However, it will not be easy for these industries to grow enough to absorb the people released from the nickel industry.

The nickel industry labor unions demanded at the beginning of November, 1982, that the Federal Government implement stockpiling and disburse subsidies for nickel sales to support nickel industry operations and assure employment. However, the Government is opposed to such an assistance policy, because it cannot give the nickel industry special treatment now, when all types of mines except gold mines are in difficulty. The Government is afraid of criticism on the grounds of promoting unfair competition. The management of nickel producers are also unenthusiastic about an aid policy.

3. Conditions in Other Countries

3.1 France

Ownership of SLN is equally shared by Imetal and Ste National Elf Acquitaine (SNAE), but the French Government controls 60% of Imetal, so SLN is virtually a government enterprise now. Because of this, the French Government gives indirect aid to SLN to counter recessions in business.

Some examples of this indirect aid are as follows: First, in order to raise SLN's sales share in the French market to 40% in 1983 (from 24% in 1981), other government corporations are made to cooperate in concluding long-term contracts with SLN. Second, the Government is planning to reduce medium and long-term loans (over 1 billion francs at the end of 1981), by alloting SLN's main share-holders, Imetal and SNAE, a 600 million franc capital increase. Third, the Government is providing funds for rationalization investments, such as the conversion of fuel for the drying furnaces in New Caledonia from oil to coal.

3.2 The Philippines

The construction of the Marinduque nickel refinery is part of the Philippine Government's policies to increase the added value of domestic products. Since operations began, the Government has extended various types of aid. As well as guaranteeing loans to this company, which is suffering from deficits, the Government has provided funds for investment in fuel conversion (from oil to coal) to reduce costs and has provided special tax exemption (Presidential Order No. 1824) concerning import duties, taxes on fixed assets, etc. Furthermore, measures to convert loans from the government banks (the Development Bank of the Philippines, DBP; and the Philippine National Bank, PNB), into shares in Marinduque are now in progress. Thus, as a pioneer industry in the Philippines, Marinduque has been backed up thoroughly by the Philippine Government.

V. Technological Innovation in Production

Except for the segregation process for laterite currently being developed, mining and ore processing technology is virtually fully established. The main points of technological innovation are in the smelting and extraction fields.

1. Solvent Extraction Process

One of the relatively new techniques currently employed in nickel production is the solvent extraction process, a method of sharply separating cobalt from nickel which produces high-purity nickel. The solvent extraction process will be actively employed to remove various types of impurity and deserves attention as a process which can also be applied to the extraction of other metals.

2. Segregation Process

Among the techniques currently being developed are many that aim at profitable extraction of the world's extensive laterite reserves. One of these is the segregation process. Nickel in laterite, unlike that in sulfide ore, cannot be concentrated by dressing.

In the segregation method, a salting agent and a carbonaceous reductant are first added to the laterite, which is then roasted. Finally, the precipitated nickel is recovered either by flotation or by magnetic separation. Because the ore can be concentrated to grades of 20-40%, it is possible to greatly reduce freight charges and smelting costs. However, although research on the segregation process has been performed all over the world, this process has not yet been used for nickel on an industrial scale.

3. Reduction Melting Process

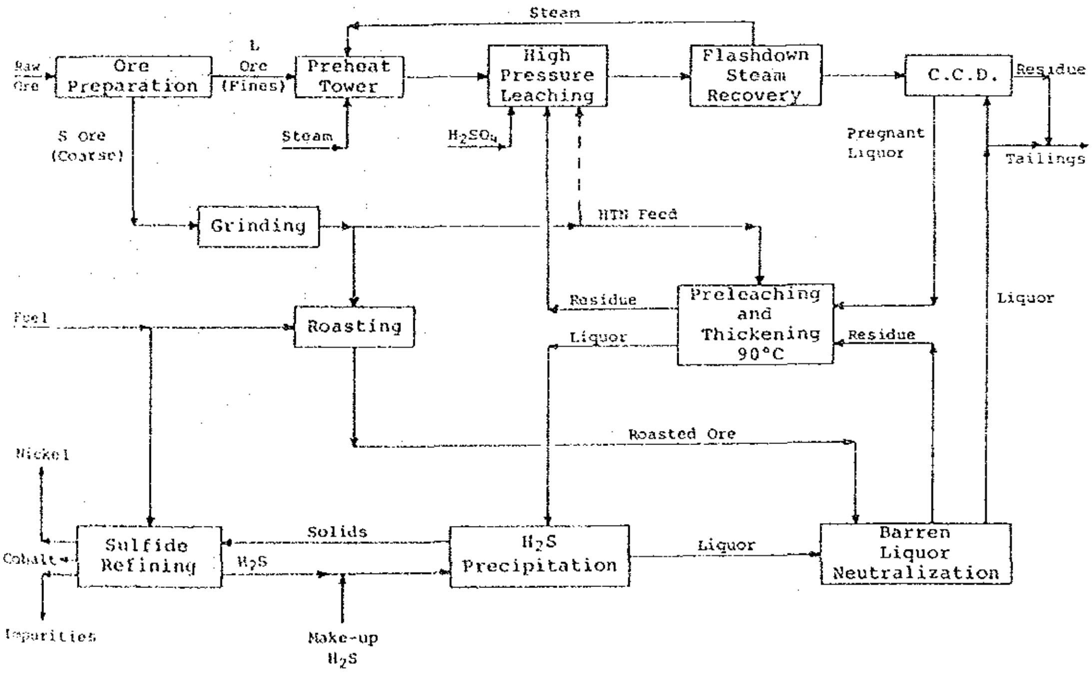
The smelting of laterite involves high energy costs. Production of ferro-nickel with the usual electric furnace process consumes 25,000-30,000 kwh per tonne of nickel. There has been active research in recent years into various methods for converting from this electric energy to inexpensive energy from coal.

One method blows laterite along with pulverized coal and oxygen, into a reactor containing a molten iron bath, gasifying the coal and simultaneously melting and reducing the ore with the heat of the gasification reaction. The ore is preheated and pre-reduced with the waste gas, which contains carbon monoxide and hydrogen, and, if necessary, this waste gas is also used to generate electricity. However, the technology of this method has not yet been perfected.

4. Sulfuric Acid Leaching Process

Sulfuric acid leaching of laterite is already being used at Moa Bay in Cuba. The technique is appropriate for low-magnesia ores, because the magnesia pushes up the consumption of sulfuric acid.

Amax Nickel Refining Co. Inc. is developing technology for efficiently recovering nickel with the sulfuric acid leaching process even from ore relatively high in magnesia. This is a flow sheet of the process:



In this process, the raw ore is first screened to separate it into high- and low-magnesia ores. The latter is pre-treated in various ways including pulverization, then leached with sulfuric acid. The high magnesia ore is pulverized and roasted and then the roasted ore is used as a neutralizing agent for barren liquor from sulfuric acid leaching of low-magnesia ores which converts the magnesia into magnesium sulfate. This residue is returned to the sulfuric acid leaching tank and the nickel contained is recovered. A special feature of this process is its efficient use of magnesia as a neutralizing agent.

VI. The Major Producers

1. INCO Ltd.

Headquarters: 1 First Canadian Place, Toronto, Canada

INCO Ltd., which held about a 30% shares of the free world's nickel market in 1980, is the biggest nickel producer in the world. INCO has 14 sulfide ore mines in the Province of Ontario, and 4 in the Province of Manitoba, Canada. Mines in Ontario are concentrated in the Sudbury region.

Nickel ore reserves in Canada total 500 million tonnes. The Ontario ore contains 1.11% nickel and 0.93% copper. The Manitoba ore contains 2.77% nickel and 0.18% copper.

INCO also has ore concentrators, smelter and refineries in these two provinces. In addition, INCO has a nickel refinery in Clydach, Wales, the United Kingdom, a copper alloy plant in Hereford, the United Kingdom, and a large scale rolling mill in Huntington, West Virginia, the United States. Owing to the declining demand for nickel and the worsening market, INCO has temporarily closed its facilities in the Sudbury region from June 1, 1982 to April 4, 1983, and those in the Thompson region of Manitoba from November 2, 1982 to March 1, 1983.

The following table shows INCO's plants in Canada, their locations, products, and production capacity:

Location	Process	Production capacity	Intermediate and final products
Copper Cliff (Sudbury, Ontario)	Smelter, Roaster Electrorefining Carbonyl process Ammonium leach	210,000 tonnes/year	matte, nickel metal nickel oxide sinter chemicals nickel pellets, powder
Port Colborne (Ontario)	Electrorefining		nickel metal
Thompson (Manitoba)	Smelter-electrorefining		nickel metal

The Clydach refinery produces nickel pellets with the carbonyl process. It can treat matte from Sudbury and from Soroako in Indonesia.

INCO has the following overseas subsidiaries:

a. P.T. INCO, Indonesia (Inco 97%, 6 Japanese companies 3%). This company owns a laterite mine and smelter that produces 36,000 tonnes of nickel sulfide matte per year in Indonesia's Sorcako region. This matte is sent to Japan and to Clydach. P.T. INCO has 190 million tonnes of reserves of ore containing 1.85% nickel.

b. Exmibal, Guatemala (INCO 80%, Hanna 20%), which owns a laterite mine and a smelter that can produce 13,000 tonnes of sulfide matte per year near Lake Izabel in Guatemala. This matte used to be refined at Clydach, but due to problems of profitability, operations have been stopped since the end of 1980. Ore reserves are 50 million tonnes; the ore contains 1.8% nickel.

2. Falconbridge Ltd.

Headquarters: P.O. Box 40, Commerce Court West, Toronto, Canada

Falconbridge has 5 sulfide ore mines in the Sudbury region of Ontario. The ore is treated by concentrators and smelters in the Sudbury region. The matte is shipped to Kristiansand in Norway to be refined. This refinery has a capacity of 45,000 tonnes of nickel metal per year. Falconbridge's reserves in Ontario amount to 80 million tonnes of ore containing 1.7% nickel and 0.8% copper.

Falconbridge has an overseas subsidiary, Falconbridge Dominicana (65.7% Falconbridge, 17.5% Armco, 9.5% the Dominican Government, 7.3% private individuals), which operates a laterite mine and a 30,000 tonnes per year smelter in the Dominican Republic. Its 70 million tonnes of reserves contain 1.64% nickel.

In response to the deteriorating nickel market and the economic recession, Falconbridge temporarily closed its Sudbury facilities from June 27, 1982 to January 3, 1983 and its Dominican facilities from January 3, 1982 to September 16, 1982.

3. Société Métallurgique le Nickel (SLN)

Headquarters: Tour Maine Montparnasse 33, Avenue de Maine, 75751 Paris, Cedex 15, France

SLN has 4 laterite mines and a smelter that produces 75,000 tonnes of ferro-nickel and matte per year in Doniambo, New Caledonia. Most of the matte has been sent by ship to the 16,000 tonnes per year refinery at Sandouville near Le Havre, France, and the rest shipped to the United States and Japan, but from 1983 on, it will all be sent to France.

4. Queensland Nickel Pty. Ltd. (Metals Exploration 50%, Freeport 50%)

Headquarters: Greenvale, North Queensland, Australia

Queensland Nickel has a laterite mine and a smelter in Greenvale, Queensland. The smelter uses the ammonium carbonate leaching process to produce nickel oxide sinter (21,000 tonnes/year) and nickel cobalt mixed sulfide (2,500 tonnes/year of nickel). Reserves are 40 million tonnes of 1.6% nickel ore containing 1.6% nickel.

5. Western Mining Corporation Ltd.

Headquarters: 459 Collins Street, Melbourne, Victoria, Australia

Western Mining is the largest nickel producer in Australia. Currently, it mines sulfide ore at Kambalda in Western Australia. Its 66,000 tonnes per year Kalgoorlie smelter processes Western Mining's own ore and also smelts, on a toll basis, sulfide ore from the Agnew mine (Western Selcast and Mount Isa Holding) and the Nepean mine (Freeport and Metals Exploration). The matte produced from Agnew mine ore is sold to AMAX Nickel. Western Mining also produces nickel powder, nickel briquettes, and nickel-cobalt mixed sulfide at its 30,000 tonnes per year Kwinana refinery with the Sherritt Gordon pressure ammonia leaching process.

6. Sherritt Gordon Mines Ltd.

Headquarters: P.O. Box 28, Commerce Court West, Toronto, Canada

Since the closure of its Lynn Lake mine in Manitoba due to depletion of the ore, Sherritt Gordon has had no mine of its own. At its 17,000 tonnes per year refinery in Fort Saskatchewan, Alberta, Sherrit Gordon processes nickel and cobalt concentrates from INCO's Thompson facilities and nickel matte from Western Mining of Australia, producing nickel briquettes, nickel powder and other products.

7. Outokumpu Oy

Headquarters: Tootonkatu 4, 00100 Helsinki 10, Finland

Outokumpu is owned by the Finnish Government. Along with producing nickel as a byproduct of its copper production, Outokumpu produces nickel from Canadian concentrates. It has a smelter and a refinery in Harjavalta (Capacity: 13,000 tonnes of nickel metal per year).

8. Larco

Headquarters: 20 Amalias Avenue, Athens, Greece

Larco has laterite deposits of 1.2 - 1.4% nickel content at Laryma and on Euboea Island and produces ferro-nickel at its 30,000 tonnes per year smelter at Larymna.

9. P.T. Aneka Tambang

Headquarters: Jl. Bungur Besar 24-26, Jakarta, Indonesia

P.T. Aneka Tambang, an Indonesian Government corporation, has a laterite mine and a 5,000 tonnes per year ferro-nickel smelter in the Pomalaa region of Sulawesi Island. It also mines laterite containing 2.2% nickel on Gebe Island and exports it to Japan.

10. Marinduque Mining and Industrial Corporation

Headquarters: 2282 Pasang Tamo Extension, Makati, Rizal, Philippines

Marinduque mines laterite ores at Nonoc Island, Surigao, and refines the ores with the ammonium carbonate leaching process to produce nickel powder and a nickel-cobalt mixed sulfide. Its refining capacity is 34,000 tonnes/year. Since operations began in 1974, the Marinduque Corporation has suffered from serious financial difficulties due to troubles with operations and the recent stagnation of the nickel and cobalt markets. Marinduque has 60 million tonnes of ore reserves on Nonoc Island. This ore contains 1.22% nickel and 0.1% cobalt.

11. Impala Platinum Ltd.

Headquarters: 70 Marshall Street, Johannesburg, South Africa

At its Springs refinery, Impala Platinum produces sulfide matte with electric furnaces, and nickel powder and nickel briquettes with the Sherritt Gordon ammonia leaching process (capacity 9,000 tonnes per year).

12. Rustenburg Platinum Mines Ltd.

Headquarters: Consolidated Building, P.O. Box 590, Johannesburg 2000, South Africa

Rustenburg Platinum shares a nickel and copper refinery at Germiston, Transvaal, with the Johnson Matthey Corporation of London. The refinery's capacity is 19,000 tonnes of electrolytic nickel per year.

13. Amax Nickel, Inc.

Headquarters: 599 West Putnam Avenue, Greenwich, Connecticut, 06830, USA

AMAX purchased a copper refinery at Port Nickel, Louisiana in 1971, reorganized it and began producing nickel briquettes and nickel powder with the wet process at the end of 1974. The raw material is nickel matte purchased from a Botswana mine in which Amax has a 29.8% interest, or from Agnew, in which case it is smelted by WMC on a toll basis. Amax's annual refining capacity is 36,000 tonnes per year.

