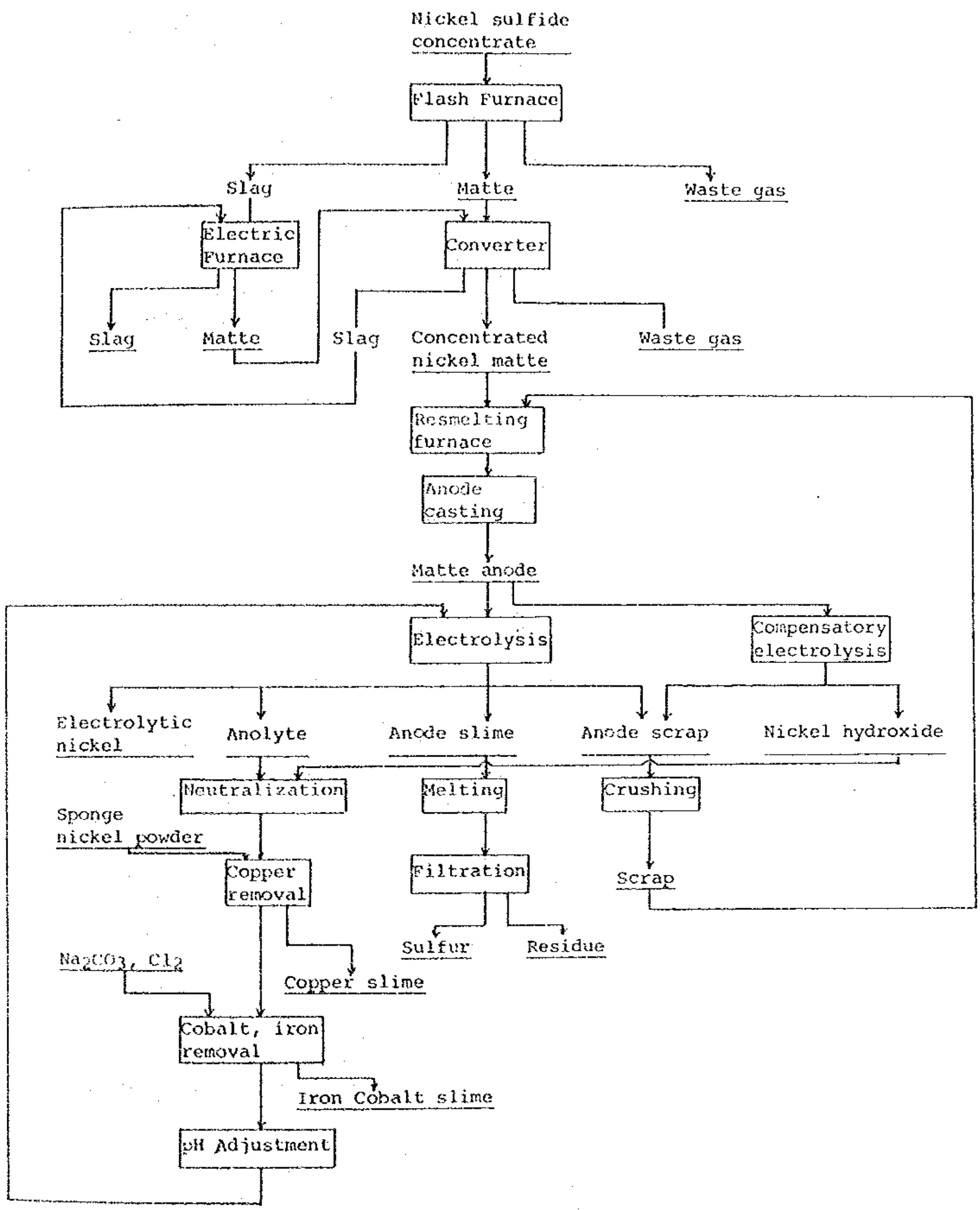
Type	Country	Plant	Specification				
Nickel matte			(Ni)	(CO)	(Fe)	(Cu)	(S)
(analysis examples)	Australia	WMC	72	0.7	0.8	6	20
	Botswana	BCL	40	0.5	-	40	Bal
	New Caledonia	SLN	75	1.5	2	-	20
	South Africa	RPM	42	0.5~0.6	-	26~28	20
	Indonesia	SOROAKO	78	1.0	0.5	0.1	20
Nickel-cobalt mixed sulfide	Philippines	Marinduque	25	12	2.6	1.5	25
(analysis examples)	Australia	Greenvale	37	15	0.8	0.7	34


Product
Company
Nickel Sulfide Ore
Floatation
Concentrate
Smelting
Matte
Slow cooling and matte separation
Matte anode
Electrolysis
(Hybinette electrolysis process)
Electrolytic nickel
INCO (Thompson) Shimura Sumitomo
Roasting
Reduction smelting
Metal anode
(Hybinette electrolysis process)
Electrolytic nickel
INCO (Port Colborne)
Falconbridge (Kristansand)
(Sumotomo)
Reduction roasting
Volatilization refining
(Carbonyl process)
Pellets, powder
Oxygen refining
Pressurized volatilization refining
(Carbonyl process)
Pellets powder
INCO (Coppercliff)
Roasting
Oxide sinter
INCO (")
Sulfuric acid leaching
Amine conversion
Hydrogen reduction
Briquettes
AMAX (Port Nickel)
Electrowinning
Electrotic nickel
Oulokumpu (Haruyaparta)
Hydrochloric acid leaching
solvent extraction
Hydrogen reduction (electrowinning)
Powder (Electro nickel)
Falconbridge (Kristansand)
Pressurized ammonia leaching
Pressure hydrogen reduction
(Sherritt process)
Briquettes powder
Sherritt Gordon (Fort Saskatchewan) WMC (Quefna)
Nickel oxide ore
Hydrochloric acid leaching
Solvent extraction
Electrowinning
Electrotic nickel
Le Nickel (Le Havre)
Smelting
Matte
Roasting
Charcoal reduction
Rondelle
Le Nickel (")
Oxide sinter
Nippon Nickel
Preheating
Reduction smelting
Refining
(Elchem process)
Ferro-nickel
Le Nickel (Doniambo), Morro de Nickel, Pacific Metals, Shimura, Nippon Mining, Sumitomo
Nickel oxide ore
Reduction
Ammonia leaching
Basic nickel carbonite
Roasting
(Nicaro process)
Calcine sinter
Nicaro, Freeport Queensland Nickel (Greenvale)
Sulfate dissolution
Electrowinning
Electrotic nickel
Serud (Czechoslovakia)
Ammonium Sulfate dissolution
Pressurized hydrogen reduction
Briquettes, powder
Marinduque (Philippines)
Roasting
Ferro-nickel
Larco (Greece)
Sulfurization
Roasting
Iron removal
Matte
Matte
I.N. Indonesia (Soroako)
Roasting
Oxide sinter
Tokyo Nickel

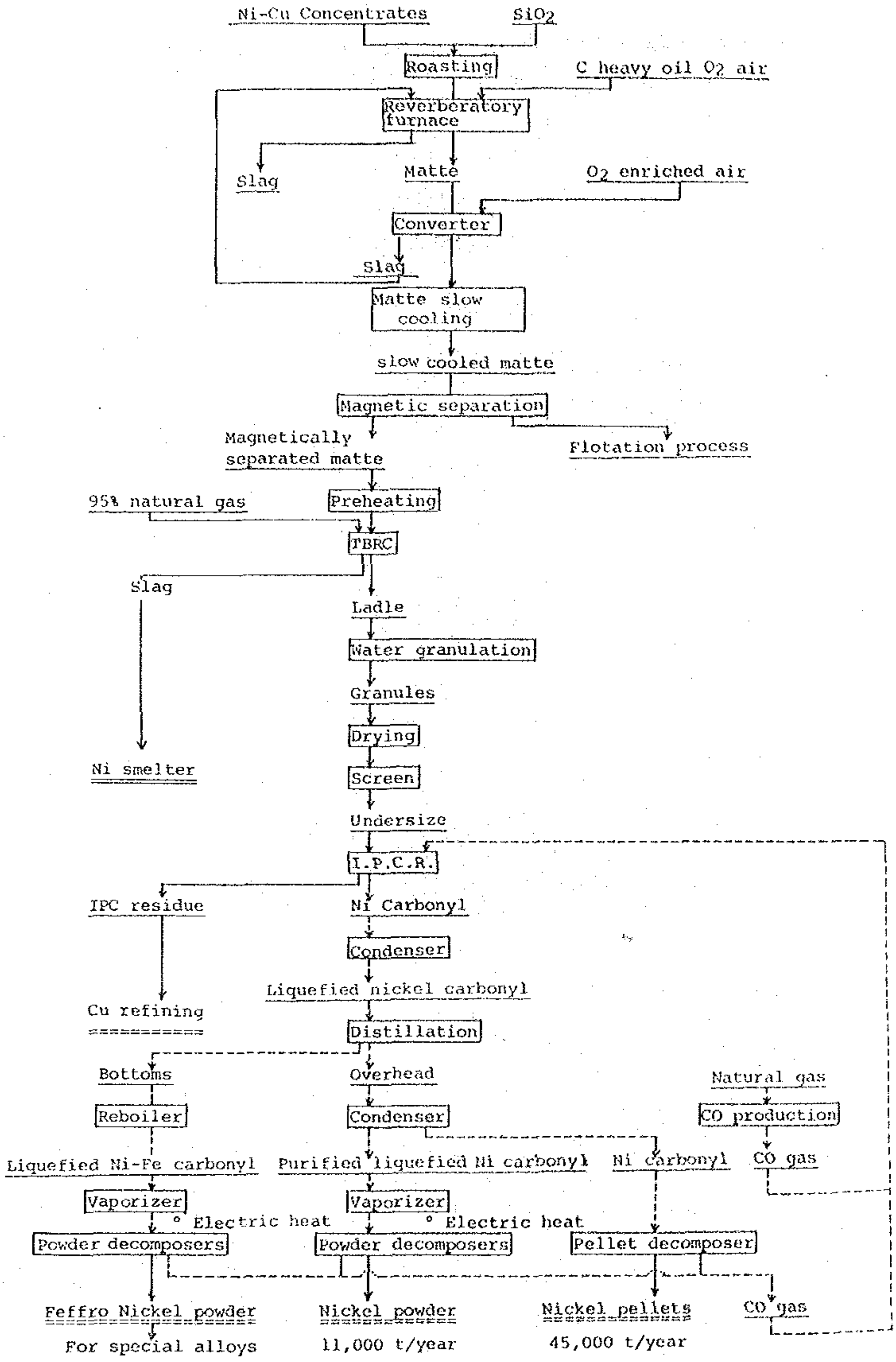
Reference Fig. A-2 Flow Chart for INCO's Thompson Plant



Reference Fig. A-3 Flow Chart for the WMC Flash Furnace Method and the Sumitomo Electrolytic Method