14. Japan

Japan imports ore and matte as raw materials from New Caledonia, Indonesia, the Philippines, Australia, and other countries, and smelts and refines it to produce electrolytic nickel, ferro-nickel and nickel oxide sinter. The electrolytic nickel is produced by Sumitomo Metal Mining and Nippon Mining, the ferro-nickel is produced by Sumitomo Metal Mining, Nippon Mining, Nippon Yakin Kogyo, and Pacific Metals; and the nickel oxide sinter is produced by Tokyo Nickel and Nippon Nickel. In 1982, Shimura Kako closed plants with ferro-nickel capacity of 12,000 tonnes per year. The production capacity for each company is as follows:

Company	Plant location	Production capacity (tonnes/year)	Finished product
Sumitomo Metal Mining Co., Ltd.	Niihama	23,000	electrolytic nickel, nickel compounds
	Hyuga	18,000	ferro-nickel
Nippon Mining Co., Ltd.	Hitachi	3,600	electrolytic nickel
	Saganoseki	14,000	ferro-nickel
Pacific Metals Co., Ltd.	Hachinohe	25,000	ferro-nickel
Nippon Yakin Kogyo Co., Ltd.	Oeyama	12,000	ferro-nickel
Tokyo Nickel Co., Ltd.	Matsuzaka	13,000	nickel oxide sinter
Nippon Nickel Co., Ltd.	Tsuruga	7,000	nickel oxide sinter

15. The Centrally Planned Economies

15.1 The USSR

The USSR has smelting and refinery plants in 3 areas — Norilsk (Northern Siberia), Severonickel (Kolskii peninsula), and Youjoural-nickel (Urals) — with a total refining capacity of 170,000 - 180,000 tonnes per year. These refineries produce nickel metal, nickel anode, and ferro-nickel.

Of the 3 areas, the facilities in the Norilsk area are the largest in scale. These facilities have been modernized with technological guidance from the Outokumpu Oy. All reports agree that the recent increase of nickel exports to the free world is due to the increased capacity at Norilsk. Furthermore, the USSR purchases nickel-cobalt mixed sulfide from Cuba as a raw material for nickel and cobalt, and in connection with Cuba's expansion plans, is expected to increase these purchases in the future. The addition of this increase to the expansion in the USSR own production suggests that the USSR will overtake Canada and become the world's top producer.

15.2 Cuba

In 1960, the Cuban Government seized the Freeport Company's refinery at Nicaro and nationalized it. Operations have since proceeded with the USSR's technological assistance. Present capacity is 23,000 tonnes of nickel oxide sinter per year at Nicaro and 24,000 tonnes of nickel-cobalt mixed sulfide per year at Moa Bay. As mentioned above, all the nickel-cobalt mixed sulfide is shipped to the USSR. Cuba's plans to expand production include construction of 30,000 tonne/year facilities at Bunta Gorda (where operations were scheduled for 1982, but have been delayed till 1983); and 30,000 tonne/year facilities at Los Camoriocas (which were scheduled for completion in 1985, but considerable delay is expected).

15.3 China

According to the U.S. Bureau of Mines' reports, China has a sulfide ore mine called Jinchuan in west Gansu and a production capacity on the scale of 10,000 tonnes of nickel metal per year, but details are not available.

(1,000 tonnes)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Europe																	
Original EC countries	8.5	13.1	13.0	10.9	10.4	11.0	9.9	13.1	10.4	9.5	10.9	11.8	10.5	8.1	2.6	9.8	13.0
UK	40.5	37.5	38.6	41.7	29.7	36.7	38.7	31.9	36.8	35.7	38.8	36.0	23.2	21.4	18.9	19.3	18.0
Norway	31.8	32.2	28.2	32.2	35.6	38.5	41.8	43.3	42.7	43.2	37.1	32.7	38.2	23.7	30.7	36.9	37.0
Finland	2.8	3.0	3.0	3.3	3.7	4.0	3.9	5.5	5.8	6.5	6.5	7.6	9.4	7.5	11.5	12.8	13.3
Greece	-	0.1	2.5	4.7	5.6	8.6	10.6	11.3	13.9	15.1	14.8	16.4	9.6	14.9	14.6	14.0	14.4
Europe total	83.6	85.9	85.3	92.8	85.0	98.8	104.9	105.1	109.6	110.0	108.1	104.5	90.9	75.6	78.3	92.8	95.7
Asia																	
Japan	26.1	29.8	42.8	54.7	65.0	89.8	102.6	79.5	87.7	104.6	78.0	94.8	93.9	79.2	105.9	109.3	93.6
Philippines	-	-	-	-	-	-	-	-	-	0.1	9.4	14.3	19.3	16.2	18.7	22.7	25.0
Indonesia	-	-	-	-	-	-	-	-	-	-	-	3.6	4.9	4.4	4.0	4.4	4.8
Asia total	26.1	29.8	42.8	54.7	65.0	89.8	102.6	79.5	87.7	104.7	87.4	112.7	118.1	99.8	128.6	136.4	123.4
Africa																	
South Africa	3.0	5.4	5.7	7.5	8.0	9.0	11.0	13.0	15.0	17.0	14.0	17.0	17.2	15.0	17.9	18.1	18.0
Other African countries	-	-	-	-	2.0	5.0	8.0	10.0	11.0	12.0	13.0	14.6	16.7	15.7	14.6	15.1	10.0
Africa total	3.0	5.4	5.7	7.5	10.0	14.0	19.0	23.0	26.0	29.0	27.0	31.6	33.9	30.7	32.5	33.2	28.0
America																	
USA	12.6	12.4	13.4	13.8	14.5	14.1	14.2	14.3	12.6	12.6	19.9	30.8	34.4	33.8	40.1	40.2	44.3
Canada	160.4	129.7	162.0	154.5	132.2	189.2	165.3	133.9	157.9	183.9	157.8	168.2	152.0	89.2	83.7	152.3	115.2
Dominican Rep.	-	-	-	-	-	-	0.2	17.4	30.1	30.5	26.9	24.4	24.9	14.3	25.4	16.3	19.5
Brazil	1.1	1.1	1.1	1.1	1.5	2.5	2.5	2.6	2.4	2.3	2.2	2.2	2.5	2.3	2.2	2.5	2.3
America total	174.1	143.2	176.5	169.4	148.2	205.8	182.2	168.2	203.0	229.3	206.8	225.6	213.8	139.6	151.4	211.3	181.3
Oceania																	
Australia						1.0	14.0	16.5	19.8	20.5	32.9	39.9	34.1	37.3	39.3	38.3	42.5
New Caledonia	15.6	20.3	20.7	22.4	23.9	27.3	29.0	36.2	35.8	48.5	52.8	38.2	28.3	19.9	30.4	32.6	28.0
Oceania total	15.6	20.3	20.7	22.4	23.9	28.3	43.0	52.7	55.6	69.0	85.7	78.1	62.4	57.2	69.7	70.9	70.5
Free world total	302.4	284.6	331.0	346.8	332.1	436.7	451.7	428.5	481.9	542.0	515.0	552.5	519.1	402.9	460.5	544.6	498.9
Centrally planned economies																	
USSR	80.0	85.0	95.0	103.0	105.0	124.0	126.0	130.0	130.0	134.5	143.0	151.0	155.0	160.0	170.0	168.0	177.8
Cuba	25.8	25.4	30.9	35.0	35.0	18.3	18.0	17.5	17.0	15.0	18.5	18.4	18.6	19.3	19.1	20.1	7.8
Other centrally planned economies	4.6	5.5	6.0	7.0	7.0	5.8	6.3	6.4	14.0	15.7	16.4	17.5	22.7	23.1	24.5	24.3	14.5
Centrally planned economies total	110.4	115.9	131.9	145.0	147.0	148.1	150.3	153.9	161.0	165.2	177.9	186.9	196.3	202.4	213.6	212.4	200.1
World total	412.8	400.5	462.9	491.8	479.1	584.8	602.0	582.4	642.9	707.2	692.9	739.4	715.4	605.3	674.1	757.0	699.0

Note : Primary nickel and nickel contained in ferro-nickel, nickel oxide sinter and Monel Metal smelted directly from ores.

Source: Metallgesellschaft Aktien Gesellschaft Metal Statistics, 1965-1980
The US Bureau of Mines, Mineral Industry Surveys, 1981 (connected to metric tonnes)

Reference Table C-2 Annual Nickel and Ferro-nickel Production

(1,000 tonnes)

	Free world total nickel production	Ferro-nickel (%)	Other nickel (%)
1965	302.4	49.5 (16)	253.1 (84)
1966	284.6	56.5 (20)	228.1 (80)
1967	331.0	68.6 (21)	262.4 (79)
1968	346.8	80.3 (23)	266.5 (77)
1969	332.1	95.9 (29)	236.2 (71)
1970	436.7	119.4 (27)	317.3 (73)
1971	451.7	134.7 (30)	317.0 (70)
1972	428.5	137.0 (32)	291.5 (68)
1973	481.9	142.2 (29)	339.7 (71)
1974	542.0	182.7 (34)	359.3 (66)
1975	515.0	168.1 (33)	346.9 (67)
1976	552.5	160.2 (29)	392.3 (71)
1977	519.1	147.2 (28)	371.9 (72)
1978	402.9	120.4 (30)	282.5 (70)
1979	460.5	160.3 (35)	300.2 (65)
1980	544.6	144.4 (26)	400.2 (74)
1981	498.9	139.1 (28)	359.8 (72)

Reference Table C-3 Nickel Production Capacity

	Company	Location	Theoretical annual capacity [a] (tonnes)	Intermediate and finished products
Europe				
France	Société Métallurgique Le Nickel-SLN	Sandouville (Le Havre)	16,000 [b]	Nickel metal Nickel oxide Nickel chemicals Nickel salts
UK	Inco Europe Ltd.	Clydach (Wales)	54,000	Nickel metal, Ni powder Nickel-cobalt salts NiO
Norway	Falconbridge Nikkel-verk A/s	Kristiansand S	45,000	Nickel metal
Finland	Outokumpu Oy	Harjavalta	13,000	Nickel metal
Greece	Larco-Ste Minière et Métallurgique de Larymna S.A.	Larymna	30,000	Ferro-nickel
Yugoslavia	Rudnici i Industrija za Nickel Celiki Antimon Ferro-Nickel Kavadarci	Kavadarci	5,300 [c]	Ferro-nickel
	Ferro-Nickel Pristina	Pristina	5,300	Ferro-nickel
Asia				
Indonesia	P.T. Aneka Tambang Mining Corp.	Pomalla (Sulawesi Is.)	5,000	Ferro-nickel
	P.T. International Nickel Indonesia	Soroako (Sulawesi Is.)	36,000	Matte
Japan	Nippon Mining Co. Ltd.	Hitachi	3,600	Nickel metal
		Saganoseki	14,000	Ferro-nickel
	Nippon Nickel	Tsuruga	7,000	Nickel oxide
	Nippon Yakin Kogyo Co. Ltd.	Oeyama	12,000	Ferro-nickel

Reference Table C-3 (cont'd.)

	Company	Location	Theoretical annual capacity a) (tonnes)	Intermediate and finished products
(Japan - cont'd.)	Pacific Metals Co. Ltd.	Hachinohe	25,000	Ferro-nickel
	Shimura Kako Co. Ltd.			
	Sumitomo Metal Mining Co. Ltd.	Niihama	23,000	Nickel metal Nickel oxide Nickel chemicals
		Hyuuga	18,000	Ferro-nickel
	Tokyo Nickel	Matsuzaka	13,000	Nickel oxide
Philippines	Marinduque Mining Corp.	Surigao	34,000	Nickel metal
		(Nonoc Is.)	3,000	Nickel-cobalt sulfide
Africa				
South Africa	Mattey Rustenburg Refines Ltd.	Rustenburg (Transvaal)	15,000	Matte
			19,000	Nickel metal
	Impala Platinum Ltd.	"	9,000	Nickel metal
	Western Platinum Ltd.	"	3,800	Matte
Botswana	BCL Ltd.	Selebi-Phikwe	18,000	Matte
Zimbabwe	BSR Ltd.	Bindura	12,000	Nickel metal
	Empress Nickel Mining Co., Ltd.	Eiffel Flats	5,000	Nickel metal
North and South America				
Canada	Inco Ltd.	Copper Cliff (Ontario) Port Colborne Thompson	210,000	Matte, Nickel metal Nickel oxide chemicals Nickel oxide sinter Nickel metal Nickel metal
	Falconbridge Ltd.	Falconbridge	45,000	Nickel-copper matte
	Sherritt Gordon Mines Ltd.	Fort Saskatchewan	17,000	Nickel metal
USA	Hanna Nickel Smelting Co.	Riddle	14,000 d)	Ferro-nickel
	Amax Nickel Refining Co. Inc.	Braithwaite-Port Nickel	36,000	Nickel metal

Reference Table C-3 (cont'd.)

	Company	Location	Theoretical annual capacity [a] (tonnes)	Intermediate and finished products
Guatemala	Exploraciones y Exploraciones Mineras Izabal S.A. (Eximbal)	El Estor (Izabal lake)	13,000 [e]	Matte
Brazil	Morro do Niquel S.A.	Pratapolis	3,000	Ferro-nickel
	Cia de Niquel Tocantins	Sao Miguel Paulista	5,000	Nickel metal
	Cia de Desenvolvimento de Recursos Minerais - CODEMIN S.A.	Niquelandia	5,000	Ferro-nickel
Colombia	Cerromatoso S.A.	Cerro Matoso	23,000 [f]	Ferro-nickel
Dominican Rep.	Falconbridge Dominicana C. por A.	Bonao	30,000	Ferro-nickel
Oceania				
Australia	Western Mining Corp. Ltd.	Kalgoorlie	66,000	Matte
		Kwinana	30,000	Nickel metal
	Greenvale-Nickel Cobalt Operation	Townsville	21,000	Nickel oxide
			2,500	Nickel cobalt sulfide
New Caledonia	Société Métallurgique Le Nickel - SLN	Doniambo	75,000	Matte
				Ferro-nickel
Centrally planned economies				
USSR	Usines D'Etat: Combinat de Norilsk	Nadezdha (Siberia)	50,000 [g]	Copper-nickel-cobalt matte
		Norilsk (Siberia)		Nickel metal
	Severonickel	Monchengorsk		Nickel metal
		Pechenga		Nickel anode
	Youjouralnickel	Verkni Oufalei	170/	Matte
		Orsk	180,000	Matte
		Rezk		Matte
		Pobuzh		Ferro-nickel

Reference Table C-3 (cont'd.)

	Company	Location	Theoretical annual capacity a) (tonnes)	Intermediate and finished products
Cuba	Cuba Nickel	Nicaro	23,000	Nickel oxide
		Moa Bay	24,000	Nickel-cobalt sulfide
Poland	Huta Miedzi	Glogow	2,500	Nickel metal, salts
Czechoslovakia	Niklova Huta	Sered nad Vahom	4,000	Nickel metal, salts
German Dem. Rep.	V.E.B. Nickelhutte Aue	Aue	1,000	Nickel metal
	V.E.B. Nickelhutte St-Egidien	Glauchau	3,000 h)	Ferro-nickel briquettes
	V.E.B. Ferrolegierungs-werk Lippendorf	Lippendorf	3,000	Ferro-nickel

a) The nickel content of sulfides, matte, salts, ferro-nickel, oxides, and nickel metal
b) From New Caledonian matte
c) Scheduled to begin production at the beginning of 1983.
d) Plant closed since April 1982.
e) Plant closed since the end of 1981.
f) Operation from 1982; full operation from 1984
g) Completion scheduled around 1982.
h) An intermediate product reprocessed at the Lippendorf plant.