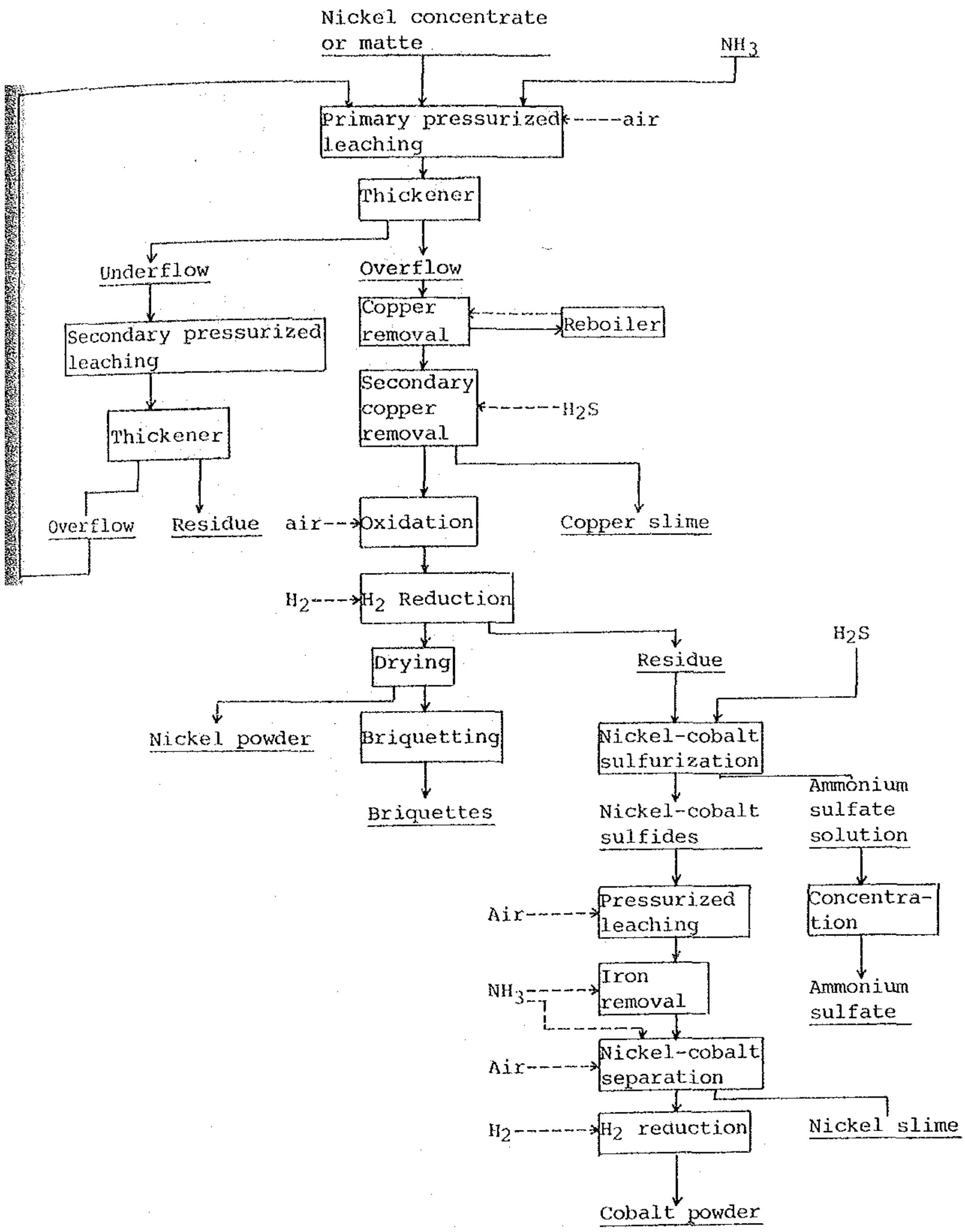


Reference Fig. A-4 Carbonyl Method

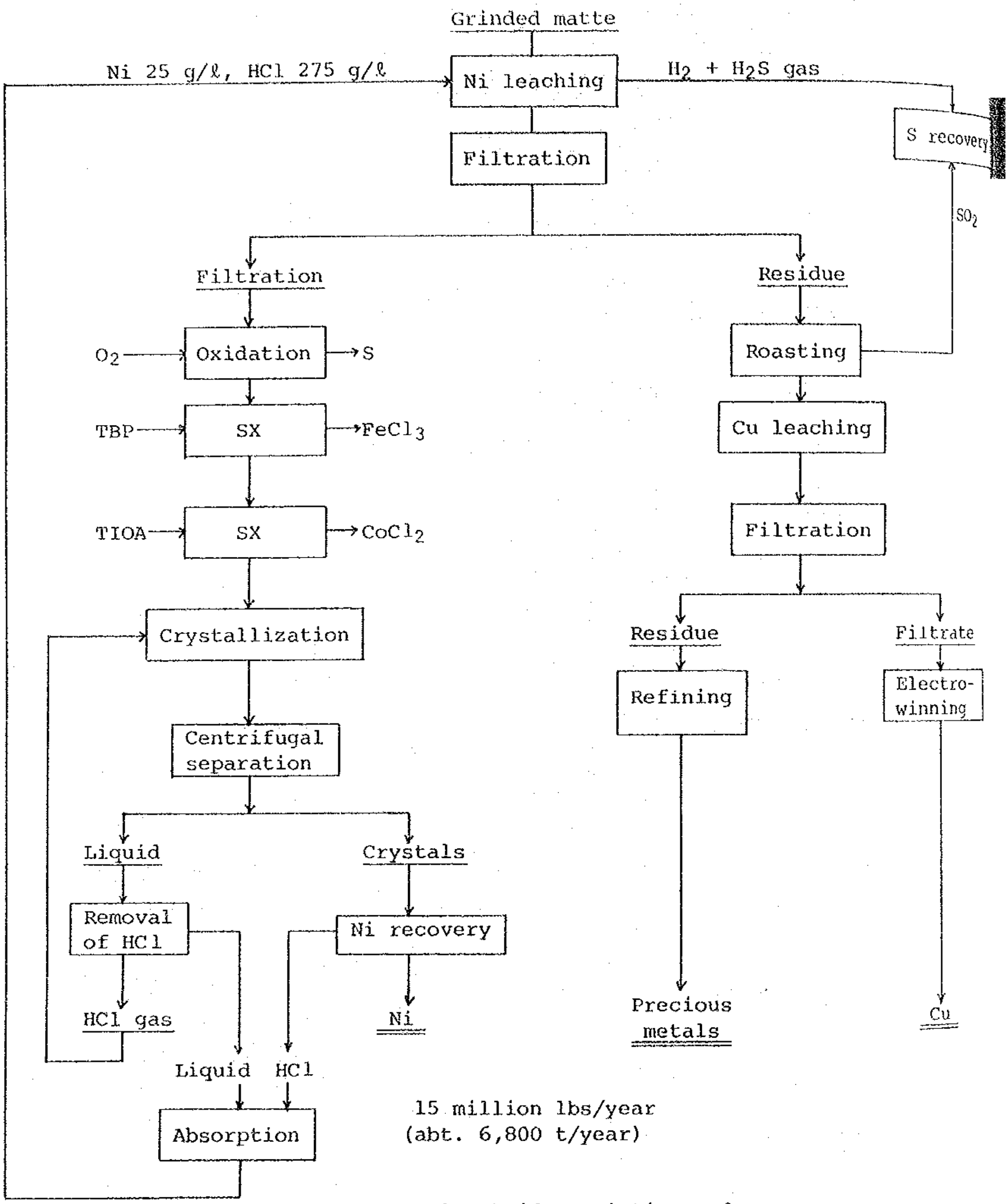


<INCO Copper Cliff Nickel Refinery flow sheet>

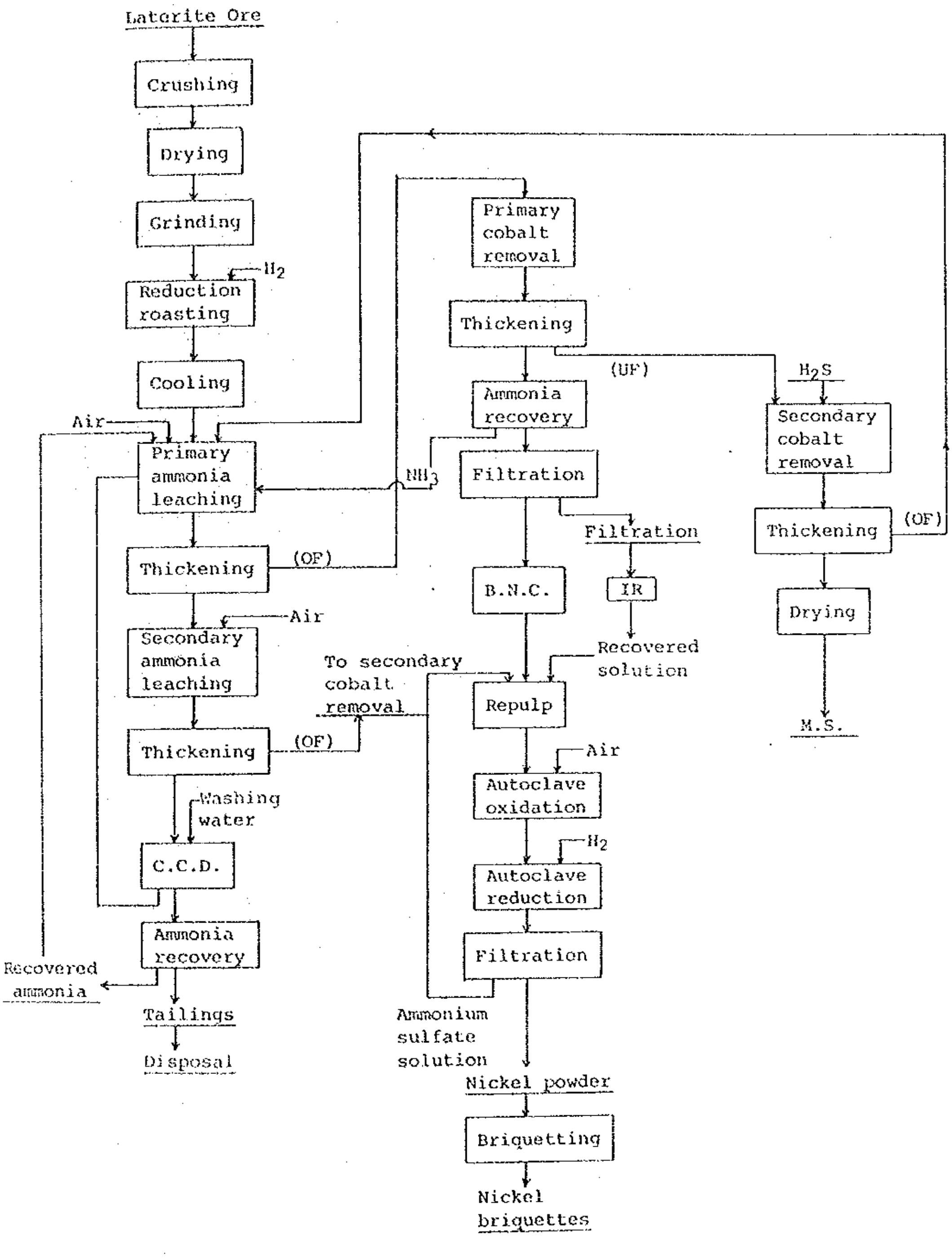
Reference Fig. A-5 Sherritt Gordon Process



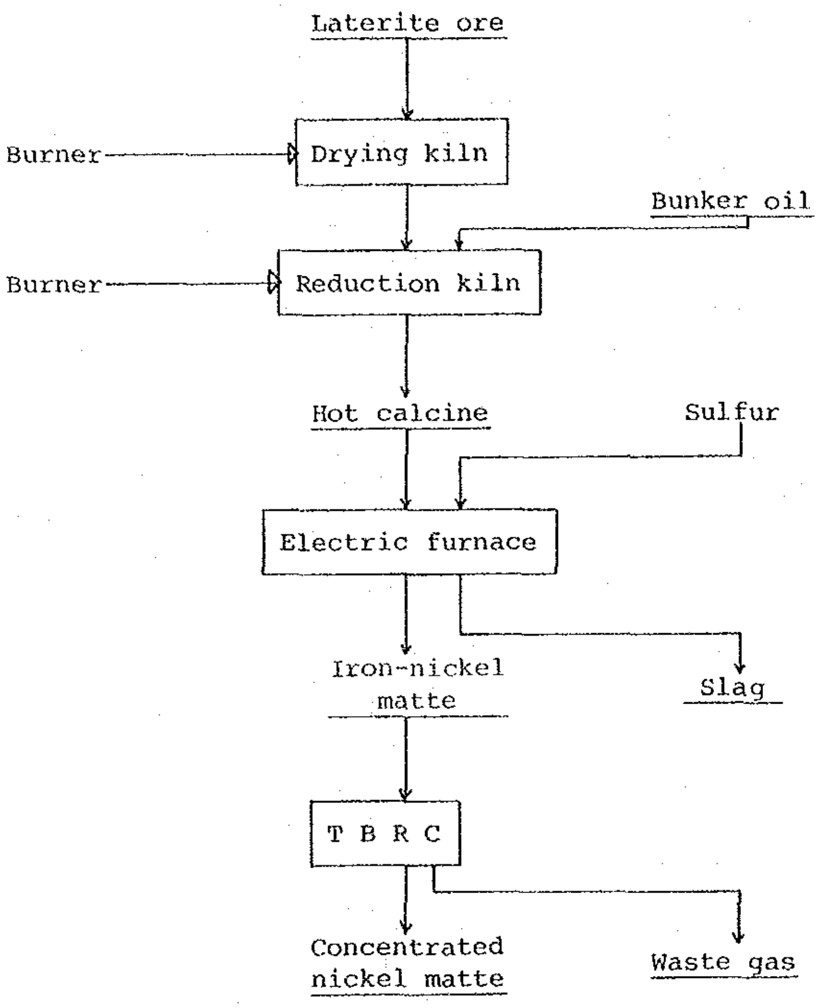
Reference Fig. A-6 Solvent Extraction Process