Source: Groupe Imetal, Annuaire Statistique Minemet, 1981

D. CONSUMPTION: TRENDS AND PRESENT STATUS

I. Consumption Trends

1. Outline

Table D-1 shows the trends in free world nickel consumption as a whole. For 14 years from 1965, until a consumption peak of 587,000 tonnes was recorded in 1979, the free world's nickel consumption showed an average annual growth of 4.5%. During this period of expansion, there were temporary decreases in 1971 and 1975. 1971 was the year when Nixon stunned Japan by going to China and by suddenly suspending soybean supplies and when there was a deterioration in the economy of the United States. In 1975, consumption fell because of distributors' purchases in response to the first oil crisis in 1973 and by the strike against INCO in the next year. Consumption in both 1971 and 1975 fell below the 1970 level, but then gradually recovered. It was probably due to the effects of the distributors' demand triggered by the second oil crisis (a result of the Islamic Revolution in Iran at the beginning of 1979), that consumption recorded the peak mentioned above. However, in 1980 and 1981, as the world economic recession deepened, consumption shrank for 2 consecutive years. The consumption in 1981, 475,000 tonnes, was about the same level as those in 1976 and 1977. Thus, nickel consumption is facing serious decline.

2. Regional Consumption

2.1 Consumption Growth Rates

The annual growth rates of consumption by regions for each five-year period after 1965 are as follows:

	1965-70	1970-79	1965-79
Europe	7.76%	3.21%	4.83%
USA	0	2.00	0.89
Japan	28.27	3.27	11.59
Free world total	7.12	2.93	4.46

This Table and Reference Table D-1 indicate that the expansion of free world nickel consumption in the 1960s was supported by the growth of European and Japanese consumption. The particularly conspicuous leap in Japanese consumption was due to the rapid growth of the special steel (stainless steel) field that accompanied the conversion of the Japanese economy into a large-scale one. It was also clear due to the fact that, as Reference Table D-2 shows, the stainless steel industry in Japan showed a rapid growth of 17.9% per annum while it grew at an annual rate of 8.0% in the free world as a whole over the 1960's. However, with the fall in the pace of annual growth of Japan's stainless steel industry in the 1970's to 2.7%, the growth rate for nickel consumption has fallen from the 28.27% of 1965-1970 to 3.27%.

2.2 Consumption Shares

As can be seen below, the consumption share of the United States has fallen greatly since 1970 and Japan's share has levelled off at about 22%. In contrast, the increased share of other areas has been significant. This is thought to be due to the economic development of the Newly Industrializing Countries (NICS), i.e., Brazil, the Republic of Korea, Taiwan and Singapore.

	1965	1970	1975	1980
Europe	37.6%	38.8%	39.2%	38.8%
USA	48.6	33.0	31.5	26.4
Japan	8.9	22.0	21.3	22.7
Others	4.9	6.0	8.0	12.1
Free world total	100	100	100	100

3. Consumption by Usage

Reference Table D-3 shows nickel consumption in the United States and Japan broken down by usage. Stainless steels and other special steels consume 80% of the nickel in Japan, but only 30 - 35% in the United States. This difference is a result of the allocation of about 30% of Japan's stainless steel production for exports, and the United States is the destination for a large proportion of these.

The leading usage in the United States is for alloys, including the special alloy fields, typically the super-alloys. Such alloys accounted for 50% of consumption in 1971 and 1975 and 42% in 1981. This makes a good contrast with Japan, where there is no aircraft or munitions industry.

As can be seen in Reference Table D-3, there is also a clear difference between the United States and Japan in the type of nickel usage. While the proportion of ferro-nickel and nickel oxide sinter used in Japan is about 70%, in the United States about 70% of the nickel used is nickel metal. This is due to the great difference previously mentioned between the natures of the United States and Japanese consumption. Specifically, in Japan, where a high proportion of the nickel consumption is for stainless steels, the consumption of ferro-nickel is extremely high because the stainless steel makers prefer ferro-nickel for its ferrous properties. At the same time, the differences between the Japanese and the United States supply systems contribute to this difference in usage proportions. To be specific, in Japan the ferro-nickel producers and the main stainless steel makers are almost all connected by capital cooperation, and ferro-nickel is used preferentially. In the United States, on the other hand, domestic nickel production is low (13,000 - 14,000 tonnes/year; since April, 1982: 0). The United States relies on supplies from INCO, the leader in neighboring Canada's nickel industry.

II. Effects of Technological Innovation in Usage on the Demand for Nickel

1. Stainless Steel

Stainless steel falls into two groups: the austenite group (commonly named the nickel group) containing 18% Cr - 8% Ni; and the ferrite group (commonly named the Chromium group including the martensite group, in which the content of cobalt is lower) containing 18% Cr. The nickel group, being superior in corrosion resistance and heat, has both a wider range of applications and a large production. In Japan, the average share of the group in the overall stainless steel production for the past 17 years was 67%, as seen in the following Table. However, the nickel group is higher in price (by around 30%) than the chromium group, due to the addition of nickel. Thus, an extreme price hike or a shortfall of nickel sometimes leads to substitution of part of the chromium group for the nickel group in same uses, or causes an addition of Mn with a reduction of Ni without any deterioration of austenite's characteristics, along with developments of new alloys containing a Cr-Mn-Cu-N combination and having no Ni at all. Consequently, a relative setback in the share of the nickel group is possible, but on the other hand, the group may possibly expand its applications far more widely with the progress of chemical technology, because it is superior to the chromium group for processing and welding, and moreover by adjusting the components such as Co, Mo, W and C, it has features that are essential for special uses in equipment for nuclear power, aircraft, desalination and chemical reactions, and precision machine parts.

Movements of Share of Ni-Group
Stainless Steel Production in Japan

1966	66.8%	1974	70.4%
1967	67.4%	1975	67.9%
1968	67.2%	1976	68.1%
1969	68.3%	1977	65.1%
1970	69.0%	1978	67.3%
1971	67.2%	1979	68.0%
1972	61.6%	1980	66.1%
1973	67.0%	1981	65.9%

2. The Alloy Field

2.1 The expansion of demand for nickel as the main ingredient or an important ingredient in high-tension steels, heat-resistant alloys, and anticorrosion alloy can be expected. In particular, the improvement in efficiency of heat engines has been an important topic since the oil crisis, and so the proportion of heat-resistant alloys used in higher temperature areas is increasing.

2.2 Nickel is the main ingredient in the super-alloys used in nuclear reactors, nuclear fuel refining, nuclear enriching, nuclear fuel reprocessing, etc., in environments too severe for stainless steels.

2.3 The actual production of nickel-cobalt-based heat- and corrosion-resistant super-alloys in Japan was 1,143 tonnes in 1979, 1,637 tonnes in 1980, and 1,474 tonnes in 1981. Although the economic standstill has caused demand to level off recently, production of these super-alloys has shown a steady growth over the past 5 years. The promotion of plans to save energy, scrapping obsolete plants and building new ones, the progress in environmental protection equipment and towards eliminating the use of petroleum in the chemical industry, and other such trends are expanding the demand for such heat- and corrosion-resistant super-alloys.

The turbo-charger boom in the Japanese automobile industry is expected to provide a future market for this field. With IHI, Mitsubishi Heavy Industries and others successfully developing a series of small turbo-chargers, a new market for super-alloys can be expected.

2.4 Nickel is an indispensable material for magnet-hydrodynamic (MHD) electric generators and coal liquefaction plants. Nickel will certainly be used in large quantities in super-heat-resistant materials and super-low-temperature resistant materials in expected future fields such as those of liquefied natural gas (LNG) and nuclear fusion.

2.5 In the energy field too, materials conditions will worsen. In the petroleum industry where the use of "sour oil" containing highly corrosive components is increasing, demand for seamless pipes composed mainly of nickel is expected to increase.

3. Magnetic Materials

3.1 Nickel is important as a super-permanent magnetic material for magnetic heads in magnetic disc units for computers, audio tape recorders, video tape recorders, data recorders etc.

3.2 Nickel is an important super-permanent magnetic material used in motors and meters, magnetic bearings and loudspeakers, etc.

4. Other Fields

4.1 Nickel has a promising future in the super-plastic alloys and shape-memorizing alloys e.g., Ni-Ti, which are anxiously-awaited-for machine parts and materials.

4.2 The super-heat-resistant super-alloys are the most important future field of demand for nickels. They require progress to be made in combining development of computerized alloy design methods with production methods that reduce the content of damaging constituents such as oxygen and sulfur as much as possible, surface coating treatments and material improvements through high-temperature, high-pressure treatment of casting defects, as well as other processes such as the control of grain boudaries.

5. Fields in which Materials Substitution is Expected

5.1 Forty-two Alloy for Integrated Circuit Lead Frames

Presently, integrated circuit (IC) lead frames almost all use 42 alloy (42% nickel, 58% iron), but along with the spreading use of ICs and of higher integration, new products are being developed as replacements for 42 alloy. In particular, there is a high likelihood of lead frames for ICs in consumer goods such as TVs and VTRs being replaced by copper alloy or iron components in terms of quantity, cost, or high conductivity of heat and electricity.

5.2 Nickel Plating for Automobile Bumpers

The switch-over from nickel-plated steel to plastic materials for automobile bumpers has been significant because of weight reduction, corrosion resistance, and energy absorption during collisions. While motor vehicle production in Japan growing from 6,294,000 four-wheeled vehicles in 1972 to 1.8 times that figure — 11,180,000 vehicles in 1981 — the consumption of nickel for plating decreased.

III. Import Policy

This section will discuss the various countries' nickel import policies in terms of their tariff situations.

Reference Table D-4 lists the tariffs imposed on nickel by the major countries. Firstly, none of the advanced industrial countries except Japan levy a tariff on nickel metal. It is thought that the reason why Canada, which produces no ferro-nickel, currently levies a 4.8% tariff on it is to protect domestic nickel metal.

Japan imposes tariffs on nickel metal, ferro-nickel and nickel oxide sinter. As of 1982, GATT tariffs are: nickel metal, 106,800 yen/tonne; ferro-nickel, 9.3% of value; and nickel oxide sinter, 9.4% of value. Japan is second in the world in nickel consumption; it is also completely dependent on supplies from domestic smelters. It is in the special position of having to maintain domestic supply from the standpoint of national security.

However, in line with what was agreed during the Tokyo Round, a series of multilateral trade negotiations that took over 7 years, tariffs are scheduled to be reduced to the following consistent rates on each product type.

	First year (Mar. 31, 1980)	1982	Final year (Jan. 1, 1987)
Nickel metal	¥150,000	¥106,880	¥81,000
Ferro-nickel	12%	9.3%	6.5%
Nickel oxide sinter	13%	9.4%	7.2%

As Reference Table D-4 shows, the United States also still levies tariffs on nickel: 4.3 to 4.5% on nickel salts and nickel compounds.

IV. Stockpile Policy

1. Outline

Nickel, as well as being an important strategic material just as cobalt is, is also an indispensable resource for economic activity. However, because of the high importance of supply from politically stable countries, such as Canada, Australia, and New Caledonia, nickel does not figure as much as cobalt in each country's stockpile plans.

2. The United States

After World War II, the U.S. Government began to stockpile various forms of nickel in its strategic stockpile. However, in February, 1971, the stockpile goal was reduced from its previous 50,000 tonnes to 0. In July of the same year, the President signed a bill releasing all the nickel in the Government's stockpile.

Afterwards, the stockpile amount was set at 185,000 tonnes in 1976, and revised in April 1980 to 181,000 tonnes (200,000 short tons), its current value.

The current stockpile is just the 294 tonnes that the U.S. Mint — which was holding it for coinage purposes — transferred to General Services Administration (GSA) in October 1981. No stockpile expansion is scheduled. The main reason for this is that Canada, a major producer, is an immediate neighbor, but the Government's financial difficulties are also thought to have some influence.

3. Other Countries

It seems that nickel is not included in the stockpile programs being implemented in Sweden and France, but the secrecy surrounding them precludes a reliable interpretation. The Federal Republic of Germany's national stockpile scheme is not being implemented because of the Government's financial difficulties; in any case, nickel is not one of the items included in the program.

Japan presently has a government-assisted non-governmental stockpile system to secure a stable supply of raw materials, and nickel is one of the five items included.

V. Major Consumers

The main free world nickel consumers are shown below. As can be ascertained from this list, the top three are the United States, Japan and the Federal Republic of Germany, in all of which usage is concentrated in the stainless steel field. (The main usages for each company's nickel are shown in parentheses.)

1. The United States

Alleghney Ludlum Industries Inc. (stainless steel)
Armco Steel Corp. (stainless steel)
Crucible Stainless Steel Division of Cobalt Industries (stainless steel, high nickel alloys)
Republic Steel Corp. (stainless steel)
United States Steel Corp. (stainless steel)
Universal Cyclops Specialty Steels Div. (stainless steel)
INCO Ltd. - Huntington Alloy (high-nickel alloys)

Carpenter Technology Corp. (high-nickel alloys)
Jones and Laughlin Steel Corp. (high-nickel alloys)
Anaconda Co. (cupro-nickel)
Phelps Dodge Corp. (cupro-nickel)
General Motors (nickel plating)
The United States Mint (coins)

2. Japan

Nippon Steel Corporation (stainless steel)
Nisshin Steel Company, Ltd. (stainless steel)
Nippon Yakin Kogyo Co., Ltd. (stainless steel)
Nippon Kinzoku Co., Ltd. (stainless steel)
Sumitomo Metal Industries, Ltd. (stainless steel, high nickel alloys)
Daido Special Steel Co., Ltd. (stainless steel, high-nickel alloys)
Kawasaki Steel Corporation (stainless steel)
Hitachi Metals, Ltd. (high-nickel alloys, magnetic alloys)
Mitsubishi Metal Corporation (high-nickel alloys, cupro-nickel)
Sumitomo Special Metals Co., Ltd. (magnetic alloys, nickel alloys)
Toshiba Corporation (nickel alloys)
Kobe Steel, Ltd. (cupro-nickel)

3. Europe

3.1 The Federal Republic of Germany

Friedrich Krupp Hüttenwerke A.G. (stainless steel)
Stahlwerke Suedwestfalen A.G. (stainless steel)
Vereinigte Deutsche Metallwerke A.G. (stainless steel, high nickel alloys, cupro-nickel)

3.2 The United Kingdom

British Steel Corp. (stainless steel)
Yorkshire Copper (cupro-nickel)
The Royal Mint (coins)

3.3 France

Creusot-Loire (stainless steel)

3.4 Spain

Acerias Forjas de Azcoitia SA (stainless steel)

3.5 Italy

FIAT SPA (stainless steel)

3.6 Sweden

Avesta Jernverks AB (stainless steel)
Fagersta AB (stainless steel)

Reference Table D-1 World Consumption of Nickel

(1,000 tonnes)

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Germany, FR	30.7	33.6	31.0	35.4	36.8	40.9	34.3	43.0	54.8	61.2	42.8	56.4	53.6	66.4	76.5	68.0	62.0
France	21.0	24.5	28.7	30.7	31.8	36.1	32.2	31.3	29.6	40.5	39.4	33.5	35.8	35.5	38.9	38.4	34.7
Italy	9.3	12.8	14.4	17.4	16.2	19.8	18.0	21.0	23.2	20.0	17.0	22.0	23.0	24.5	26.7	27.0	20.0
UK	36.9	34.4	30.5	33.1	32.5	37.5	31.0	30.0	31.5	33.5	25.5	30.5	30.5	32.0	35.0	22.8	22.8
Sweden	13.1	13.5	15.5	16.5	16.1	23.1	19.0	22.6	26.8	31.9	22.0	24.0	17.5	20.0	22.2	20.0	16.0
Rest of Europe	9.7	10.7	11.5	12.6	14.5	17.8	13.1	16.3	20.1	22.0	18.6	21.3	24.2	29.3	32.3	32.2	26.1
Europe total	120.7	129.5	131.6	145.7	147.9	175.2	147.6	164.2	186.0	209.1	165.3	187.7	184.6	207.7	231.6	208.4	181.6
Japan	28.6	36.3	50.0	59.3	74.7	99.3	89.5	85.7	111.2	113.0	90.0	121.2	97.3	99.0	132.0	122.0	105.0
Rest of Asia	1.5	1.3	1.7	1.7	1.7	2.2	4.7	5.0	6.1	11.4	4.3	0.7	9.7	10.0	11.3	17.9	14.3
Asia total	30.1	37.6	51.7	61.0	76.4	101.5	94.2	90.7	117.3	124.4	94.3	121.9	107.0	109.0	143.3	139.9	119.3
Africa, Oceania	4.5	5.9	7.5	7.0	6.9	7.7	7.4	6.8	10.0	10.8	9.0	9.0	9.5	10.5	10.2	11.9	11.8
USA	156.1	170.4	157.7	144.5	136.6	149.1	133.2	156.9	182.1	194.5	136.0	147.8	140.8	164.1	178.1	148.2	138.6
Brazil	0.8	0.9	0.9	1.0	0.9	1.9	2.5	2.9	5.3	6.6	4.0	4.7	5.2	6.5	7.9	11.2	8.0
Canada	8.1	7.8	8.0	10.2	13.2	15.0	11.3	12.5	13.7	14.3	10.8	10.0	9.0	11.8	12.0	12.0	10.0
Rest of America	0.7	0.4	0.5	0.8	1.2	1.5	2.2	3.1	2.3	2.4	2.7	6.8	4.8	4.7	4.3	5.5	5.7
America total	165.7	179.5	167.1	156.5	151.9	167.5	149.2	175.4	203.4	217.8	153.5	169.3	159.8	187.1	202.3	176.9	162.3
Free world	321.0	352.5	357.9	370.2	383.1	451.9	398.4	437.1	516.7	562.1	422.1	487.9	460.9	514.3	587.4	537.1	475.0
USSR	—	—	—	NA	—	—	—	100.0	100.0	105.0	115.0	121.0	125.0	127.5	130.0	132.0	NA
Rest of centrally planned economies	—	—	—	NA	—	—	—	44.3	45.5	48.3	51.5	57.4	56.8	58.2	59.5	56.1	NA
Centally planned economies	110.0	115.0	115.0	120.0	120.0	125.0	130.0	144.3	145.5	153.3	166.5	178.4	181.8	185.7	189.5	188.1	NA
World total	431.0	467.5	472.9	490.2	503.1	576.9	528.4	581.4	662.2	715.4	588.6	666.3	642.7	700.0	776.9	725.2	NA

Note : Including nickel content in ferro-nickel and nickel oxide sinter.

Source: WHS and Metallgesellschaft Aktien Gesellschaft Metal Statistics

Reference Table D-2 Free World Production of Stainless Steel Ingots

(1,000 MT)

	USA	Japan a)	Germany, Fed, Rep.	France	Sweden	Italy	UK	Others	Total
1955	1,105	40	132	70	84	18	137	54	1,640
1960	908	238	259	186	176	58	224	101	2,150
1965	1,353	528	285	240	275	127	240	162	3,210
1968	1,297	958	416	362	352	226	226	213	4,050
1969	1,422	1,238	485	416	366	214	233	256	4,630
1970	1,158	1,643	504	460	394	238	257	296	4,950
1971	1,141	1,404	370	394	340	216	164	261	4,290
1972	1,413	1,421	518	480	382	260	196	330	5,000
1973	1,716	1,995	620	521	467	288	240	403	6,250
1974	1,950	1,910	688	570	519	311	226	476	6,650
1975	1,008	1,543	437	419	419	267	148	389	4,630
1976	1,528	2,066	673	497	418	366	222	480	6,250
1977	1,696	2,032	636	572	325	418	194	557	6,430
1978	1,763	1,944	761	538	360	440	238	636	6,680
1979	1,913	2,136	821	613	418	502	266	697	7,500
1980	1,537	2,216	816	584	379	493	144	705	6,885

Notes: a) Hot-rolled production converted on a 75% basis up to 1972
Hot-rolled production converted on a 80% basis for 1973-77

Reference Table D-3 Nickel Consumption by Usage and by Form of Nickel

USA

(1,000 tonnes of nickel)

	1965		1971		1975		1981	
Steel			30.1	26%	30.8	23%	45.9	35%
Special alloys			33.0	28	33.6	25	36.8	28
Other alloys			25.5	22	32.8	25	18.6	14
Plating			18.8	16	16.6	12	20.2	15
Others			9.4	8	19.1	14	9.8	8
Total	156.1	100%	116.8	100	132.9	100	131.3	100
Metallic nickel Ferro-nickel	132.8		86.8 10.4	74 9	90.4 23.0	68 17	92.4 23.9	70 18
Nickel oxide	20.9		15.0	13	15.9	12	8.5	6
Ferro & oxide			25.4	22	38.9	29	32.4	24
Others	2.4		4.7	4	3.6	3	6.5	6
Total	156.1	100	116.9	100	132.9	100	131.3	100

Source: WBMS and USBM. (However, 1970 data not available.)

Japan

(1,000 tonnes of nickel)

	1965		1971		1975		1981	
Steel	22.4	78%	85.1	86%	74.6	83%	82.5	79%
Plating	2.7	9	7.0	7	5.4	6	6.9	7
Others	3.5	13	7.2	7	10.0	11	15.6	14
Total	28.6	100	99.3	100	90.0	100	105.0	100
Nickel metal	8.3	29	22.3	22	24.1	27	35.5	34
Ferro & oxide	20.3	71	77.0	78	65.9	73	69.5	66
Total	28.6	100	99.3	100	90.0	100	105.0	100

Source: Japanese Ministry of International Trade and Industry, Yearbook of Non-Ferrous Metals Statistics

Reference Table D-4 Tariffs of Major Countries

Country	Item	Item No.- Statistical breakdown	Tax rate/Amount of tax (1982)			Tokyo Round	Remarks
Japan			(Agreed)	(Most favored nation)	(Temporary)		
	Nickel metal (ingot)	75.01 - 219	¥106.88/kg	6.5% or 53.44 whichever is lower	13%	'85 ¥98.25/kg - '86 89.63 - '87 81.00	
	Nickel metal for slating (nickel anode for electroplating)	75.05 - 000	¥120,63/kg	Free	13%		
	Crude nickel oxide	75.01 - 110	9.4%	Free	13%	not yet determined — not yet determined — 7.2%	(Cu<1.5%)
	Matte, spice, other intermediate products	75.01 - 120	Free				
	Ferro-nickel	73.02 - 400	9.3%	Free	12%	8.4% — 7.4% — 6.5%	
USA				(Agreed)			
	Unwrought nickel	620.03		Free			
	Nickel oxide	419.72		"			
	Nickel matte	603.60		"			
	Ferro-nickel	606.20		"			
	Nickel chloride	419.70		4.5%		('81)('82)'83 '84 '85 '86 '87 4.7% 4.5 4.4 4.2 4.0 3.9 3.7	
	Nickel sulfate	419.74		4.3%		4.6 4.3 4.1 3.9 3.7 3.4 3.2	
	Other nickel compounds	419.76		4.5%		4.7 4.5 4.4 4.2 4.0 3.9 3.7	
	Nickel salts: acetate	426.58		4.5%		4.7 4.5 4.4 4.2 4.0 3.9 3.7	
	" : formate	426.62		4.5%		4.7 4.5 4.4 4.2 4.0 3.9 3.7	
	" : other	426.64		4.5%		4.7 4.5 4.4 4.2 4.0 3.9 3.7	
Canada	Nickel or nickel alloys: (matte, sudges, spent catalysts, scrap and conc.)	35520 - 1		Free			
			(UK)	(Most favored nations)	(Others)		
	Ferro-nickel	37506 - 1	Free	Free	4.8%	('81)('82)'83 '84 '85 '86 '87 5.0% 4.8 4.7 4.5 4.3 4.2 4.0	
Other countries			(Autonomous), (Conventional)				Autonomous (basic) Conventional (agreed)
EEC	Unwrought nickel	75.01	Free , Free				
Czecho-slovakia	"	75.01 - 02	Free , Free				
Sweden	"	75.01 - 100	Free				
Yugoslavia	"	75.01 - 3	3%				
Brazil	"	75.01 - 0200	(GATT) 10%, (In force) 15%				
South Africa	"	75.01 - 10	(General) Free				
USSR	"	270 - 76	(Min.) Free, (Max.) 5%				

E. PRICE TRENDS AND THE PRICE SETTING MECHANISMS

I. Price Trends

Free-world nickel prices are dominated by the published producer prices [1]: INCO's for nickel metal and nickel oxide sinter, and SLN's for ferro-nickel. However, the prices for the three types of nickel are not set independently, but are generally based on the producer price for nickel metal announced by Canada's INCO, the dominant force of the world's nickel industry.

Because nickel is a rare metal, stable supplies are considered important and the producers' power over prices is great. Because the producer price is set to cover the producer's costs, nickel prices have generally been on the rise for a long period. Since 1965, the only times the producer price have fallen were in 1977 - 1978 and in 1981 - 1982. At other times, the producer price rises mostly coincided with INCO's negotiation of a new labor contract. During this period, the years of long strikes against INCO, 1969 and 1979, are particularly worthy of attention. In 1969, the producer price was US$1.03/lb at the beginning of the year and US$1.28 at the end, but the gray market price [2] leapt from US$1.70/lb to US$7.00/lb due to supply shortages and speculative purchases. The 1979 strike occurred during a period of excess supply, so the gray market price showed no exceptional jumps, but the producer price was broadly increased from US$2.05 at the beginning of the year to US$3.20 at the end.

On the other hand, many new development projects were materialized to take advantage of the supply shortage of 1966 - 1969. From 1974 to 1975, they were completed and started operations, but just at that point, struggle for market shares broke out between the producers due to the depressed real demand for nickel during the world economic stagnation caused by the oil crisis. In 1977 - 1978, the publication of producer prices was suspended, and there were cases in which price wars ensued.

Nickel has been traded on the London Metal Exchange (LME) since April 1979. At first, little nickel trading was done and this was mostly in briquettes, so its influence was not great, and the London Metal Exchange price was regarded as just another index. However, in recent years, with the excess in supply becoming more marked owing to factors such as centrally planned economies policies of exporting low-priced nickel in disregard of economic principle, and the depressed demand caused by the economic recession, it has become impossible to

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1) Explained in Item E.II.1

2) Explained in Item E.II.3

ignore the price trends on the London Metal Exchange in setting prices for real transactions. In fact, the continuous fall of the London Metal Exchange prices has rendered the producer price quite nominal and pricing leadership has passed to the London Metal Exchange. As of the end of 1982, while the producer price is US$3.20, the London Metal Exchange price is about US$1.60 and the gray market price, about US$1.70, marking a return to the 1973 - 1974 level.

It is to be expected that when the economy recovers and nickel supply and demand becomes normalized, the producer price will make a comeback, since nickel is a rare metal. However, considering the prolonged excess of capacity over demand, the actual transactions on the London Metal Exchange and other factors, the former one-sided producer pricing system (producer price hikes) will gradually disappear. In following pages are shown the movements of nickel prices and the major events that accompanied them.

II. Price Setting Mechanisms

1. Producer Price

Producer prices are list prices published by producers. They are based on the producer's cost of production plus profits, but the current supply/demand balance is also taken into account in setting them. INCO's producer price dominates where nickel metal and nickel oxide sinter are concerned. The producer price announced by SLN is the dominant one for ferro-nickel, but it is actually set on a sliding scale based on INCO's producer price for nickel metal. Reference Table E-1 shows the producers who announce producer prices together with their prices as of the end of 1982.

2. London Metal Exchange (LME)

The London Metal Exchange price has two values, the spot price and the three months future price for Class 1 nickel.[1] This exchange is a market economy system that sets prices according to the relationship between nickel supply and demand. The intentions of buyers are a major element in price setting. However, because spot trading is slight and most other trading is in future transactions by investors who do not need the nickel immediately, prices

1) Nickel metal of a purity of 99.8% or higher, including cathode, briquettes, and pellets.

Nickel Price Trends and Major Events

(¢/lb)

	Nickel metal P.P. a)	Ferro-nickel P.P. a)	Nickel oxide sinter P.P. a)	Free market price b)	LME c)	Major events
1965/ 1	77.75		75.25			
66/ 1	"		"	76.00		(July-Aug.) Strike at INCO Sudbury
11	85.25		81.00	200.00		
67/ 9	94.00		88.50	"		(Mar.) Devastating floods in New Caledonia
68/ 1	"		"	180.00		
7	"		"	170.00		
10	"		"	160.00		
12	103.00		97.50	"		
69/ 2	"		"	170.00		
3	"		"	180.00		
4	"		"	200.00		
5	"		"	250.00		
6	"		"	300.00		
7	"		"	350.00		(July-Nov.) Strike at INCO Sudbury
8	"		"	400.00		(Aug.-Nov.) Strike at Falconbridge
9	"		"	500.00		Sudbury
10	"		"	600.00		(Sept.-Jan. '70) Strike at INCO Clydach
11	128.00		122.00	700.00		
12	"		"	600.00		
70/ 1	"		"	500.00		
2	"		"	350.00		
3	"		"	300.00		
4	"		"	245.00		
5	"		"	230.00		
6	"		"	200.00		
7	"		"	180.00		
8	"		"	170.00		
9	"		"	165.00		

(cont'd.)

(¢/1b)

	Nickel metal P.P. a)	Ferro-nickel P.P. a)	Nickel oxide sinter P.P. a)	Free market price b)	LME c)	Major events
1970/10	133.00		127.00	150.00		
11	"		"	145.00		
12	"		"	140.00		
71/ 1	"		"	130.00		
2	"		"	127.50		
7	"		"	122.50		(July-Aug.) Strike at SLN Doniambo
11	"		"	117.50		
72/ 1	"		"	120.00		
2	"		"	125.00		
3	"		"	130.00		
7	"		"	125.00		
9	153.00		137.00	140.00		
12	"		"	142.00		
73/ 1	"		"	143.00		
2	"		"	147.00		
3	"		"	151.00		
4	"		"	148.00		
7	"	147.00	140.00	153.00		
9	"	"	"	152.00		
10	"	"	"	150.00		
11	"	"	"	147.00		
12	"	"	"	149.00		
74/ 1	162.00	158.00	149.00	149.00		
2	"	"	"	152.00		
3	"	"	"	164.00		
4	"	"	"	207.00		
5	"	182.00	"	225.00		
6	185.00	"	173.00	226.00		
7	"	"	"	233.00		
8	"	"	"	246.00		
9	"	"	"	225.00		

(cont'd.)