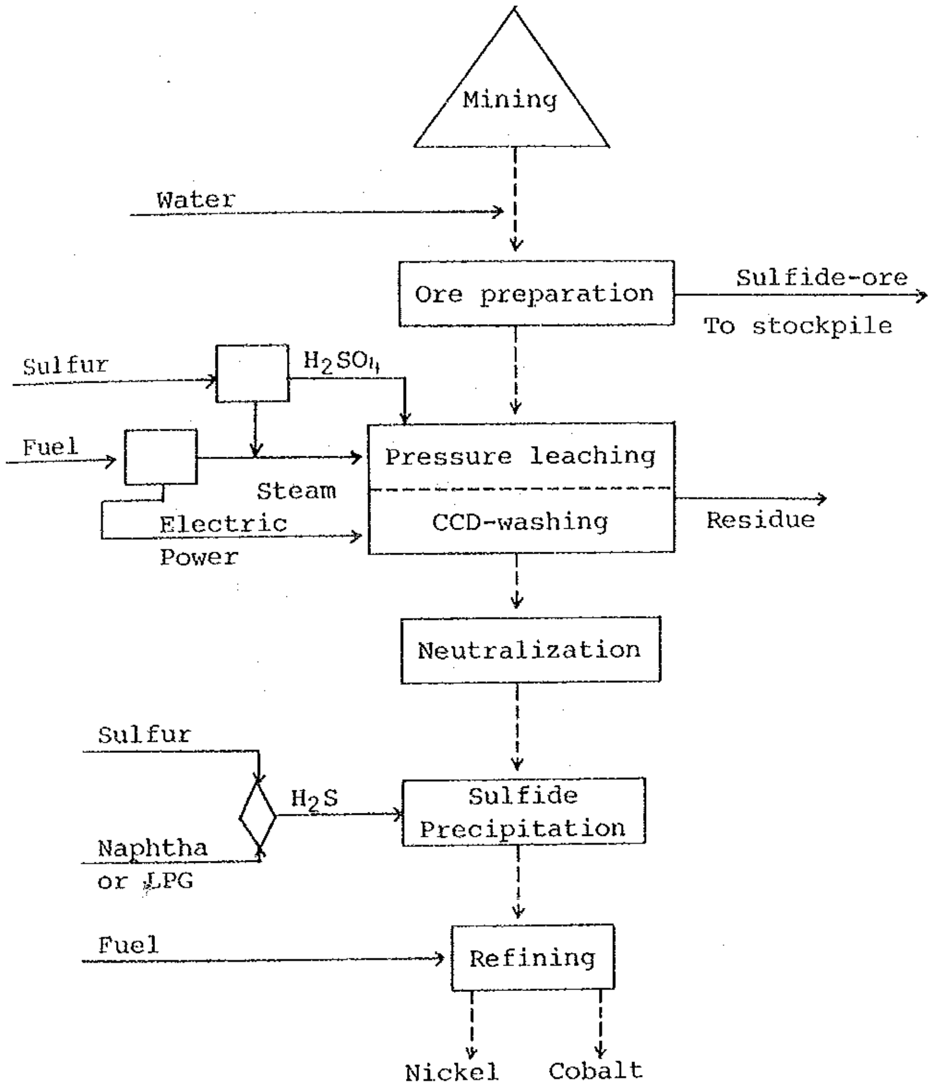
Reference Fig. A-7 Marinduque Corporation's Smelting Method (Surigao Smelter)



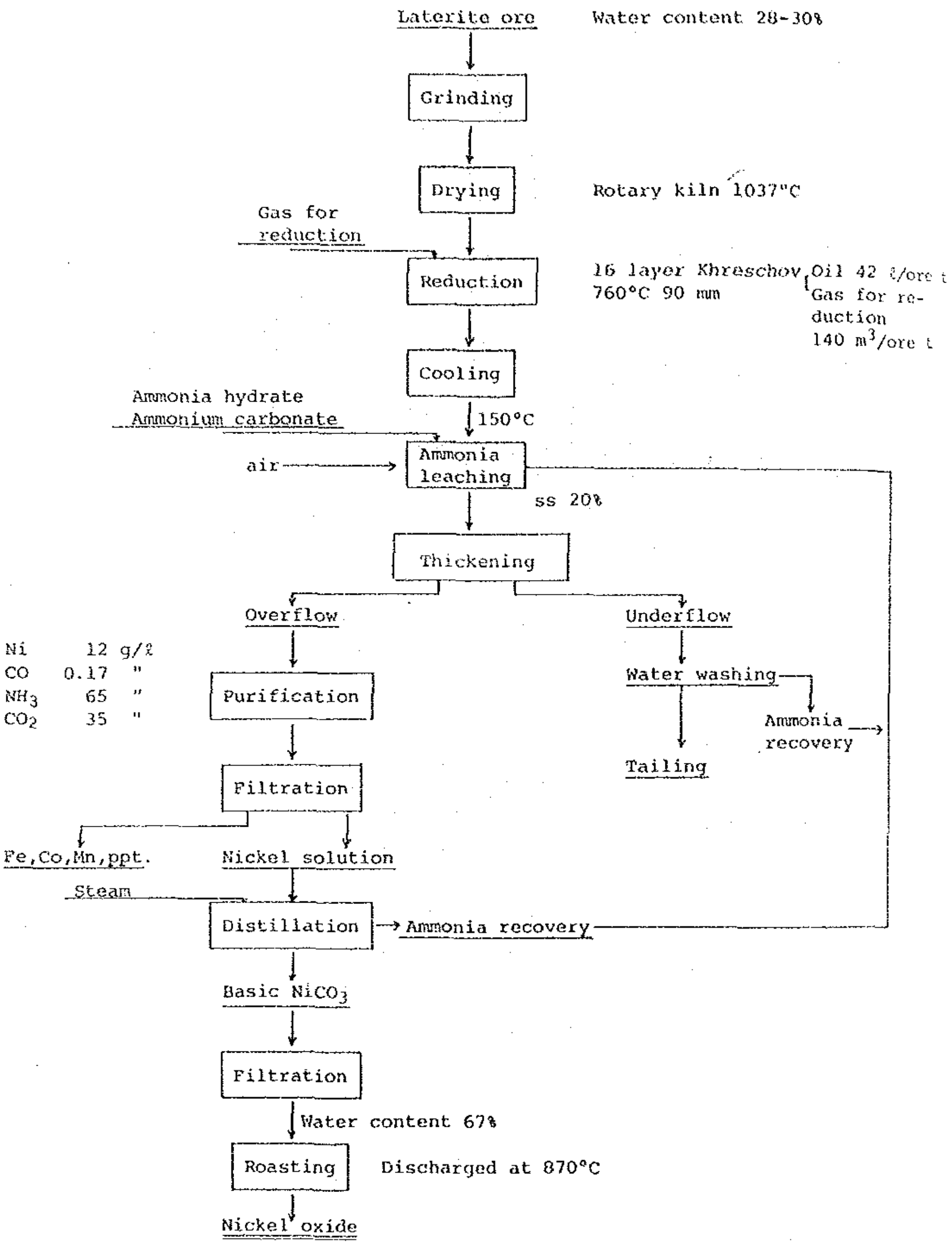
Reference Fig. A-8 Flowsheet for P.T. INCO's Soroaco Plant



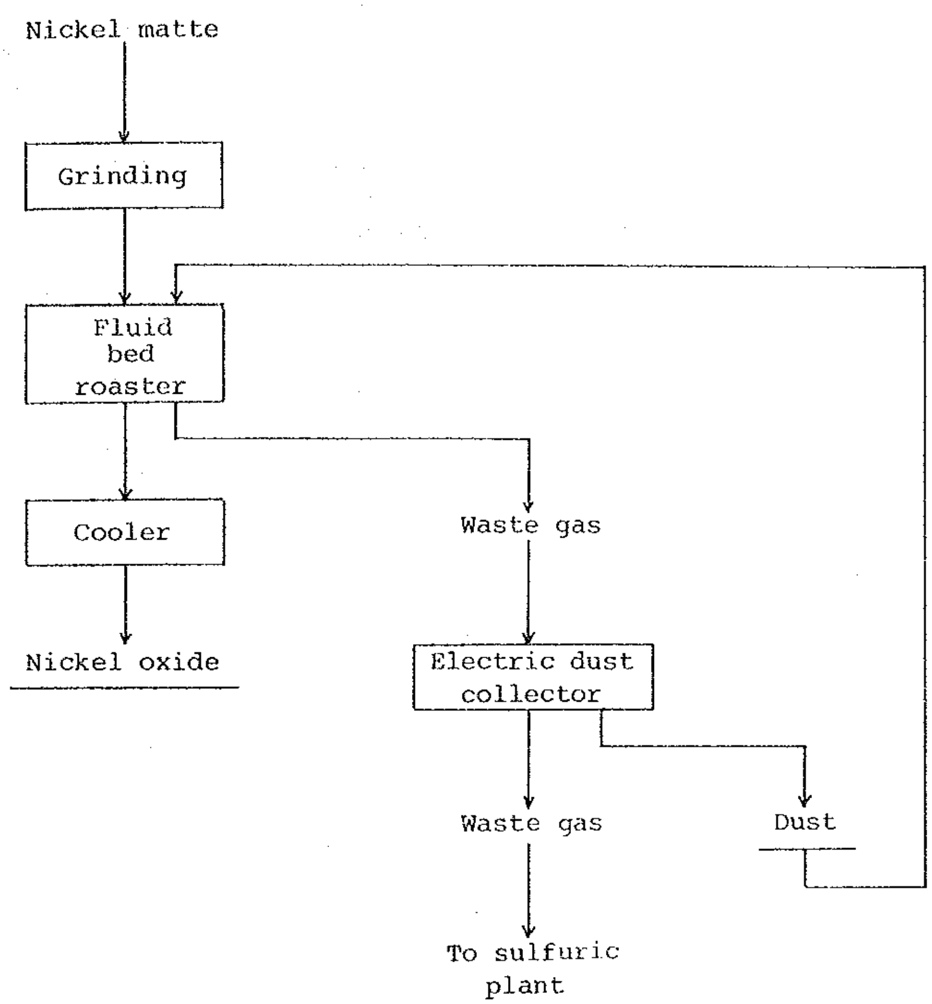
Reference Fig. A-9 Moa Bay Process



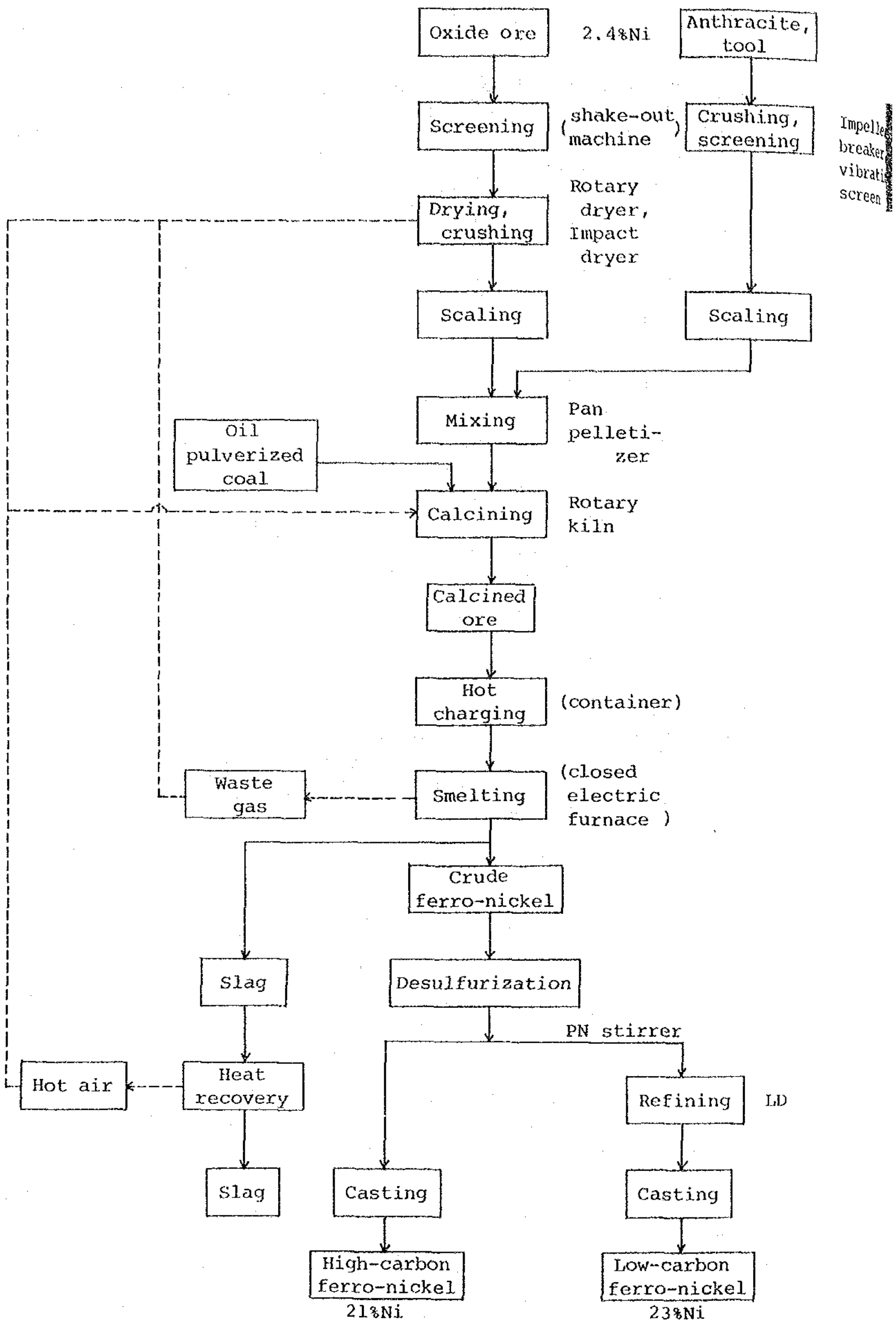
Reference Fig. A-10 Nicaro Process



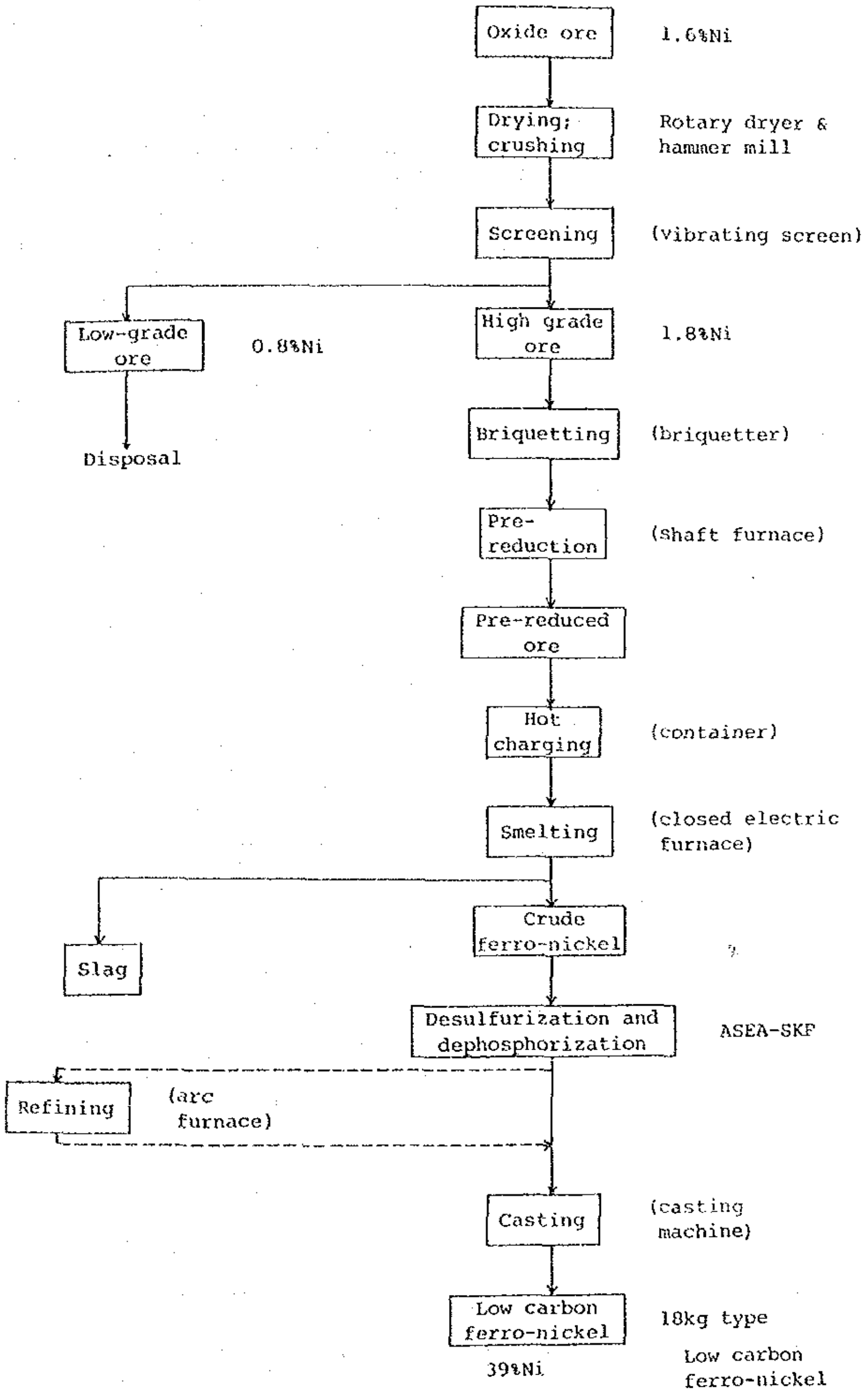
Reference Fig. A-11   Nickel Matte Roasting Process



Reference Fig. A-12 Kiln-Electric Furnace Process



Reference Fig. A-13 Shaft Furnace - Electric Furnace Process



B. GEOGRAPHIC DISTRIBUTION AND PRODUCTION TRENDS OF NICKEL ORES

I. Resources and Reserves

As Reference Table B-1 shows, the world's total nickel resources on land are estimated to be about 240 million tonnes (nickel content). Of this, the nickel reserves that can be recovered with current mining and ore processing technology are estimated to total about 69 million tonnes. Nickel is the second most common metal on earth, after iron, but because it is concentrated in the earth's core and mantle, it is not very common in the earth's crust.

On the other hand, the United States Geological Survey's data gives a figure of about 140 million tonnes for the amount of nickel resources with an average grade of about 1% as sulfide ores and laterite. Furthermore, it is thought that the amount of nickel resources will increase because nickel is expected to be recovered in future from manganese nodules found on the seabed.

Nickel resources can be classified into lateritic ores and sulfide ores. The former, which account for about 60% of nickel reserves, are mostly found in equatorial areas. In particular, high-grade laterite is mined in New Caledonia and Indonesia. Low-grade laterite is found in the Caribbean countries, the Philippines, Australia, and Africa. The rest, about 40%, the sulfide ores, are found mainly in Canada, the USSR, China, and Australia. However, when laterite resources and sulfide ore resources are compared, the ratio is about 80:20. This is because the unrecoverable resources include much low-grade laterite.

Of the currently estimated 69 million tonnes of nickel reserves, 19.9% are in New Caledonia, 13.4% in China, 11.5% in Canada, 10.7% in the USSR, 10.3% in Indonesia, 7.5% in the Philippines, and 7.4% in Australia. These 7 main countries account for 80.7% of the reserves. The uneven distribution of nickel resources is evident.

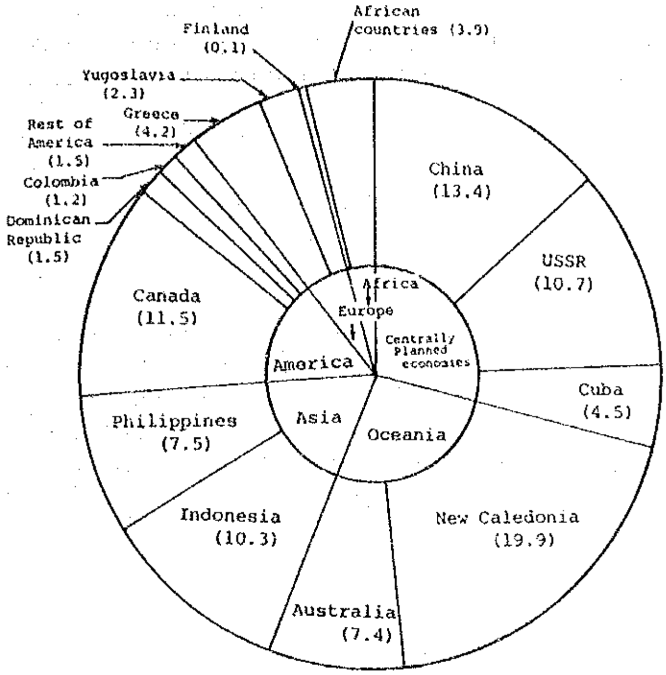
The following graph shows the regional and national proportions of nickel resources.

II. Reserves by Mine, and Mine Production by Nation

Reference Table B-2 shows the reserves of nickel in each mine. It lists the mines and deposits for which the quantity and grade of nickel ore are known. When the year in which the mine opened or is scheduled to open is known, this information is attached.