(¢/lb)

	Nickel metal P.P. a)	Ferro-nickel P.P. a)	Nickel oxide sinter P.P. a)	Free market price b)	LME c)	Major events
10	"	202.00	"	200.00		
11	"	"	"	195.00		
12	"	"	"	185.00		
1975/ 1	201.00	"	188.00	190.00		
2	"	"	"	187.00		
3	"	"	"	185.00		
4	"	"	"	183.00		
5	"	"	188.00	180.00		
6	"	"	"	188.00		
7	"	"	"	183.00		(July) 9-day strike at INCO Sudbury
8	220.00	"	207.00	"		
9	"	219.00	"	188.00		
10	"	"	"	185.00		
11	"	"	"	188.00		
12	"	"	"	195.00		
76/ 1	"	"	"	198.00		
2	"	"	"	200.00		
3	"	"	"	210.00		
4	"	"	"	216.00		
5	"	"	"	213.00		
7	"	"	"	208.00		
8	"	"	"	210.00		
9	"	"	"	212.00		
10	241.00	239.00	227.00	"		
11	"	"	"	208.00		
12	"	"	"	203.00		
77/ 1	"	"	"	204.00		
2	"	"	"	209.00		
3	"	"	"	214.00		
4	"	"	"	"		
6	"	"	"	209.00		

(cont'd.)

(¢/lb)

	Nickel metal P.P. a)	Ferro-nickel P.P. a)	Nickel oxide sinter P.P. a)	Free market price b)	LME c)	Major events
1977/ 7	List	239.00	List	206.00		(July) INCO abolishes list prices.
8	prices	"	prices	203.00		
9	abol-	214.00	abol-	198.00		
10	lished	"	ished	193.00		
11		"		188.00		
12		206.50		185.00		
78/ 1		"		189.00		
2		"		192.00		
3		"		195.00		
4		"		198.00		
5		213.50		199.00		
6		"		196.00		
7		"		188.00		
8		"		183.00		
9		"		184.00		(Sept.-Apr. 1979) Strike at INCO Sudbury
11		"		177.00		
12		"		173.00		
79/ 1		"		168.00		
2	205.00	206.00	196.00	184.00		(Feb.) INCO resumes list prices.
3	225.00	227.50	216.00	225.00		
4	250.00	252.50	241.00	264.00	270.00	(Apr.) Nickel futures trading begins on London Metal Exchange.
5	285.00	287.50	276.00	303.00	315.00	
6	300.00	6/5 324.00 18-304.00	291.00	315.00	293.00	
7	"	"	"	280.00	269.00	(July) Actual nickel trading begins on London Metal Exchange.
8	"	"	"	270.00	258.00	(Sept.-Jan. '80) Strike at Amax Port Nickel
10	"	"	"	273.00	267.00	(Oct.-Feb. '80) Strike at INCO Clydach
11	"	"	"	274.00	268.00	

(cont'd.)

(¢/lb)

	Nickel metal P.P. a)	Ferro-nickel P.P. a)	Nickel oxide sinter P.P. a)	Free market price b)	LME c)	Major events
12	320.00	326.00	311.00	294.00	284.00	(Dec.) Flood damage at INCO's Clydach plant
80/ 1	"	351.00	"	304.00	299.00	
2	"	"	"	315.00	317.00	
3	345.00	"	335.00	312.00	306.00	(Mar.) INCO's list price raised to highest level ever: US$3.45/lb
4	"	"	"	298.00	283.00	
5	"	"	"	289.00	273.00	
6	"	347.00	"	296.00	286.00	
7	"	"	"	303.00	301.00	(July-Jan. '81) Operations stop at Falconbridge's plant in Dominican Rep.
8	"	"	"	306.00	299.00	(Aug.) INCO announces production reductions in Canada, Guatemala, UK and Indonesia.
9	"	"	"	303.00	302.00	
10	"	"	"	"	304.00	(Nov.) INCO announces 6% discount sales (until June '81).
11	"	"	"	302.00	293.00	(Nov.) INCO announces closures for summer 1981. (Nov.) INCO announces delay in reopening operations in Guatemala until end 1981.
12	"	"	"	294.00	291.00	(Dec.) SLN announces reduced production in New Caledonia.
81/ 1	"	"	"	296.00	291.00	
2	"	"	"	"	289.00	
3	"	"	"	290.00	286.00	
4	"	"	"	288.00	287.00	
5	"	"	"	290.00	288.00	(May) Falconbridge announces reduced production at its Dominican plant.
6	"	"	"	288.00	280.00	
8	"	"	"	285.00	272.00	(Sept.-Nov.) Strike at INCO's Thompson plant
9	"	"	"	272.00	253.00	(Oct.) INCO records first losses in 50 years, in 3rd quarter.
10	"	"	"	257.00	237.00	(Nov.) INCO announces closure of Exmibal (Guatemala).
11	"	"	"	247.00	232.00	(Nov.) INCO announces a list price reduction (from US$3.40/lb - US$3.20/lb)

(cont'd.)

(¢/lb)

	Nickel metal P.P. a)	Ferro-nickel P.P. a)	Nickel oxide sinter P.P. a)	Free market price b)	LME c)	Major events
1981 12	320.00	321.00	312.00	255.00	249.00	(Dec.) INCO and Falconbridge both announce closures for summer 1982.
82/ 1	"	"	"	265.00	256.00	(Jan.) INCO announces production cutbacks.
2	"	"	"	272.00	260.00	(Feb.) INCO announces 1981 losses of 46.95 million dollars; SLN announces production cutbacks.
3	"	"	"	265.00	257.00	
4	"	"	"	254.00	245.00	(Apr.) Hanna stops ferro-nickel production.
5	"	"	"	246.00	237.00	(June) Strikes at INCO plants in Sudbury and Port Colborne. SLN announces further production cuts. Inco and Falconbridge announce extensions of summer closures.
6	"	"	"	247.00	236.00	
7	"	"	"	242.00	230.00	(July) Falconbridge announces personnel cuts.
8	"	"	"	237.00	225.00	(Aug.) INCO announces layoffs.
9	"	"	"	216.00	196.00	(Sept.) Falconbridge resumes operations at its Dominican Rep. plant. Inco announces extended closures in Sudbury and Manitoba.
10	"	"	"	195.00	178.00	(Oct.) INCO announces an extension of Sudbury area closures. Falconbridge dismisses 1,100 workers at Sudbury area.
11	"	"	"	170.00	156.00	(Nov.) INCO announces summer closure of Thompson plant in 1983. LME price falls to US$1.44/lb - lowest price since 1973.
12	"	"	"	163.00	162.00	

Notes: a) P.P. = producer price: Nickel metal - INCO Melting Cathode; Ferro-nickel - SLN FN3; Nickel oxide sinter - Inco Sinter 75
b) Free market price: Metal Bulletin's monthly average
c) LME: monthly average

are moved by speculation. The London Metal Exchange prices respond sensitively to various economic factors such as changes in exchange rates and interest rates.

Nickel was the 7th metal to be listed on the London Metal Exchange on April 23, 1979 (future transactions). INCO, Falconbridge, and other major producers opposed this action saying that it would bring speculation into nickel prices and invite large price fluctuations and confusion. However, the London Metal Exchange has diverse functions, for example, to maintain pricing standards, as a spot market, to make hedging possible with future transactions, and for financing. It is not necessarily disadvantageous for producers, but since the London Metal Exchange began to list nickel, it has steadily built up its position as the leader of the world's nickel market. Ferro-nickel and nickel oxide sinter are not transacted on the London Metal Exchange and their prices are not directly related to its prices, but the gray market price, which is described below, now fluctuates according to the latter. In this sense, the influence of the London Metal Exchange on the market price for nickel as a whole is great. Pricing is based on the its prices.

3. Gray Market Price (free market price)

During the nickel supply shortages of 1967 - 1970, some nickel that had been transacted at the producer price up to that time was at a price that greatly exceeded the producer price. The term "gray market price" began to be used as a name for the free market or black market prices of that time.

These prices were set with a market economy mechanism reflecting the balance of supply and demand. The market prices announced in the world's industry magazines, such as Metals Week and Metal Bulletin represent the gray market prices. The basis for the calculation of the prices in these two magazines is not clear, but it is thought that the average actual transaction prices paid or received by the dealers and users (or producers) for a number of selected companies were employed.

Since nickel was listed on the London Metal Exchange, the gray market price is based on the London Metal Exchange price plus freight charges, miscellaneous expenses, premiums, etc.

Reference Table E-1 Current Prices of Producers
(Only producers who announce them are included.)

Producer	Product	Price (US$/lb)	Effective date
INCO	Electro 4x4"	3.20	Nov. 25, '81
	Pellets	"	
	Electro 1x1, 2x2	3.29	
	S-Rounds	"	
	NOS 75, INCOMET	3.12	
	Utility	"	
Falconbridge	Melting grade	3.20	Nov. 27, '81
	Plating grade	3.29	
	Ferro-nickel	3.18	
SLM	FN-1	3.23	Dec. 18, '81
	FN-3	3.21	
	SLN 25	3.18	
	Plating	3.29	
	High-purity electrolytic nickel	3.20	
WMC	Briquettes	3.20	Dec. 3, '81
Amax	Briquettes	3.45	Mar. 1, '80
	Corrugates	3.39	
Hanna	Fe-Ni	3.16	Dec. 15, '81

F. TRENDS AND PRESENT CONDITIONS IN INTERNATIONAL TRADE

I. Value of Trade

Reference Table F-1 gives the figures for the world's nickel trade. The volume figures use World Bureau of Metal Statistics (WBMS) data; the dollar figures are inferred from the INCO producer price.[1]

The total volume of trade in nickel metal, ferro-nickel, and nickel oxide sinter in 1979 was 446,000 tonnes, and the value of this trade was about US$2.44 billion. In 1980, the volume was 416,000 tonnes, a decrease of 30,000 tonnes compared to the previous year, and the value of trade was about US$3.12 billion. Reference Table F-2 divides this into trade in nickel metal, ferro-nickel, and nickel oxide sinter.

II. The Flow of International Trade

1. Free World

The following charts show the flow of trade in nickel in the free world.

1.1 Raw Materials (Ore)

(1,000 MT, Ni)

Producing (exporting) countries			Importing countries
New Caledonia	36.8	71.6 (New Caledonia + Indonesia + Philippines) →	Japan
Indonesia	25.1		
Philippines	9.7		
Norway	0.6	→	Finland
Other	1.6		
Total	73.8		

1) Since the World Bureau of Metal Statistics began publishing its World Flow Table only in 1979, there is no data for 1978 or earlier.

1.2 Intermediate Products

(1,000 MT, Ni)

Commodities	Producer/ exporting countries	Importing countries: USA	Norway	Japan	UK	France	Canada	Total
Nickel matte	New Caledonia	4.0		3.2		9.2		16.4
	Australia	5.8	2.0	10.8			4.3	22.9
	Botswana	14.2						14.2
	Indonesia			15.6				15.6
	Canada		36.0		18.8			54.8
	Guatemala				6.9			6.9
	Finland		1.2					1.2
	S. Africa	6.1	2.8					8.9
	Total	30.1	42.0	29.6	25.7	9.2	4.3	140.9
Ni/Co mixed sulfide	Philippines			2.7				2.7
	Australia			2.8				2.8
	Total	-	-	5.5	-	-	-	5.5
Total		30.1	42.0	35.1	25.7	9.2	4.3	146.4

1.3 Products

1.3.1 Ferro-nickel, nickel oxide sinter

(1,000 MT, Ni)

	Production	Importing countries: USA	Germany, FR	France	Japan	Holland	Italy	UK	Sweden	Others	Total	Balance
Greece	14.0		8.5	0.8				0.2	0.3	2.1	11.9	2.1
Brazil	2.5										-	2.5
Canada	17.0	7.6	2.0	0.6		0.1	0.4			6.3	17.0	-
Dominican Rep.	16.4	7.7	0.9	1.4	3.4		0.8	0.6	1.1	0.4	16.3	0.1
USA	10.3			0.4	0.3				0.1		0.8	9.5
Indonesia	4.4				3.6						3.6	0.8
Australia	18.3		7.4	0.5	5.8		0.6	1.4	2.6		18.3	-
N.C.	32.6	0.4	2.9	26.3	1.3		0.8		0.9	0.1	32.7	-0.1
Japan	84.5	0.7				2.6				0.1	3.4	81.1
Others	-	-	8.9	0.8	-	-	3.4	0.1	1.9	3.6	18.7	-18.7
Total	200.0	16.4	30.6	30.8	14.4	2.7	6.0	2.3	6.9	12.6	122.7	77.3

Source: WBMS

1.3.2 Nickel metal

(1,000 MT, Ni)

	Production	Importing countries: USA	Germany, FR	France	Japan	Holland	Italy	UK	Sweden	Others	Total	Balance
France	9.8	0.9	1.6			0.1	0.1	0.2	0.5	2.5	5.9	3.9
UK	19.3	0.1	2.9	1.1		0.6	0.8		0.9	3.3	9.7	9.6
Finland	12.8	3.7	1.5	0.5	0.6		0.7	1.5	0.4	1.7	10.6	2.2
Norway	36.9	16.1	3.8	0.5	1.3	1.5	0.5	2.5	0.6	4.5	31.3	5.6
Canada	135.3	50.3	6.7	2.4	4.0	0.3	2.7	5.8	3.1	12.8	88.1	47.2
USA	29.9		0.2	1.2	1.1	8.1		0.1	0.1	3.1	13.9	16.0
Japan	24.8	0.7								0.6	1.3	23.5
Philippines	22.7	13.4			1.3	7.8				2.2	24.7	-2.0
S. Africa	18.1	3.5	3.1	1.9	1.1	2.3	3.5	0.2	0.7	2.5	18.8	-0.3
Zimbabwe	15.1	1.3	2.1	0.9	0.7	0.8	0.2	0.2		9.2	15.4	-0.3
Australia	20.0	6.0	4.0	2.0	2.3	0.1	1.7	1.4	1.1	1.5	20.1	-0.1
Others	-	0.2	0.7	1.5		2.3	3.0	0.4		3.6	11.7	-11.7
Total	344.7	96.2	26.6	12.0	12.4	23.9	13.2	12.3	7.4	47.5	251.5	93.2

Source: WBMS

Exports from New Caledonia, Indonesia and the Philippines to Japan account for 97% of nickel ore trading as a whole. All this ore is for ferro-nickel.

Nickel matte trading is divided into: a. outright purchases by custom smelters which either have no nickel resources themselves or whose countries have none; b. imports by such custom smelters which were secured by investing in the development of matte production; c. trade within large producer corporate groups, e.g. INCO, Falconbridge, or SLN.

Pattern a. is typified by Japan's imports from Australia, Indonesia, and New Caledonia; the imports of the Amax Nickel Refining Company Inc. of the United States from Botswana are a good example of pattern b.