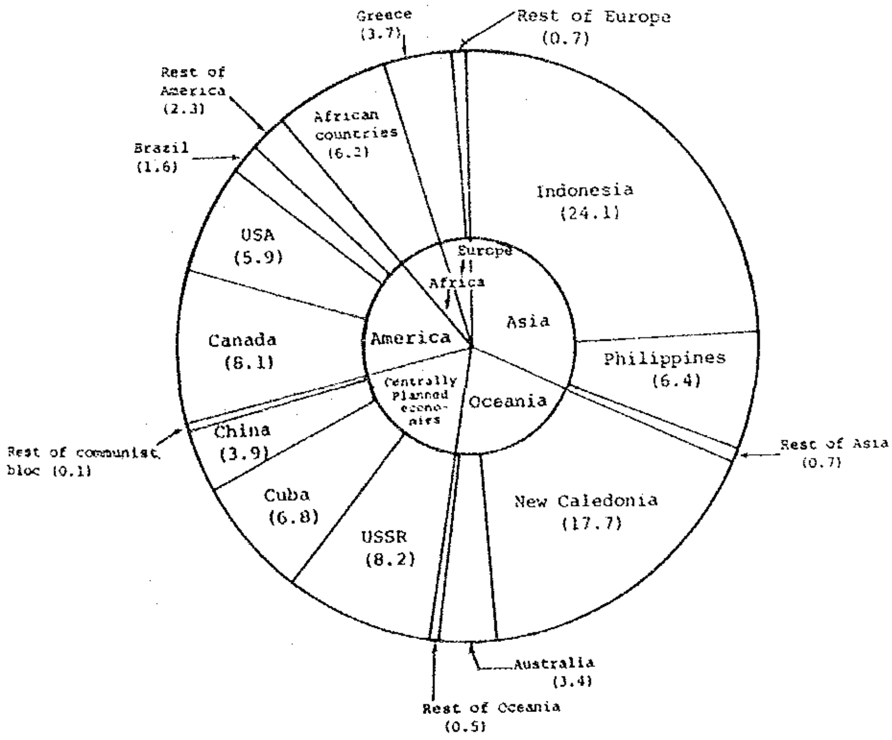
(1) Nickel Reserves

68,503,200 tonnes (Nickel content)



(2) Nickel Resources

236,338,000 tonnes (Nickel content)

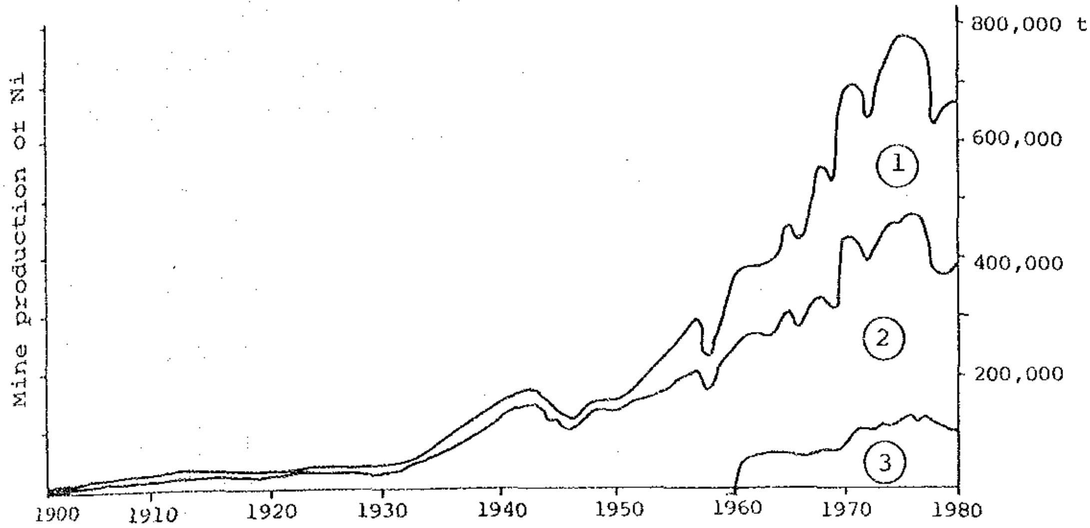


Reference Table B-3 shows the mine production by country. The seven major countries mentioned before that account for 80.7% of the amount of nickel reserves held an 85.4% share of production in 1970 and 77.6% in 1980.

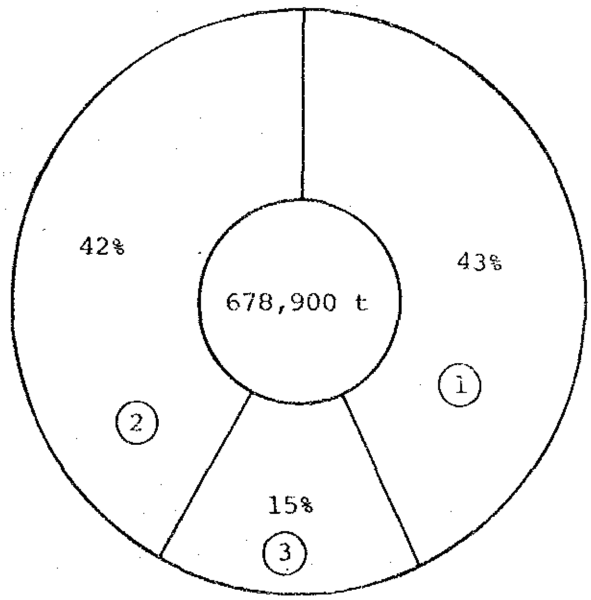
III. Production by Deposit Type

The main types of deposits from which nickel is being produced are: a. lateritic nickel deposits, b. sulfide nickel deposits in gabbroic rock, and c. sulfide nickel deposits in komatiite and tholeiite basalt. These three types of deposits account for over 99% of the world's nickel mine production. The following diagrams show the production shares of each deposit type.

(1) Movements in Nickel Production by Deposit Type



(2) 1979 Nickel Production by Deposit Type



1 Laterite Nickel

2 Sulfide nickel ore together with Gabbroic rock

3 Sulfide nickel ore together with komatiite or tholeiite basalt

Reference Table B-1 Nickel Resources and Reserves by Country

(1,000 tonnes)

	Resources	Recoverable reserves a)
Finland	122.1*	101.6*
Greece	8,810.0*	2,890.0*
Yugoslavia	1,644.0*	1,546.0*
(European subtotal)	10,576.1	4,537.6
Burma	1,152.8*	NA *
Indonesia	56,971.0	7,076.0
Philippines	15,126.0*	5,171.0
India	419.1*	0.0*
(Asian subtotal)	73,668.9	12,247.0*
(African subtotal)	14,648.9**	2,691.3**
USA	13,880.0	327.0
Brazil	3,719.0	417.0
Dominican Rep.	1,088.0	998.0
Guatemala	1,088.0	272.0
Canada	19,232.0	7,893.0
Puerto Rico	816.0	0.0
Venezuela	635.0	0.0
Colombia	1,361.0	816.0
Nicaragua	39.6*	0.0*
(American subtotal)	41,858.6	10,723.0
Australia	7,983.0	5,080.0
New Caledonia	41,731.0	13,608.0
Papua New Guinea	616.5*	0.0*
Solomon	520.0*	0.0*
(Oceania subtotal)	50,850.5	18,688.0
USSR	19,323.0	7,348.0
Albania	200.0*	0.0*
German Dem. Rep.	62.5*	0.0*
Cuba	15,966.0	3,084.0
China	9,184.3*	9,184.3*
(Centrally planned economies subtotal)	44,735.8	19,616.3
World total	236,338.0	68,503.2

Notes: a) The amount of nickel in the reserves recoverable by current mining and ore processing technology.

1) Due to error in calculating the conversion from pounds to tonnes and rounding off, the totals do not match.

Source: USBM, Mineral Facts & Problems, 1980
* Sumitomo Metal Mining's Mine Information System (MIS)
** OSBM and MIS

Reference Table B-2 Reserves by Mines

COUNTRY	MINE OR COMPANY	RANK	PRODUCT	TYPE	ORE RESERVE (1000T)	Co (%)	Ni (%)	Cu (%)	METAL Ni(T)	START OF OPERATION
ALBANIA	KUKES	A	Ni Co	L	20,000	0.060	1.000		200,000	
AUSTRALIA	AGNEW	A	Ni Co	O	35,000	0.100	2.200		770,000	July 1979
	BROLGA	C	Ni	L	29,000		1.000		290,000	
	CARNILYA HILL	B	Ni		500		4.200		21,000	
	CARR BOYDROCKS	D	Cu Ni	O	558		1.520	0.49	8,482	
	CLAUDE HILLS	C	Ni	L	91,000		1.161		1,056,510	
	DAISY BATE	C	Ni	L	56,000	0.087	0.900		504,000	
	DIGGERS ROCK	B	Ni	O	3,962		1.520		60,222	
	DIGGERS ROCK SOUTH	B	Ni	O	3,325		1.390		46,218	
	DORDIE	C	Ni	O	200		1.200		2,400	
	E.SCOTIA	C	Ni	O	186		1.600		2,976	
	GREEN VALE	A	Ni Co	L	26,691	0.110	1.280		341,645	January 1975
	KAMBALDA	A	Ni	O(K)	24,000		3.300		792,000	1967
	MIRIAM	C	Ni		600		1.200		7,200	
	MT. CLIFFORD	C	Ni	O	1,200		1.500		18,000	
	MT. KIETH -(A)	C	Ni	O	270,000		0.600		1,620,000	
	MT. SHOLL	C	Cu Ni	O	2,000		0.810	1.030	16,200	
	MT. WINDARRA	A	Cu Ni	O	7,000		1.600		112,000	September 1974
	NEPEAN	A	Ni	O	263		4.000		10,520	July 1970
	ORA BANDA	C	Ni	L	80,000		1.300		1,040,000	
	PEACOXSFIELD	C	Ni	L	6,000		0.700		42,000	
	PIONEER	C	Ni	O	300		1.210	0.170	3,630	
	PYKES HILL	C	Ni	L	12,000		1.200		144,000	
	SHIRLOCK BAY	C	Ni	O	75,000		0.500	0.100	375,000	
	SIR SAMUEL(6MILES)	C	Ni	O	100,000		0.600		600,000	
	SOUTH WINDARRA	A	Cu Ni	O	2,500		1.000		25,000	NA
	TROUGH WELL	C	Ni	O	170		2.000		3,400	
	WANAWAY	C	Ni	O	2,200		2.200		48,400	
	WEEBO WELL	C	Ni	O	10,000		1.000		100,000	
	WIDGIEMULTHA	C	Ni Cu	O	1,540		2.200	0.200	33,880	
	WIDGIEMULTHA NO.3	C	Ni Cu	O	900		1.230	0.100	11,070	
BOTSWANA	B.C.L.	A	Cu Ni Co	O	37,890		0.96	1.05	363,744	1974
	SELEBI NORTH	C	Cu Ni	O	1,905		0.860	0.970	16,383	
BRAZIL	AMERICANA DO	C	Ni Cu	O	2,000		(1.20)← Ni+Co			
	BARRO ALTO	B	Ni	L	42,000		1.900		798,000	
	IPANEMA SANTO	A	Ni	L	5,000		1.500		75,000	NA
	MORRO DO NIQUEL	A	Ni	L	4,000		1.800		72,000	1962
	NIQUELANDIA	C	Ni		18,000		1.450		261,000	
	SAN JOSE DO TOCANTING	B	Ni	L	4,000		2.000		80,000	
	SANJOAO DO PANCAS	C	Ni Co	L	20,000	0.020	2,660		532,000	
BURMA	MWETAUNG NO.4	C	Ni	L	30,000		1.100		330,000	
	MWETAUNG NO.6	C	Ni	L	80,000		1.000		800,000	
	TAGAUNGTAUNG	C	Ni	L	1,300		1.750		22,750	

Reference Table B-2 (cont'd.)

COUNTRY	MINE OR COMPANY	RANK	PRODUCT	TYPE	ORE RESERVE (1000T)	Co (%)	Ni (%)	Cu (%)	METAL Ni(T)	START OF OPERATION
BURUNDI	BUHINDA	C	Ni Co Cu	O	73,000	0.100	1.600	0.300	1,168,000	
	MOSONGATI	C	Ni	L	200,000		1.500		3,000,000	1985
	NYABIKERE	C	Ni	L	45,000		1.300		585,000	
	WAGA NYABIRE	C	Ni	L	35,000		1.300		455,000	
CANADA	ACHAK	C	Ni	O	1,364		0.600		8,184	
	AXIS LAKE	C	Cu Ni Co	O	3,409	0.150	0.500	0.280	17,045	
	BASIC	C	Ni	O	18,144		0.200		36,288	
	BEAUVALE	C	Cu Ni	O	554		1.030	0.350	5,706	
	BLUE LAKE	C	Cu Ni	O	459		0.500	0.850	2,295	
	BOWDEN LAKE	C	Ni	O	72,560		0.600		435,360	
	BUCHO LAKE	C	Ni	O	27,210		0.780	0.040	212,238	
	CANALASK	C	Cu Ni	O	455		1.500	0.040	6,825	
	CAPE SMITH-UNGAVA	C	Cu Ni	O	15,270		1.92	0.75	293,184	
	CARMAN BAY	C	Ni	O	672,660		0.200		1,345,320	
	CAT LAKE	C	Cu Ni	O	586		0.240	0.580	1,406	
	CHANCE LAKE	C	Cu Ni	O	651		0.890	0.660	5,794	
	CHRYSLER NO.2	C	Cu Ni	O	526		0.480	1.790	2,525	
	CLEARWATER	C	Cu Ni	O	14,512		0.300	0.310	43,536	
	DIADEM	C	Cu Ni	O	455		0.100	0.500	455	
	DISCOVERY	C	Ni	O	1,814		0.900		16,326	
	DONALDSON	C	Ni Cu	O	10,920		3.110	0.710	339,612	
	DUMONT	C	Ni	O	14,059		0.646		90,821	
	E & L	C	Cu Ni	O	2,999		0.800	0.620	23,992	
	EAGLE.	C	Cu Ni	O	586		0.240	0.580	1,406	
	ELMHIRST	C	Cu Ni	O	850		0.410	0.420	3,485	
	ERICKSON NO.1	C	Ni Cu	O	520		0.320	1.120	1,664	
	EXPO UNGAVA	C	Cu Ni	O	3,688		0.960	1.040	35,405	
	FALCONBRIDGE-SUDBURY	A	Cu Ni	O	71.815		1.490	0.930	1,070,044	1887
	GAGNE	C	Cu Ni	O	268		0.880	0.440	2,358	
	GR-34	C	Ni	O	6,640		1.330		88,312	
	GRAHAM	C	Cu Ni	O	2,268		0.630	0.38	14,288	
	GREAT LAKE NICKEL	C	Cu Ni	O	41,450		0.183	0.344	75,854	
	HAINAUT	D	Cu Ni	O	1,207		0.700	0.700	8,449	
	HAMBONE	C	Ni	O	3,272		0.810		26,503	
	HAWK JUNCTION	C	Cu Ni	O	1,814		0.600	0.400	10,884	
	INCO	A	Ni Cu	O	446,342		1.494	0.902	6,668,349	
	IVY	C	Cu Ni	O	3,874		0.300	0.081	11,622	
	JACOBUS	C	Ni Cu	O	852		0.410	0.420	3,493	
	JUNEAU LAKE	C	Cu Ni	O	2,000		0.870	0.590	17,400	
	KAPKICHI LK. J	C	Cu Ni	O	33,633		0.210	0.400	40,360	
	KAPKICHI LK. G	C	Cu Ni	O	6,818		0.120	0.410	8,182	
	KEEVIL	C	Cu Ni	O	2,273		0.600	1.000	13,638	
	KELLY LAKE	C	Cu Ni	O	1,246		0.670	0.730	8,348	
	KEN LAKE	D	U Ni	[illegible]	1,922		1.210		23,256	1983

Reference Table B-2 (cont'd.)

COUNTRY	MINE OR COMPANY	RANK	PRODUCT	TYPE	ORE RESERVE (1000T)	Co	(%) Ni	Cu	METAL Ni(T)	START OF OPERATION
CANADA	LAC DES ISLES	C	Pg Pt Ni	O	9,072		NA		NA	
	LAKEMOUNT	C	Cu Ni	O	1,818		0.600	0.400	10,908	
	LANGMUIR	D	Ni	O(K)	489		1.300		6,357	
	LESLIE No.2	C	Cu Ni	O	694		0.830	1.560	5,760	
	LETT LAKE	C	Cu Ni		227		0.450	0.450	1,022	
	MACKENZIE	C	Cu Ni Co	O	972	0.090	0.920	0.270	8,942	
	MASKWA	C	Cu Ni	O	816		1.340	0.230	10,934	
	MASTADON	C	Ni	O	354,715		0.241		854,863	
	MC WATTERS	C	Ni	O	585		1.040		6,084	
	MIDRIM	C	Ni Cu	O	388		0.460	0.700	1,785	
	MISTERY LAKE	C	Ni		227,250		0.600		1,363,500	
	MOAK	C	Ni	O	45,360		0.710		322,056	
	MOGADOR	C	Cu Ni	O	318		0.820	0.680	2,608	
	MONT CALM	C	Cu Ni	O	4,090		1.440	0.680	58,896	
	NEMEIBEN LAKE	C	Cu Ni	O	15,815		0.360	0.206	56,934	
	NICOBI LAKE	C	Cu Ni	O	1,641		0.467	0.255	7,663	
	NICOPOR	C	Cu Ni	O	341		0.440	0.190	1,500	
	NORPAX	C	Cu Ni	O	918		1.200	0.500	11,016	
	OLD NICK	C	Ni	O	90,720		0.220		199,584	
	ORE FAULT	C	Cu Ni	O	1,487		0.480	0.200	7,138	
	POPULUS LAKE	C	Cu Ni	O	2,974		NA		NA	
	RENNER	C	Cu Ni	O	2,625		0.290	0.260	7,613	
	RETTY LAKE	C	Cu Ni	O	1,364		0.550	0.950	7,502	
	SCHEFFERVILLE	C	Cu Ni	O	1,360		NA		NA	
	SHAKESPEARE	C	Cu Ni	O	2,727		0.340	0.400	9,272	
	ST FABIEN-SOUTH	C	Cu Ni	O	869		0.150	1.520	1,304	
	ST.FABIEN-NORTH	C	Ni	O	354		0.910		3,221	
	ST.STEPHEN	C	Ni Cu	O	711		1.070	0.590	7,608	
	TEMAGAMI	D	Cu Ni	O	699		0.470	1.040	3,285	
	TEXMONT	D	Ni	O	2,894		0.925		26,770	1971-
	THIERRY	D	Cu Ni	O	13,605		0.200	1.630	27,210	
	THOMPSON	D	Cu Ni	O(K)	22,680		NA		NA	1983
	VISTA	C	Cu Ni	O	215		0.870	0.420	1,871	
	ZULAPA	C	Cu Ni	O	1,527		0.550	0.480	8,399	
CHINA	JIN CHUAN	A	Cu Ni Co	O	500,000		1.060	0.670	5,300,000	
HAINAN	YIN CHUAN	A	Cu Ni Co		313,609		1.240	1.200	3,888,752	
COLOMBIA	CERRO MATOSO	A	Ni	L	33,500		2.159		723,265	July 1982
CUBA	CUBAN-LOW GRADE	C	Ni	L	1,600,000		0.800		12800,000	
	MAYARI	C	Ni Co	L	100,000	0.100	1.300		1,300,000	
	MOA BAY	A	Ni	L	50,000		1.450		725,000	November 1959
	NICARO	A	Ni	L	300,000		1.350		4,050,000	1944
	PINAR DEL RIO	A	Ni	L	24,000		1.300		312,000	
DOMINICAN REP.	BONAO	D	Ni	L	59,875		1.640		981,950	1972-1982
ETHIOPIA	ADORA	C	Ni	L	47,000		1.000		470,000	

Reference Table B-2 (cont'd.)

COUNTRY	MINE OR COMPANY	RANK	PRODUCT	TYPE	ORE RESERVE (1000T)	(%) Co	Ni	Cu	METAL Ni (T)	START OF OPERATION
FINLAND	HITURA	A	Cu Ni	V	10,000		0.500		50,000	1969
	KOTALAHTI	A	Cu Ni Co	V	4,300		0.700		30,100	1959
	OUTOKUMPU	A	Cu Zn Ni	V	11,000	0.240	0.120	3.800	13,200	1913
	STORMI	A	Cu Ni Co	V	6,600	0.026	0.440	0.71	29,040	1975
GERMANY, FR	FRANKENSTEIN	C	Ni	L	2,500		2.500		62,500	
GREECE	ATALANTI-LARYMNA	A	Ni	L	115,000		1.400		1,610,000	
	EUBOEA	A	Ni		600,000		1.200		7,200,000	
GUATEMALA	BUENA VISTA	C	Ni	L	43,000		1.790		769,700	
	CHILIS	C	Ni	L	9,000		1.700		153,000	
	LAKE IZABEL	D	Ni	L	50,000		1.800		900,000	1978
	RIO NEGRO	C	Ni Co	L	40,000	0.040	1.250		500,000	
GUYANA	BLUE MOUNTAIN	C	Ni	L	15,000		1.000		150,000	
INDIA	KALLAPANI	C	Ni	L	65,000		0.500		325,000	
	KANSA	C	Ni		15,000		NA		NA	
	SIMILIPAL	C	Ni		9,700		0.970		94,090	
	SUKIN DA	C	Ni		38,000		NA		NA	
INDONESIA	DANAWAN	C	Ni	L	7,450		0.550		40,975	
	GAG	B	Ni	L	262,241		1.520		3,986,063	
	GEBE	A	Ni	L	80,740		1.67		135,170	
	HALMAHERA	C	Ni	L	173,176		1.180		2,043,477	
	PALAIHARI	C	Ni	L	12,500		NA		NA	
	POMALAA	A	Ni	L	40,000		1.570		628,000	1976
	SEBOEKOE	C	Ni	L	86,610		NA		NA	
	SOROAKO	A	Ni	L	172,368		0.800		1,378,944	1977
	SUNGEIDUWA	C	Ni	L	49,050		NA		NA	
	SWANGI	C	Ni	L	1,840		0.550		10,120	
	WAIGEO	C	Ni Co	L	63,140	0.160	1.410		890,274	
MADAGASCAR	MANAKARA	C	Ni	L	30,000		1.000		300,000	
NEW CALEDONIA	BOGATA	C	Ni	L	50,000		1.600		800,000	
	G.I.A.	C	Ni		400,000		1.370		5,480,000	
	ILE ART	C	Ni Co	L	13,000		NA		NA	
	MONEO	A	Ni	L	7,300		2.200		160,000	
	NAKETY	A	Ni	L	14,075		NA		NA	
	POUM	C	Ni Co	L	39,000	0.100	2.400		936,000	
	POUM-B.R.G.M-G	C	Ni Co	L	35,000		2.150		752,500	
	POUM-B.R.G.M-L	C	Ni Co	L	41,000		1.340		549,400	
	POUM-S.M.C.	C	Ni Co	L	42,600		NA		NA	
	TIEBAGHI-G	C	Ni Co	L	13,250		2.900		384,250	
	TIEBAGHI-L	C	Ni Co	L	17,110		1.200		205,320	
NICARAGUA	ROSITA-NICKEL	C	Ni	O	4,600		0.860		39,560	
PAPUA-NEW GUINEA	RAMU	C	Ni Co	L	41,100	0.127	1.500		616,500	
PHILIPPINES	AJO	C	Ni	L	165,000		1.250		2,062,500	
	LINAPACAN ISLAND	C	Ni	L	10,000		0.700		70,000	

Reference Table B-2 (cont'd.)