Canada and Australia account for 55% of nickel matte exports; Norway (30%), the United States (21%), and Japan (21%) account for 72% of imports.

To turn to the flow of nickel products, Canada is the largest exporter and accounts for 25% of the total of each product, followed by Australia, New Caledonia, Norway, and the Philippines. The exports from these 5 countries are 56% of the world total. Exports from the centrally planned economies to the free world have been increasing, reaching 10% of the total exports in 1980.

On the import side, the United States imports are 28% of the free world imports as a whole, followed by those of the Federal Republic of Germany, France, Japan, Italy, the United Kingdom and Sweden. These 7 countries import 76% of the total.

One characteristic of imports is that they reflect differences in the composition of demand. Ferro-nickel and nickel oxide sinter take up a mere 14% of the U.S. imports. The remaining 86% is nickel metal. In world imports as a whole, the ratio between ferro-nickel and nickel oxide sinter on the one hand and nickel metal on the other is about 3 to 7.

2. East-West Trade

There is absolutely no East-West trade in intermediate products. World Bureau of Metal Statistics data on East-West trade in nickel products since 1977 indicate that trade between the centrally planned economies and the free world from 1977 to 1981 was as follows:

(1,000 MT)

	1977	1978	1979	1980	1981
Centrally planned economies → free world	19.9	34.8	42.0	45.3	29.1
Free world → centrally planned economies	1.8	0.9	3.5	3.4	1.6
Net flow from the centrally planned economies	18.1	33.9	38.5	41.9	27.5

It is considered that since 1967 the centrally planned economies production has constantly exceeded consumption and that during almost the same period exports to the free world have become a regular feature. The volume of these exports has been roughly 30,000 to 40,000 tonnes for the last 4 years, although in 1981 exports decreased slightly. As shown in the following Table, the main importing countries are the Federal Republic of Germany, France, the United States, Italy, and Japan, and the main centrally planned economies exporting countries are the USSR and Cuba.

					(1,000 MT)
	1977	1978	1979	1980	1981
Imports					
Germany, Fed. Rep.	3.2	8.9	10.7	8.9	8.0
France	1.7	1.1	2.3	5.1	5.0
USA	2.3	6.2	5.3	8.9	4.1
Italy	2.5	4.9	4.5	4.0	3.6
Japan	2.2	2.6	4.7	4.0	3.2
Subtotal	11.9	23.7	27.5	30.9	23.9
Other countries	8.0	11.1	14.5	14.4	11.7
Total	19.9	34.8	42.0	45.3	35.6
Exports					
USSR	10.8	21.4	27.8	32.0	25.6
Cuba	8.8	12.7	13.5	12.9	9.3
Other centrally planned economies	0.3	0.7	0.7	0.4	0.7
Total	19.9	34.8	42.0	45.3	35.6

The general view of the world's major producers and research agencies is that the flow to the free world will continue at the 40,000 to 50,000 tonne level from 1982 on. However, considering the capacity increase at Norilsk in the USSR, and Cuba's expansion plans (30,000 tonnes/year at Bunta Gorda and 30,000 tonnes/year at Las Camoriocas), it is also forecast that flow from the eastern bloc will increase gradually, reaching the 80,000 to 90,000 tonne level by 1990.

III. Forms of Trading

Nickel ore trading consists, as mentioned earlier, almost entirely of purchases by Japanese ferro-nickel smelters. Japanese smelters entrust their importing to Japanese trading companies as buyer's agents, and obtain their imports from mines in New Caledonia, Indonesia, and the Philippines. Nickel ore trading involves extremely high delivery costs, so all trading is carried out on an FOB basis. Many of the smelters prepare their own specialized bulk carriers. Almost all the ore purchases are outright purchaes,[1] but the

1) In contrast to development imports, these are imports by direct purchase. The relationship between buyer and seller only occurs for transaction.

Philippines' Rio Tuba ore is obtained constantly by the same purchases via investment and financing.[1] This is a special form of trading in which the purchaser assumes responsibility for all or part of the development risk in order to obtain an inexpensive, secure supply. However, with the creation of a buyer's market (both in quantity and in price) such as exists now, the merits of this type of trade are slight while the risk is greater.

Some trading in intermediate products - mostly nickel matte - uses a tolling arrangement [2] (refining on toll contract), but the basic pattern is by direct purchasing. However, many transactions take the form of sales within corporate groups such as INCO, Falconbridge, and SLN. The form of transactions between these parties is not yet clear. In any case, it is not unusual for a trading company to take on the role of agent for these sales.

On the other hand, there are only three streams of nickel-cobalt mixed sulfide trading. First, Australia's Western Mining Corporation sends the sulfide to Canada's Sherritt Gordon Mines, Ltd., and Nippon Kogyo buys this material from Greenvale, also of Australia. Also, the Philippines' Marinduque Mining and Industrial Corporation's is purchased by Sumitomo Metal Mining of Japan.

As reported earlier, there is no East-West trade in intermediate products. Trade in nickel products, i.e. nickel metal, ferro-nickel and nickel oxide sinter, is through: a. direct sales by producers themselves, and b. sales via agents. Agent sales comprise not only outright sales,[3] but also those using a consignment system.[4]

The big producers set separate sales system for each region, such as Europe and the United States, Southeast Asia and Japan. For example, INCO conducts direct sales through its own sales network for sales in Canada (domestic sales), and to the United States and Europe, but sales to Southeast Asia are under the control of INCO Australia, which is used as the sole agent. Sales to Japan are conducted through its subsidiary Shimura Kako in addition to 3 Japanese trading companies that act as agents. However, there are also cases in which a sub-dealer is established below the agent in order to meet demands from users of small amounts, such as the demand for plating.

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1) This is the typical form of development import in which the pursuit of profits is satisfied by developing a mine and assuring stable resources. The purchaser participates in, invests in, and finances the development of these resources in the country possessing them.
2) This is smelting based on toll contract. The conversion of the raw material into a product is entrusted to another company and the product is received back. A toll charge is paid for the refining.
3) Simple sales: the item is completely bought and sold.
4) This is a sales method in which the producer, bearing his own expenses, has product inventories in the consumption area and the producer, or in which his agent conducts on-the-spot sales.

Most of the East-West nickel trade is trade in the USSR products but apart from the sales to the West by the centrally planned economies' own state corporations, the number of western traders who travel behind the Iron Curtain and conduct business there themselves is increasing.

Let us now examine how prices are set for this trading. Although there are the INCO producer price, the London Metal Exchange price and the gray market price for nickel products, each transaction basically uses a price decided individually according to the market condition at the time.

First, between the mines and Japan's ferro-nickel smelters, the prices are set by deducting smelters' refining costs (R/C) and profit-equivalent portions from the producer prices. At present, with the market deteriorating, the London Metal Exchange and gray market prices are occasionally being taken into account. Because the INCO producer price is not expected for the present to recover its authority, this price-setting mechanism will probably become the normal practice in future.

Price setting for nickel matte and nickel-cobalt mixed sulfide — the intermediate product — is of the same form as that for ore: the base price is negotiated between the buyer and the seller. The base price is the INCO producer price or the London Metal Exchange and gray market price, but Amax has recently begun using its own realized sales price as the base price for purchases of nickel matte from Botswana RST, another reflection of the confusion in nickel prices.

Formerly, either the INCO or the SLN producer price was used as a reference price for sales of each nickel product, nickel metal, ferro-nickel, or nickel oxide sinter. However, as long as INCO's lowered market share, the poor market conditions and the constant over-supply continue, sales at the London Metal Exchange price or the gray market price will be the most common.

In any case, the age in which uniform prices were set by the prices of the major producers is over. Market conditions have become such that it will be impossible, in setting any price, to avoid some influence of the London Metal Exchange and gray market prices. Furthermore, actual prices are changed within broad limits by controlling the payment conditions.

East-West trade in nickel is almost all based on gray market prices.

IV. International Cooperation

There is a movement now to establish an Intergovernmental Nickel Discussion Group (INDG) [1]. This is one example of international cooperation, but it is essentially different from an international cartel.

The foundation of the INDG was first proposed as a combination of government and private interests by the Canadian Government. The Australian Government agreed to this and has assumed the leadership. The purpose of the INDG is to hold international meetings of governments, not only of producing countries but also of consuming countries, at fixed intervals and by preparing statistics relevant to nickel to close the nickel market information gap, make the market more transparent and be of use to both producers and consumers. Concretely, its aim is to organize the 27 countries that produce or consume at least 1% of the world's nickel respectively. Beside utilizing existing organs such as the WBMS, there is a plan to found an association of producers and consumers.

However, since the first proposal in 1978, roughly 5 years have passed, but the various countries have not acted in concert and the Intergovernmental Nickel Discussion Group has not yet been established. Canada and Australia gave an interim report on the establishment of this group at the meeting of the 6 major nickel consuming countries (Australia, Canada, the United States, the Federal Republic of Germany, France, and Japan) in October 1982 in Geneva. According to this report, 31 countries (including the EC Commission deemed as a country) were sounded out as to their opinions on the establishment of the INDG. It was reported that 20 countries showed positive attitudes. Future plans are for Australia and Canada, in particular, to quickly draw up the final report and present it at the next meeting of the 6 countries.

1) Intergovernmental Nickel Discussion Group (Temporary name)

Reference Table F-1 Nickel Trading Figures (1)
(actual values)

[Amount: 1,000 tonnes (Ni); Value: US million dollars)

	Exports					Imports			
	1979		1980			1979		1980	
	Amount	Value	Amount	Value		Amount	Value	Amount	Value
Commodities: Ferro-nickel, nickel oxide sinter, nickel metal									
Canada	98.1	537.0	105.1	789.6	USA	117.5	643.3	118.2	888.0
New Caledonia	44.5	243.6	32.7	245.7	Germany, FR	71.1	389.2	66.0	495.8
Australia	38.1	208.6	38.4	288.5	France	53.8	294.5	47.9	359.9
Norway	33.1	181.2	31.3	235.2	Japan	29.0	158.7	30.8	231.4
Dominican Rep.	24.5	134.1	16.3	122.5	Italy	23.5	128.6	23.1	173.5
South Africa	24.5	134.1	18.8	141.3	UK	17.9	98.0	15.3	115.0
Philippines	18.8	102.9	24.7	185.6	Sweden	15.7	85.9	16.6	124.7
USA	18.0	97.4	14.7	110.4	Others	117.5	643.2	98.0	736.4
Greece	15.7	85.9	11.9	89.4					
Zimbabwe	13.9	76.1	15.4	115.7					
UK	13.3	72.8	9.7	72.9					
Finland	9.5	52.0	10.6	79.6					
France	4.4	24.1	5.9	44.3					
Japan	4.4	24.1	4.7	35.3					
Indonesia	4.0	21.9	3.6	27.0					
Others	41.9	230.5	30.4	228.4					
Free world total	406.7	2,226.3	374.2	2,811.4					
Centrally planned economies	39.3	215.1	41.7	313.3					
World total	446.0	2,441.4	415.9	3,124.7	Total	446.0	2,441.4	415.9	3,124.7

Source: WBMS, World Flow (for trade volume)

Reference Table F-2 Nickel Trading Figures (2)
(actual values)

[Amount: 1,000 tonnes (Ni); Value: US thousand dollars)

	Exports					Imports			
	1979		1980			1979		1980	
	Amount	Value	Amount	Value		Amount	Value	Amount	Value
Commodities: Ferro-nickel and nickel oxide sinter									
New Caledonia	44.5	243.6	32.7	245.7	USA	22.3	122.1	16.4	123.2
Dominican Rep.	24.5	134.1	16.3	122.5	Germany, FR	34.2	187.2	33.0	247.9
Australia	18.9	103.5	18.3	137.5	France	40.5	221.7	31.4	235.9
Canada	16.4	89.8	17.0	127.7	Japan	10.0	54.7	16.0	120.2
Greece	15.7	85.9	11.9	89.4	Italy	12.9	70.6	9.0	67.6
Indonesia	4.0	21.9	3.6	27.0	UK	4.6	25.2	2.3	17.3
Japan	2.6	14.2	3.4	25.5	Sweden	7.0	38.3	7.8	58.6
Others	28.0	153.3	19.5	146.5	Others	37.5	205.3	18.8	141.3
Free world total	154.6	846.3	122.7	921.8					
Centrally planned economies	14.4	78.8	12.0	90.2					
World total	169.0	925.1	134.7	1,012.0	Total	169.0	925.1	134.7	1,012.0
Commodity: Nickel metal									
Canada	81.7	447.2	88.1	661.9	USA	95.2	521.2	101.8	764.8
Norway	33.1	181.2	31.3	235.2	Germany, FR	36.9	202.0	33.0	247.9
S. Africa	24.5	134.1	18.8	141.3	France	13.3	72.8	16.5	124.0
Australia	19.2	105.1	20.1	151.0	Japan	19.0	104.0	14.8	111.2
Philippines	18.8	102.9	24.7	185.6	Italy	10.6	58.0	14.1	105.9
USA	17.8	97.4	13.9	104.4	UK	13.3	72.8	13.0	97.7
Zimbabwe	13.9	76.1	15.4	115.7	Sweden	8.7	47.6	8.8	66.1
UK	13.3	72.8	9.7	72.9	Others	80.0	437.9	79.2	595.1
Finland	9.5	52.0	10.6	79.6					
France	4.4	24.1	5.9	44.3					
Others	15.9	87.1	13.0	97.7					
Free world total	252.1	1,380.0	251.5	1,889.6					
Centrally planned economies	24.9	136.3	29.7	223.1					
World total	277.0	1,516.3	281.2	2,112.7	Total	277.0	1,516.3	281.2	2,112.7
Total production	446.0	2,441.4	415.9	3,124.7		446.0	2,441.4	415.9	3,124.7

Source: WBMS, World Flow (for trade volume)

G. SUPPLY AND DEMAND PROJECTIONS

I. Demand Projection

1. Past Trends and Recent Conditions

The demand for nickel in the free world has expanded steadily along with the economic growth since World War II, but the growth rate has been greatly dulled since the beginning of the 1970s. Specifically, while the average annual growth was 7.1% in the 1965-70 period, it decreased to 2.9% during the period from 1970 to 1979. Fluctuations have been particularly drastic since the first oil crisis. Demand recorded a historic high of 562,000 tonnes in 1974, but fell by 25% to 422,000 tonnes in 1975.

After that, demand for nickel peaked at 587,000 in 1979, the year of the second oil crisis, but declined unremittingly to 537,000 tonnes in 1980 and 475,000 tonnes in 1981. It is forecast that free world demand for nickel will fall to 450,000 tonnes in 1982, about the same level as 12 years ago, in 1970 (452,000 tonnes). Actually, this will be the first time since World War II that demand has fallen in three successive years.

It is said that the demand for nickel is two-thirds dependent on capital goods and one-third dependent on consumer goods. It has grown at a rate corresponding to the growth of overall industrial production. Incidentally, while industrial production in the OECD countries as a whole grew at an average annual rate of 3.9%, free world demand for nickel during the same period grew 3.2% per year, a similar level.