COUNTRY	MINE OR COMPANY	RANK	PRODUCT	TYPE	ORE RESERVE (1000T)	(%) Co	(%) Ni	(%) Cu	METAL Ni(T)	START OF OPERATION
PHILIPPINES	HOMONHON ISLAND	C	Ni	L	8,230		0.800		65,840	
	INFANTA	D	Ni	L	7,500		2.040		153,000	
	IPILAN	C	Ni		6,149		1.750		107,608	
	ISABELA NICKEL	C	Ni		20,000		1.700		340,000	
	MAKAMBAL	C	Ni	L	90,719		1.000		907,190	
	MANICANI ISLAND	C	Ni	L	58,000		0.800		464,000	
	MAYDOLONG	C	Ni	L	7,233		1.800		130,194	
	MIDWAY	C	Ni	L	5,000		0.700		35,000	
	OLYMPIC	C	Ni Co	L	6,680	0.040	2.130		142,284	
	PALAWAN	C	Ni		10,795		1.600		172,720	
	PUJADE	C	Ni	L	220,000		1.190		2,618,000	
	PULOT	C	Ni Co	L	2,242	0.050	2.070		46,409	
	RIO TUBA	A	Ni	L	14,000		2.300		322,000	1974
	SABLAYAN	C	Ni	L	49,000		0.940		460,600	
	SORIANO	C	Ni	L	204,100		1.350		2,755,350	
	STA.MONICA	C	Ni	L	1,752		1.880		32,938	
	SURIGAO NONOC	A	Ni Co	L	67,118	0.100	1.230		825,551	1974
	SURIGAO-MINDANAO	C	Ni Co	L	387,712	0.090	0.650		2,520,128	
	TRIDENT	C	Ni Co	L	21,967		2.000		439,340	
	ZAMBALES	C	Ni	L	27,300		1.670		455,910	
PUERTO RICO	MAYAGUEZ	C	Ni Co	L	90,500	0.090	0.600		543,000	
SOUTH AFRICA	PILANSBURG	C	Cu Ni	O	113		3.800	0.730	4,292	
SOLOMON	SANTA IZABEL	C	Ni		40,000		1.300		520,000	
USA	BRADY GRACIER	C	Cu Ni	O	163,296		0.530		865,496	
	ELY	C	Cu Ni	O	248,000			0.460	1,140,800	
	GASQUET MOUNTAIN	C	Ni Co	L	21,401	0.070	0.750		160,508	
	MADISON	B	Cu Ni Co		4,000	0.250	0.300		12,000	
	MINNAMAX	C	Cu Ni	O	4,400,000		0.150	0.500	6,600,000	
	NICKEL MIN	D	Ni	L	28,395		1.050		298,148	1954-1982
	SNIPE BAY	C	Ni	O	247		0.250	0.250	618	
	STILLWATER	C	Cu Ni Pt	O	136,957		NA		NA	
	STONE CORRAL	C	Ni Co	L	4,900	0.050	1.020		49,980	
	YACOBI LSC.	C	Ni Cu	O	4,300		0.30	0.16	12,600	
USSR	KHALILOVO	A	Ni	L	4,000		1.500		60,000	1976
UPPER VOLTA	BONGA	C	Ni Co	L	50,000	0.200	1.500		750,000	
VENEZUELA	LOMA DE HIERRO	C	Ni	L	45,900		1.180		541,620	
YUGOSLAVIA	GOLESH MOUNTAIN	C	Ni	L	7,000		1.400		98,000	
	RAZANOVO	A	Ni Co	L	134,000	0.006	0.900		1,206,000	1979
	STARE CIKATOVE	B	Ni		25,000		1.360		340,000	
ZIMBABWE	EMPRESS	A	Cu Ni	O	8,627		NA	NA	NA	
	EPOCH	A	Ni	O	5,320		0.630		33,516	1976
	HUNTERS ROAD	C	Ni	O	60,000		1.000		600,000	
	MADZIWA	A	Cu Ni	O	2,840		0.610	0.250	17,324	1969
	SHANGANI	A	Ni Cu Co	O	15,340		0.610		93,574	October 1975

Reference Table B-2 (cont'd.)

COUNTRY	MINE OR COMPANY	RANK	PRODUCT	TYPE	ORE RESERVE (1000T)	Co (%)	Ni (%)	Cu (%)	METAL Ni(T)	STATE OF OPERATION
ZIMBABWE	TROJAN	A	Ni	O(K)	13,940		0.690		96,186	1968
	UMTALI	C	Cu Ni	O	3,628		1.500	0.750	54,420	

Rank
A: Working Mine
B: Planned Mine
C: Potential Mine
D: Inactive Mine

Type
L: Laterite Ni
O: Orthomagmatic Deposit (associated with Gabbroic Rock)
O(K): " " (" " Komatiite, Tholeiite Basalt)
V: Volcanogenic Deposit
H: Hydrothermal Deposit

Source: Sumitomo Metal Mining

Reference Table B-3 Nickel Mine Production by Country

(1,000 MT)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Finland	5.0	3.5	5.2	5.8	6.0	5.7	6.4	5.8	4.4	5.8	6.4
Greece	8.6	10.6	11.3	13.9	15.1	14.8	16.4	9.6	14.9	14.6	14.0
Yugoslavia	-	-	-	-	-	-	-	-	1.0	1.5	1.5
Norway	-	0.5	0.5	0.6	0.7	0.4	0.4	0.5	0.5	0.6	0.6
Burma	0.1	0.1	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Indonesia	10.8	14.7	14.1	15.8	16.0	14.6	13.8	16.1	30.2	35.8	40.5
Philippines	-	0.2	0.4	0.4	0.3	9.5	15.2	36.7	29.5	33.3	34.9
Botswana				0.5	9.6	6.3	12.6	11.8	16.1	16.2	15.4
Morocco	0.1	0.2	0.2	0.3	0.4	0.3	0.1	0.1	0.1	0.5	0.5
South Africa	11.6	12.8	11.7	19.4	22.1	20.8	22.4	22.0	22.5	25.3	25.7
Zimbabwe	8.6	9.3	10.1	10.9	10.7	9.1	14.6	16.7	15.7	19.0	14.6
USA	14.1	14.2	14.3	12.6	12.8	13.0	11.9	12.6	11.8	12.1	12.8
Brazil	3.0	3.3	3.4	4.1	3.5	3.2	5.3	4.2	3.6	2.9	2.5
Dominican Rep.	-	0.2	17.4	30.1	30.5	26.9	24.5	24.5	14.3	25.1	15.5
Guatemala	-	-	-	-	-	-	-	0.3	1.8	6.3	6.9
Canada	277.5	267.0	234.9	249.0	269.1	242.2	240.8	232.5	128.3	126.5	194.9
Australia	29.8	35.5	35.5	40.1	45.9	75.8	82.5	85.9	82.4	69.7	69.8
New Caledonia	138.5	150.9	108.1	115.9	137.0	133.5	119.7	116.8	67.2	82.9	86.3
USSR	110.0	110.0	110.0	110.0	120.0	125.0	130.0	135.0	140.0	145.0	143.0
Albania	5.4	6.0	6.0	5.8	5.6	6.5	7.0	7.5	8.0	8.5	8.5
German Dem. Rep.	1.8	1.8	1.9	2.0	2.2	2.4	2.5	2.5	2.7	2.5	2.7
Poland	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.3	1.2	1.1
Cuba	36.8	36.5	36.8	35.1	33.9	37.3	36.9	36.8	35.8	32.3	38.2
Centrally planned economies	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
China				7.0	8.0	8.0	9.0	10.0	10.0	11.0	11.0
World total	663.4	679.0	623.5	681.1	751.2	757.1	773.7	789.6	642.4	678.9	747.6

Source: Metallgesellschaft, Metal Statistics, 1970-1980
68th edition (1981)

C. PRODUCTION TRENDS AND THE CURRENT SITUATION

I. Trends in Production Volume

Canada has led the free world's nickel production continuously since the Sudbury region was established in the late 19th century, with the exception of 1979, when there was a long strike by the INCO Ltd. workers. However, as Reference Table C-1 shows, because Canada's production was virtually steady from 1965 to 1980, its share of the free world production, which was 50% up to the early 1960s, gradually decreased from later in the decade. This is because of the entry of new producers into the field and of great increases of the production of other regions, thanks to the nickel boom of 1966-1970. Thus, the production share of the American continent as a whole also decreased, from 57% in 1965 to 39% in 1980.

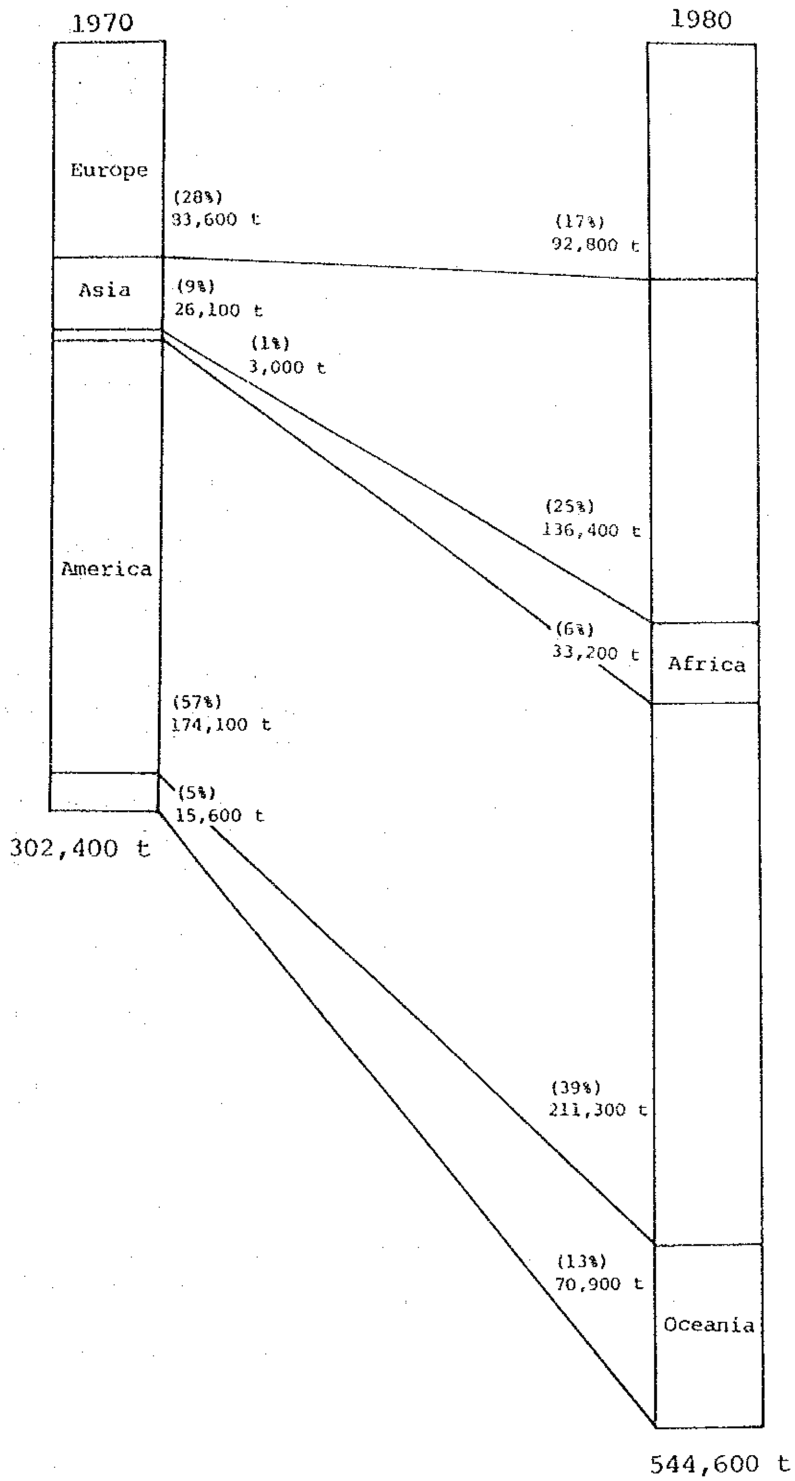
In Europe also, the production share decreased as a result of the stagnation of British production (due to Inco policy) - from 28% in 1965 to 17% in 1980.

In contrast, Asia's production share leapt from 9% in 1965 to 25% in 1980, with the broad increase in Japan's metallic nickel and ferro-nickel production from early 1970, the initiation in 1974 of the Marinduque's nickel briquette production in the Philippines, and the start of ferro-nickel production in Indonesia, by P.T. Aneka Tambang Mining Corporation in 1976 and that of nickel matte production in 1977 by INCO's subsidiary, P.T. INCO.