After that, the OECD's industrial production stagnated, with its growth rate dropping to minus 0.8% in 1980, rising to 0.8% in 1981 (estimate), and falling again to about minus 3% in 1982 (estimate). This is mainly because: a. the deflationary effect of the simultaneous belt-tightening policies which each country adopted to suppress the inflation that followed the first oil crisis; b. the blow felt by the developing countries from the interest rate hikes and antiinflation policies in the United States and other major countries; c. the chronic stagnation of investment in facilities in Europe made the economic recession more serious than had been expected. This has been reflected in the nickel consumption in the past 3 years.

2. Forecast by Governmental and Other Organizations

The recent recession, which is said to be the most serious since Great Depression of 1929, was forecast by few agencies or businesses a few years before. Almost all the forecasts published until now were based on the high-level years of 1978 or 1979, and estimated growth after that. For this reason, the forecast values for 1981 and 1982 differed greatly from actual figures, putting a distance between the forecasts and reality.

For example, the forecast by the U.S. Bureau of Mines published in Mineral Facts and Problems, 1980, estimates demand in 2000 based on 1978 figure, assuming a 3.9% annual growth. This forecast was for the entire world, including the centrally planned economies, but if this same growth rate is applied to the free world, the calculations are:

(1,000 MT)

	1978	1979	1980	1981	1982
U.S. Bureau of Mines' Forecast	514.3	534.4	555.1	576.7	599.2
Actual Demand	514.3	587.4	537.1	475.0	450.0
Difference	-	-53.0	18.0	101.7	149.2

Furthermore, on the user's side, materials substitution has progressed and endeavors are under way to reduce the use of nickel by aiming at the lighter, thiner, shorter and smaller products. Changes in the demand structure for nickel brought about by these efforts along with the trends of economic activity cannot be ignored. Accurage forecasting of these movements is extremely difficult. In the forecasts by Ontario Provincial Government in Canada a comparison of the 1977 figures and the 1981 figures shows a broad decrease in the latter (Reference Fig. G-1).

In preparing this survey report, 11 nickel producers and research agencies in Europe and the North America were visited, and interviews were conducted. Overall, the view was common in the latter half of 1982 that the growth in nickel demand will be 2-3% per year based on the actual demand in 1980 of 537,000 tonnes, giving a demand of 650,000 - 700,000 tonnes in 1990.

The forecast by Falconbridge Ltd. is close to the average of the above 11 forecasts. It takes the approach of: a. dividing demand into 6 fields; b. with 1980 as the base year, making forecasts that sum up the opinions of specialists in each field on future growth and take actual past data into account; and c. collecting the results of these forecasts to predict demand as a whole.

Falconbridge's forecast indicates that the annual growth rate of the demand for the main end-use, stainless steel, will continue to decline from 3.5% during the period between 1980 and 1985 to 2.5% during the period between 1986 and 1990 and for high-nickel alloys from 4.5% during 1980 and 1985 to 3.5% during 1986 to 1990. The annual growth rate of demand for the six fields as a whole will be 2.8% during 1980 and 1985 and 2.5% during 1986 and 1990, with a projected demand of 689,000 tonnes in 1990.

NCW Nickel Consumption Growth Trends by End Use
(1,000 tonnes nickel)

	Stainless	Low alloy	High alloy	Plating	Foundry	Chem/ other	Total
1980 Consumption							
%	47	10	20	10	8	5	100
1,000 tonnes	247.2	52.6	105.2	52.6	42.2	26.3	526.1
Growth rate							
1970 - 1980 (%)	3.9	2.3	6	-2.6	0.2	-4.6	
Estimated rate							
1980 - 1985 (%)	3.5	2	4.5	1.5	1	1	
Consumption							
1981	255.8	53.5	109.8	53.5	42.6	26.8	542.0
1985	293.5	58.1	131.1	56.7	44.5	27.7	611.6
						5 years	∿ 2,858
							∿ 2.8%
Estimated rate							
1986 - 1990	2.5	2	3.5	1.5	1	1	
Consumption							
1986	300.7	59.4	136.1	57.6	44.9	28.1	626.8
1990	332.0	64.0	155.6	61.2	46.7	29.0	688.5
						5 years	∿ 3,286
							∿ 2.5%

3. Factors to be Considered in Demand Projection

Consumption of nickel is closely tied to industrial production, in particular steel production, and to production of capital goods and consumer durable goods in general. Free world nickel consumption grew at an annual rate of 7.1% from 1965 to 1970, but since 1970 the annual growth rate has decreased to 2.9%, reflecting stagnant economic activity after the first oil crisis. In predicting future nickel demand, the important factors are trends in industrial production, which mirror economic conditions, and the actual economic growth rate.

To turn to the usage of nickel, stainless steel accounts for about half of the demand. This share was about 33% in 1960, but thereafter expanded at a rapid pace due to the increasing demand for such steel. The expansion of stainless steel's share of the demand for nickel increased until the growth of equipment investment levelled off in the 1970s. However, while usage for stainless steel is expected to grow rather more rapidly than other uses, if austenitic stainless steels containing nickel are replaced by ferritic stainless steels containing none, it will give a considerable effect to the demand for nickel. Currently the share of austenitic stainless steels is about 70%. Also, while the proportion of primary nickel, i.e. excluding scrap, in the nickel used in stainless steel is around 50% in Europe and the United States and 60% in Japan, it is necessary to look out for changes in the scrap ratio.

One field in which growth is expected to be higher than that of stainless steel is the super-alloys. Demand for nickel for jet engines and gas turbines will be increased mainly in the United States, owing to the super-alloys' superior properties at high temperature. Nickel for plating has been replaced by aluminum and plastics and this field has shrunk. A comeback is expected in industries such as the automobile industry, but the growth of this field will be quite slow.

As far as demand by regions is concerned, while the expansion of nickel consumption in advanced countries is likely to be dull, growth is expected in the developing countries. These accounted for only a 0.4% share of free world nickel consumption in 1961, but this figure reached 7.6% in 1980. However, because the developing countries are now being affected by the simultaneous world-wide recession and because their foreign currency situations are difficult, it is thought that their growth in the future will slow down.

4. Short-term Projections

In the major advanced countries, the post-oil-crisis inflation has gradually eased and interest rates have been falling since August, 1982. However, the recession has further deepened. Because economic activity was worse in the second half of 1982 in Europe, the United States and Japan than in the first half, and because it is forecast that a proper recovery will not start until 1984, investment activity that will induce expanded demand for nickel cannot be expected to revive in 1983.

It is extremely difficult at present to forecast the relatively short-term demand for nickel up to 1985. The reason is that it is difficult to forecast from past patterns whether the mature advanced countries' economies, including Japan's, can regain their previous vigor in the face of deficits in government finances, partly because each country's industrial structure is changing. Furthermore, for the purpose of forecasting a future rise, it is difficult to judge, since demand for nickel fell by 23% in the three consecutive years following 1979, to what extent a cyclical function should be included.

Major producers INCO and Falconbridge announced the following forecasts for nickel demand in 1983:

INCO [1]	500,000 tonnes	(1.1 billion pounds)
Falconbridge [2]	520,000 "	(1.15 ")

This is more than 10% above 1982's estimated demand of 450,000 tonnes. However, judging from the delay in the recovery seen in the forecast of 1.5% real economic growth for the OECD as a whole and the 2.0% growth forecast for industrial production in 1983, the above view seems to be excessively optimistic.

All the above factors, taken together, suggest that the attainment of the 520,000 tonnes demand forecast by Falconbridge will be delayed by one year, to 1984. Then, on the basis of past cyclical patterns, that demand can be expected to expand greatly from 1984 to 1985. The free world demand for nickel until 1985 is consequently estimated to be:

1982	450,000 tonnes	
1983	470,000 "	(+5%)
1984	520,000 "	(+10%)
1985	570,000 "	(+10%)

5. Medium and Long-term Projections

5.1 Projections by Linear Regression Analysis

Analysis of actual free world nickel demand for the 1965 to 1980 period by linear regression in order to estimate demand in 1990 and 2000 gives figures of 705,000 tonnes for 1990 and 851,000 tonnes for 2000. Incidentally, the projected value for 1985 according to this linear regression analysis is 631,000 tonnes.

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1) Source: Metal Bulletin, December 14, 1982

2) Source: Metals Week, October 18, 1982

For these analyses,

$$y = 322,710 + 14,689.9\, x \quad \text{(tonnes)}$$

y : nickel demand in the x-th year;
x : the year number (with 1965 as 1).

The estimates of linear regression analysis are based on the assumption that past trends will continue into the future. The effect of expected changes in the demand structure is not included.

Furthermore, the wild fluctuations in demand seen since the oil crisis are not necessarily reflected precisely. This is also clear from the fact that, while the forecast for 1985 demand in the previous section was 570,000 tonnes, the forecast made by linear regression analysis is 631,000 tonnes.

5.2 Projections Based on GDP Elasticity

The value for the elasticity of the Free World's nickel demand against income obtained from nickel consumption and the real growth rate of the GDP in the OECD countries were, as shown below, 1.5 from 1965 to 1970 and 0.6 from 1970 to 1980, indicating a nickel decline in the 1970s.

	Average annual growth rate for real GDP in the OECD	Growth of nickel consumption	Elasticity
1965-70	4.7%	7.1%	1.5
1970-80	3.2%	1.8%	0.6

The annual growth rate in the stainless steel production that consumes a large amount of nickel, and the component ratios of Japan and other countries, have been computed from Reference Table D-2 and are shown in the following Table. As this Table shows, Japan's steep expansion of production resulted in a high annual growth rate of 9.0% in the 1960s, but this rate become substantially reduced in the 1970s.

	Free World Total (1,000 MT)	(%)	Japan (1,000 MT)	(%)	Others (1,000 MT)	(%)
1965	3,210	(100)	528	(16.4)	2,682	(83.6)
1970	4,950	(100)	1,643	(33.2)	3,307	(66.8)
1980	6,885	(100)	2,216	(32.2)	4,669	(67.8)
Annual growth rate						
1965-1970	9.0%		25.5%		4.3%	
1970-1980	3.4%		3.0%		3.6%	

The elasticity of nickel consumption against the real GDP of the OECD countries fell in the 1970s. The reasons for this are considered to be:

a. the sluggish growth of stainless steel production,

b. the lowered ratio of primary nickel used in the stainless steel production, although hardly any back-up data for this are available, and

c. the decline in the demand for nickel for plating.

Premises for estimation of the nickel demand in 1990 and 2000 are:

a. the elasticity of nickel demand against the GDP is 0.6, the same as in the 1970s,

b. the annual growth rate of the GDP of the OECD countries after 1985 is given as 2.5% in a pessimistic outlook (Case I), 3.1% in an ordinary outlook (Case II), and 3.7% in an optimistic one (Case III), and

c. the base year for this forecast is set at 1985, when the nickel demand is projected to be 570,000 tonnes (See Clause 4 of this Section).

The reason for the assignment of 0.6 for the elasticity, the actual figure for the 1970s, is that Japan's share in the free world's stainless steel production settled around 33% in the 1970s, following the steep expansion in the 1960s, and it may be assumed that this stability will continue at least through the 1980s. After 1990, the shares of the developing countries, where the growth rates of demand for nickel are now high, will increase, while the growth in the advanced countries is expected to become sluggish, and so it is projected that the elasticity in the free world as a whole will be similar to that in the 1980s.

The projections, based on the above premises, for nickel demand in 1990 and 2000 are summarized in the following Table.

(1,000 MT)

	Case I	Case II	Case III
1990	614	626	636
2000	713	756	790

5.3 Projections Based on Projected Growth Rates for Each Application Field

The following Table shows the demand forecasts for 1990 and 2000, based on the movements in 1980 in each of six application fields: stainless steel, low-nickel alloys, high-nickel alloys, plating, castings, and chemicals and others.

	Stainless Steel	Low-Ni Alloys	High-Ni Alloys	Plating	Castings	Chemical and Others	Total
1990	295	66	151	65	48	48	673
2000	360	80	224	72	52	53	841

The details for each application field are shown in Reference Table G-1. the annual growth rate of the demand for nickel for stainless steel, which accounted for 43% (in 1980) is expected to be 2.5% from 1980 to 1990 and 2.0% from 1990 to 2000. This 2.5% value for the period from 1980 to 1990 is the result of multiplying 3.1% [1], the projected growth rate of the real GDP of the OECD countries during the same period, by the elasticity of 0.8 (the actual figure from 1976 to 1980). As a result, the projected growth rate for this period is the same as the growth rate achieved in the production of stainless steel from 1976 to 1980. The annual growth rate of 2.0% from 1990 to 2000 has been derived from the anticipation of a somewhat lowered growth rate, with reference to past trends, for the production of stainless steel in the future.

1) This figure of 3.1% comes from that for the ordinary outlook (Case II) for the growth rate of the GDP of OECD countries stated previously.

	Production of stainless steel	Real GDP	Elasticity
1970-80	3.4%	3.2%	1.1
(1970-76	4.0%	3.4%	1.2)
(1976-80	2.5%	3.0%	0.8)

In contrast with stainless steel, a growth in demand can be expected for high-nickel alloys (including super-alloys), which in 1980 held a 20% share of the overall consumption of nickel. This expectation, combined with other relevant factors, suggests that the annual growth rate will be 3.5% in the 1980s and 4.0% in the 1990s in this field. The annual growth rate for plating is expected to be 1%, because of the widespread view that the substitution has been completed in the main. A 1-2% annual growth rate is anticipated for low-nickel alloys, castings, and chemicals and others.

Comparison of the expected consumption structure for 2000 with that for 1990, based on the above estimation, indicates that the share should level off at 43% for stainless steel, rise from 20% to 27% for high-nickel alloys, but fall by one to two percentage points from each of the other application fields. The overall annual growth rate is projected at 2.3% in the 1980s and 2.2% in the 1990s.

5.4 Summary

To summarize, the projected demands above fall into the following ranges: (See Reference Fig. G-2)

1990	614,000 - 705,000 tonnes
2000	713,000 - 851,000 tonnes

For both years, the linear regression analysis forecast in Item 5.1 above is the largest and the Case I forecast (the low case) in Item 5.2 is the smallest.

There was no conclusive reason for selecting the base year or the elasticity in any of the forecasts. In the light of present conditions, even forecasting the GDP is not without its problems. Making medium and long-term forecasts is risky at the present juncture when the movement of future demand trends is extremely unclear. The following forecasts are made taking these points into account, and omitting the maximum and minimum values discussed above:

	Forecast range (1,000 MT)	Mean value (1,000 MT)	Growth rate (median value)	
1990	626 - 673	650	1980-1990	1.9%
2000	756 - 841	798	1990-2000	2.0%

In other words, the forecast for Case II in Item 5.2 is the lower limit, and the forecast in Item 5.3 the upper limit.

II. Supply and Demand Balance Projections

1. Short-term Outlook for New Projects

Commercial production began in 1982 at Cerro Matoso in Colombia (ferro-nickel), Kavadarci in Yugoslavia (ferro-nickel), and Tocantins (nickel metal) and CODEMIN (ferro-nickel) in Brazil. Cerro Matoso's production capacity is 23,000 tonnes of nickel per year, Kavadarci's production capacity is 5,300 tonnes of nickel per year, and Tocantins's and CODEMIN's production capacities are each 5,000 tonnes of nickel per year.

Kavadarci is planning a second line, and it is expected that it will reach a capacity of 22,000 tonnes of nickel per year in the future. In addition, there are plans to construct a smelter to produce 7,000 tonnes of Class II nickel per year funded with INCO and Taiwanese capital. These plans aim to replace Taiwan's imported nickel and have a high possibility of being realized in the near future. There are other projects such as an Indonesian ore (P.T. Pacific's Gag project) and one in New Caledonia (COFREMI), but there is little expectation that they will be developed in the near future.