In the oceania area, after the discovery of large deposits of high-grade nickel in the vicinity of Kanbarda in western Australia in 1966, a series of other new deposits were found. The Western Mining Corporation constructed a nickel refinery in 1970 and a nickel smelter in 1972. Australia's share of free world production was non-existent in 1965 but reached 7% in 1980, and the production share of Oceania as a whole, including New Caledonia, grew from 5% in 1965 to 13% in 1980.

Africa's production share also increased: from 1% in 1965 to 6% in 1980. The traditional African nickel producer, South Africa, increased its production and Zimbabwe (Rhodesia) in 1968 and Botswana in 1973 were added to the ranks of producers.

With the above developments, the free world's nickel production increased between 1965 and 1980 by a factor of 1.8 (4% annual growth rate) from 302,000 tonnes to 544,800 tonnes. The special features of this growth were the great increase of production in Japan (83,200 tonnes), which has no ore of its own; and the new entry of the Philippines, Australia, the Dominican Republic, and Greece into the ranks of producers. The production (about 110,000 tonnes) in these countries, where there had previously been none, accounted for almost the entire increase in free world production. For reference, the following graph shows a comparison of free world production shares in 1970 and 1980:



In addition, nickel production in the eastern bloc has definitely been increasing since 1965. Centrally planned economies' share of world production bottomed out at 23% in 1974 and peaked at 33% in 1978. In particular, the USSR increased its production from 80,000 tonnes in 1965 to 177,800 tonnes in 1981; and since 1977, has overtaken Canada as the world's largest producer.

The breakdown of nickel production by product is not known, since such figures are not published by the producers. However, Reference Table C-2 shows estimates in the form of proportions of ferro-nickel - about one-third - and of other nickels.

II. Production Capacity

1. Nominal Capacity

Reference Table C-3 shows the present status of the world's nickel producers, and the production capacities, products, and locations of their smelteries. In this Table, the term production capacity includes the capacity for intermediate production.

For example, the 16,000 tonne production capacity of France's Societe Metallurgique Le Nickel (SLN) uses matte produced as part of New Caledonia's 75,000 tonne production capacity. Thus, these 16,000 tonnes are counted twice as production capacity.

After adjustment for capacity that has been counted twice, estimates of the free world's nominal production capacity in 1982, broken down by nickel products, are shown in the following Table.

(1,000 tonnes)

	Nickel metal		Ferro-nickel		Nickel oxide sinter		Total	
		%		%		%		%
Europe	128	25	41	18	-	-	169	21
Asia	60	12	74	31	20	30	154	19
Africa	45	9	-	-	-	-	45	6
America	243	48	75	32	25	38	343	42
Oceania	30	6	45	19	21	32	96	12
Total	506	100	235	100	66	100	807	100

For the free world's nominal production capacity at present, a variety of figures have been reported. Falconbridge, for example, estimated it at between 770 and 815 thousand tonnes at the AMM London Metal Forum in October 1982, and another producer assessed it at 820 thousand tonnes. However, the 807 thousand tonnes shown in the above Table —— an estimate based on up-to-date data and information —— is commonly regarded as the nominal production capacity of the free world.

As the Table shows, the American Region, including Canada, holds a 42% share of the nominal production capacity of nickel products as a whole.

2. Effective Production Capacity

The effective production capacity naturally almost coincides with the nominal production capacity when the demand is vigorous. A prolonged sluggish demand like that at present, however, cuts off parts of the nominal production capacity, and this activity cannot instantly be recovered, so that the effective production capacity is usually below the nominal one.

Estimation of the effective production capacity is very difficult. For instance, the world's leading producers and research institutes have generally put the Free Wrold's effective production capacity at 650 to 750 thousand tonnes, while Falconbridge considered it to be 590 to 635 thousand tonnes at the AMM London Metal Forum.

The reasons for such differences among estimations are that the ways in which immediately effective production capacities of plants that are currently closed or have been recently established are taken into consideration as the effective production capacities vary from institute to institute.

Making use of the up-to-date data and information used to estimate the free world's nominal production capacity described in Item II-1, the current effective production capacity can be estimated as shown in the following Table with adjustments for a. production capacities of facilities encountering difficulties in obtaining crude ore (INCO Europe and Zimbabwe), b. production capacities where problems such as deterioration are affecting the plants themselves (SLN's New Caledonia plant and Marinduque), c. production capacities related to intermediate products (many plants), d. production capacities in facilities where environmental pollution controls such as restrictions on exhaust gases are causing problems (Canada), and e. production capacities of plants thought to have been completely closed.

(1,000 tonnes)

	Nickel metal	Ferro-nickel	Nickel oxide sinter	Total
Europe	118	37	-	155
Asia	50	74	15	139
Africa	39	-	-	39
America	223	28 - 58*	25	276 - 306
Oceania	30	30	21	81
Total	460	169 - 199	61	690 - 720

* Falconbridge Dominicana temporarily closed at the beginning of 1982 and reopened operation in the second half of the same year, but there is no saying when its 30 thousand tonne production capacity will fall to nil. It was therefore taken as zero to 30 thousand tonnes for this estimation.

3. Rate of Utilization

The demand in 1982 has been estimated to be 450 thousand tonnes, while the production in the same year has been put at 400 thousand tonnes taking into account an inflow from the centrally planned economies and inventory adjustments of producers. The estimated production, 400 thousand tonnes, is equivalent to 50% of the current nominal production capacity, 807 thousand tonnes, and to 57% of the current effective production capacity, 705 thousnad tonnes (the average of 690 thousand tonnes and 720 thousand tonnes).

This rate of utilization was presented to indicate the present situation into which the nickel industry has been forced. If demand becomes lively, the ratio can reach 100% before new production capacities corresponding to the newly recovered demand will have been completed.

III. Production Costs

1. Outline

Nickel production can be divided into three categories:

a. production from laterite with no cobalt recovery;

b. production from laterite with cobalt recovery;
c. production from sulfide ore.

Typical production costs (including mining, dressing, smelting and refining costs) for each of these three cases are as follows:

Production Costs

(US$/lb of nickel in 1981)

	Laterite Ore		Sulfide Ore
	Without cobalt recovery	With cobalt recovery	
	Dominicana	Marinduque	Falconbridge (Ontario)
Energy	1.65	2.31	0.35
Chemicals, etc.	1.35 (Chemicals and Labor combined)	0.67	0.62
Labor		0.42	2.18
Total operating cost	3.00	3.40	3.15
Byproduct credit	-	0.40	1.83
Net operating cost	3.00	3.00	1.32
Form of product	Ferro-nickel	Nickel metal (briquettes)	Nickel metal

2. Production of Nickel from Laterite

2.1 Non-recovery of Cobalt

Relatively high-grade laterite is treated to produce ferro-nickel or nickel matte. This type of ore has a relatively low cobalt content, so cobalt is not recovered as a byproduct.

2.2 Cobalt Recovery

Relatively low-grade laterite is treated to produce high-purity nickel, e.g., as briquettes. Since this type of ore has a relatively high cobalt content and cobalt is generally recovered as a byproduct. This is an important source of profits.

3. Production of Nickel from Sulfide Ores

Sulfide ores generally contain valuable metals, primarily copper, cobalt, and precious metals, apart from nickel. The recovery of these byproducts not only reduces costs but also provides a large source of profits.

4. Production Cost Breakdown

Estimates of production costs for the world's major nickel producers are as follows:

Production Costs in Main Producing Countries

(US$/lb of nickel)

Production cost	Laterite				Sulfide		
	No byproducts			By-products	INCO		Falconbridge
	Dominican Rep.	Indonesia	Guatemala	Marinduque	Manitoba	Ontario	Ontario
Energy	1.65	0.93	1.65	2.31	0.31	0.31	0.35
Chemicals, etc.] Labor	1.35	1.35	1.11	0.67	0.52	0.52	0.62
				0.42	0.82	2.00	2.18
Total operating cost	3.00	2.28	2.76	3.40	1.65	2.83	3.15
Income from byproduct							
Copper	-	-	-	0.00	0.07	1.06	0.93
Cobalt	-	-	-	0.40	0.07	0.08	0.58
Precious metals	-	-	-	0.00	0.20	0.52	0.32
Total	0.00	0.00	0.00	0.40	0.34	1.66	1.83
Production cost after deduction of income from byproducts	3.00	2.28	2.76	3.00	1.31	1.17	1.32
Form of product	Ferro-nickel	Matte	Matte	Nickel metal (briquette)	Nickel metal	Nickel metal (pellet)	Matte

Note: These costs are estimated by the Working Group, based on 1980 annual report of major produces, and take inflation into account.

Production costs are largely affected by factors such as energy, labor costs, and byproduct income deduction.

4.1 Energy

The production of nickel consumes large amounts of energy, and energy costs account for a large proportion of production cost. Only the case of sulfide ores is an exception. Ore with a nickel grade of 1 to 2% can be concentrated until its nickel grade is about 12% by ore processing that consumes little energy. Furthermore, it is possible to make effective use of the heat of oxidation of the sulfur in the ore. For these reasons, energy costs are much lower than for laterite. In contrast to this, because it is difficult to concentrate the nickel in laterite prior to metallurgical extraction, energy costs are unusually high. The basic amount of electricity necessary to produce nickel is 25,000 to 30,600 kWh per Ni tonne for ferro-nickel from laterite ores through an electric furnace, and 5,000 to 6,000 kWh per Ni tonne for nickel metal from sulfide ores through matte.

As was seen earlier in the production cost table, the energy cost for sulfide ores is US$0.3 per pound, but US$1.60-2.3 per pound for laterite. Even considering that the unit cost of electricity varies from region to region, sulfide ores still normally have an advantage over laterite.

4.2 Labor Costs

The labor costs for sulfide ores are higher than those for laterite. This is because underground mining is used for these comparatively deep deposits, requiring more numerous and more skilled miners. Laterite ore, on the other hand, is located close to the surface where it can be mined easily, and so labor costs are low. Furthermore, Canadian labor costs are on a higher level than those of other countries, so labor costs are a double burden in the case of sulfide ores.

4.3 Deduction for Byproducts

The recovery of byproducts is of great importance, since it provides a major source of profits. Here is an example of the contribution of byproducts from the production of nickel from sulfide ores by Falconbridge and INCO:

Byproduct revenue

(US$ million 1980)

	INCO		Falconbridge	
	Amount	Proportion of total sales	Amount	Proportion of total sales
Copper	286	18%	53	17%
Precious metals	153	10%	15	5%
Cobalt (estimated)	39	3%	34	11%
Others	10	1%	25	8%
Total	488	32%	127	42%

Of these products, because the price of cobalt has declined greatly since 1981, its contribution as a byproduct would be extremely low.

IV. Mining Industry Policy

1. Outline

Because of stagnant markets and receding demand, the nickel industry world-wide is in difficult straits. Private corporations in advanced industrial countries such as Canada, the United States, Australia, and Japan, cannot expect government rescue measures because they operate in free economies. They must make efforts to reduce the cost with layoffs, reduced production, or other rationalization measures. State corporations and corporations having strong ties with their governments may be able to expect various types of support from their governments. However, as the recession continues, there are inherent limits to this state support, so that each company is likely to have to rely on its own resources.

2. Current Conditions in Canada

Canada's nickel industry operates in a free economy. There is no basic government aid policy except for temporary countermeasures such as the extension of unemployment insurance benefits for laid-off workers and the creation of short-term employment opportunities in other fields. However, because the Canadian nickel industry has played a major role in the Canadian economy for a long time, both the Federal Government and the provincial governments are concerned about the current difficult situation.

In particular, the nickel industry employed 27,000-30,000 people in the Sudbury area of Ontario province until just a few years ago, but due to rationalization and modernization measures, employment is expected to be halved, to 13,000-15,000 people, when production reopens in 1983. In order to counter this situation, the Government plans to foster or attract substitute industries, as follows:

a. To foster a natural resources distribution center;
b. To expand the tourist industry;
c. To attract service industries related to the mines (mine machinery and facilities, drilling machines, etc.).