2. Changes in the Supply Structure

Before 1960, the three main producers, INCO, Falconbridge, and SLN, accounted for 90% of free world production. Since the beginning of the 1960s, consumption has increased steadily, but in addition to the main producers' delay in meeting the increased demand there were strikes at INCO in 1966 and 1969. Since the latter half of the 1960's, periodic supply shortages have continued.

Against this background, Amax, WMC, Marinduque, the Greenvale project, and other organizations have entered the market one after another; and this new production capacity along with the production capacity expansion of the existing producers are factors in the creation of today's excess supply. Moreover, in the present production structure, even within the free world, there are producers who receive government aid such as Marinduque, ANTAM, Outokumpu, SLN and Larco, and such a structure has diminished the flexibility required for adjusting supply to reduced demand.

The centrally planned economies have more than a quarter of the supply capacity of the world. Its exports to the free world since 1978 have been about 30,000 to 40,000 tonnes per year and are expected to reach 80,000 to 90,000 tonnes per year. The centrally planned economy bloc is increasing production with no reference to world supply and demand trends. Because of this, the ability of supply to adjust to reduced demand is being depleted further all over the world. These changes in the supply structure will exert strong and diverse effects on future supply and price trends.

3. Order for Expanding Supply Capacity

New production capacity would be neither planned nor implemented until the rate of operation becomes 90% for the nominal production capacity. Considering production costs (shown in Item D.III.4) and the estimated initial costs, the order for increasing production capacity would be:

a. Expansion of facilities processing sulfide ore.
   (Canada, Australia, etc.)

b. Expansion of facilities processing laterite ore.
   (New Caledonia, Colombia, Indonesia, Yugoslavia, etc.)

c. Development of new sulfide ore deposits.
   (Canada, Australia, etc.)

d. Development of new laterite ore deposits.
   (New Caledonia, Indonesia, Brazil, etc.)

4. Supply and Demand Balance

As reported in Subsection G-I, the future free-world demand is forecast to be 570 thousand tonnes in 1985, 650 thousand tonnes in 1990, and 797 thousand tonnes in 2000.

However, the current supply capacity is 807 thousand tonnes with the nominal, and 690 to 720 thousand tonnes with the immediately effective, production capacity. Even if Falconbridge Dominicana should close permanently by 1985, Taiwan's smelter is expected to be operating by that time, thus the nominal production capacity of 784 thousand tonnes can be expected in 1985.

The effective production capacity at that time, though difficult to estimate, as stated previously, can be expected to be 697 thousand tonnes, if changes are limited only to the smelters of Falconbridge Dominicana and Taiwan. This means that the demand in 1985 will not even take up the effective production capacity, so that the continuation of adjustment of production on the supply side is necessary. Nevertheless, in view of the increasing supply inflexibility discussed earlier, it is obvious that an over-supply will continue until 1985. Because the forecast demand in 1990 is 650 thousand tonnes, there is no doubt that such a glut pattern will exist unless some facilities are demolished or permanently closed.

The projected demand of around 800 thousand tonnes in 2000 is roughly equivalent to the present nominal production capacity, if the current supply pattern lasts until 2000. On the assumption, the simplest measure for expanding the supply capacity, i.e. the reopening of idle facilities, is a sufficient addition to the supply to satisfy demand in the 2000s. Thus, a sufficient supply capacity in fact already exists to meet the annual demand until 2000.

Attention must also be paid to the possibility that a quantity of over 100 thousand tonnes of nickel may flow into the free world before 2000, due to the potential production capacity in the planned economy bloc. On the other hand, because it is against sound economic principle for a producer to operate while holding such facilities idle until year 2000, it may be realistic to anticipate that the production capacity will settle at a good supply-demand balance in 2000, through a process by which the less competitive facilities are gradually abandoned, while the inflow from the planned economy bloc is consumed. However, whether such circumstances will come about, though commonsense suggests that they will, is uncertain, since the incidence of government-assisted production capacity discussed previously and the policy decisions of each nickel producer is highly unpredictable.

Thus, the supply and demand will proceed in a roughly balanced state until 2000, unless one of the following situations occurs:

a. A continued growth exceeding the projections of this report, bringing about a deficiency in supply.

b. Excessive disposal of facilities by producers which may arise if all producers anticipate the previously stated long-term forecast, i.e., an occurrence of over supply, resulting in short supply.

However, a trend towards reinforcing existing facilities or towards building new plants for production may arise in the 1990s, because the demand will be over 90% of the nominal production capacity, whereby expansion of the production capacities will be put into force according to the order described previously.

Reference Table G-1 Forecasts for Nickel Demand Based on Estimates of Growth in Each Use Field

	Stainless steel	Low-nickel alloys	High-nickel alloys	Plating	Foundry	Chemicals and others	Total
1980 Consumption structure	43%	10%	20%	11%	8%	8%	100%
Amount of consumption (1,000 tonnes)	230.8	53.7	107.4	59.1	43.0	43.1	537.1
Annual growth rate from 1980 to 1990	2.5%	2.0%	3.5%	1.0%	1.0%	1.0%	2.3%
1990 Consumption (1,000 tonnes)	295.4	65.5	151.5	65.3	47.5	47.6	672.8
Consumption structure	44%	10%	22%	10%	7%	7%	100%
Annual growth rate from 1990 to 2000	2.0%	2.0%	4.0%	1.0%	1.0%	1.0%	2.2%
2000 Consumption (1,000 tonnes)	360.1	79.8	224.3	72.1	52.5	52.6	841.4
Consumption structure	43%	9%	27%	9%	6%	6%	100%

Basis of calculations for 1980 consumption

(1) Stainless steel

Free world stainless steel production		Ratio of nickel containing stainless steel (austenitic)		Nickel content		Ratio of primary nickel*		Nickel demand	(* Portion other than scrap)
6,885,000 tonnes	x	70%	x	9%	x	53.2%	=	230,800 tonnes	

(2) Plating

(1,000 tonnes)

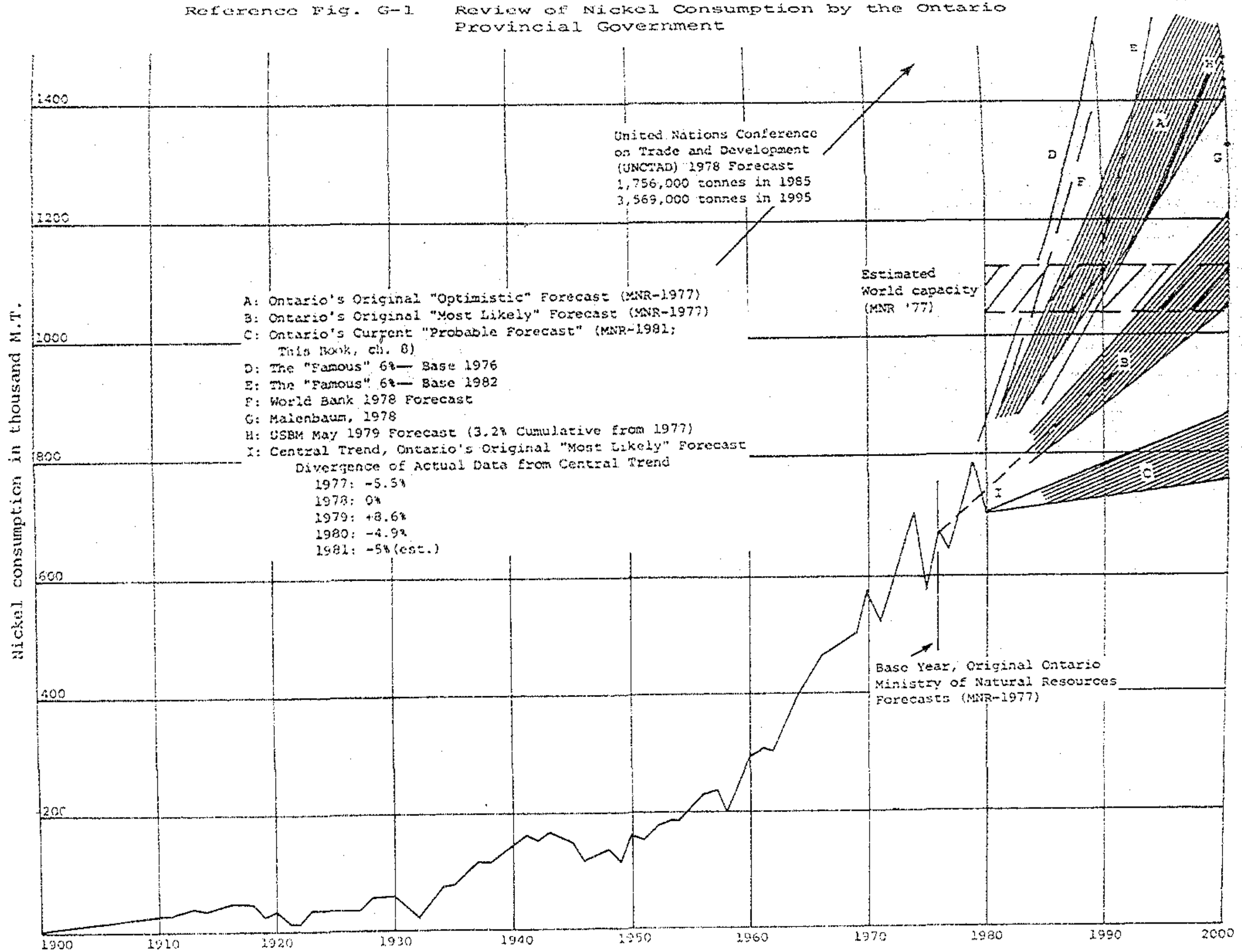
	USA			Japan			USA-Japan weighted average		
	Total nickel consumption	Consumption for plating	Ratio (%)	Total nickel consumption	Consumption for plating	Ratio (%)	Total nickel consumption	Consumption for plating	Ratio (%)
1978	164	24.8	15.1	99	9.0	9.1	263	33.8	12.9
1979	178	25.9	14.6	132	6.7	5.1	310	32.6	10.5
1980	142	17.0	12.0	122	5.7	4.7	264	22.7	8.6
1981	131	20.2	15.4	105	6.6	6.3	236	26.8	11.4
								Average:	10.9≒11%

Free world nickel consumption		Ratio of plating nickel		
537,100 tonnes	x	11%	=	59,100 tonnes

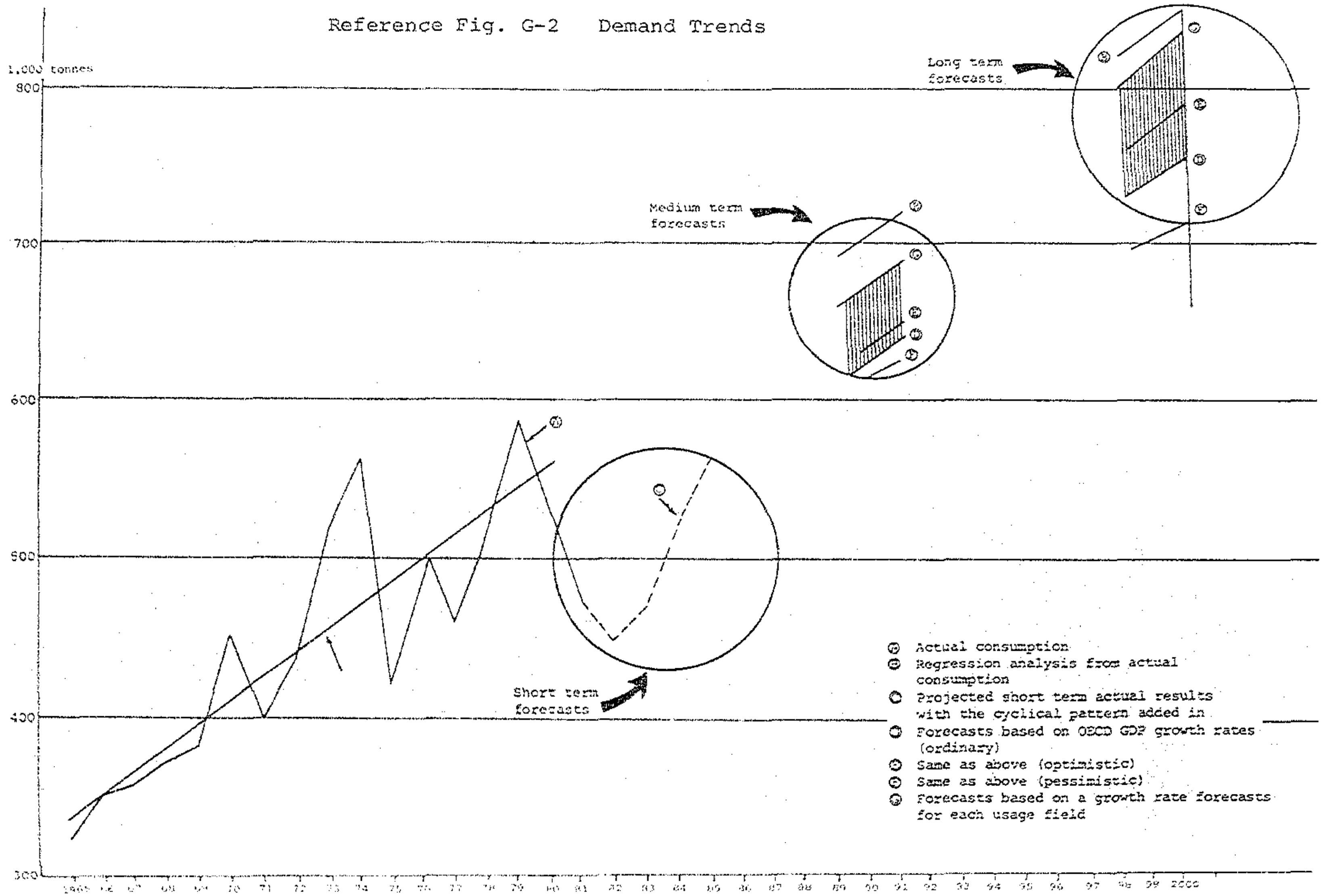
(3) Others

Calculations are based on estimates of ratio made by [illegible] Ltd. The differences are adjusted [illegible]

Reference Fig. G-1 Review of Nickel Consumption by the Ontario Provincial Government



Reference Fig. G-2 Demand Trends



II. CONCLUDING REMARKS

It is necessary to comprehensively investigate relevant domestic and foreign factors and determine the profitability of a nickel development project in Brazil's Carajas region. Many elements are important in determining the competitiveness of the nickel product output: the amount of ore reserves, its grade, the availability of byproducts in the deposit to be developed, the process to be employed and the incidental environmental measures, the degree of infrastructural development necessary, the transport routes, the condition of electricity supplies, the amount of investment, the production and transport costs, etc.

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[3] COBALT

[3] COBALT

CONTENTS

[3] COBALT

A. AN OUTLINE OF COBALT

I. Properties of Cobalt

Cobalt is a hard, magnetic metal. Its fracture is silvery white. Cobalt resembles iron and nickel in appearance and, like iron and nickel, is a ferromagnetic substance. Its magnetic permeability is about 2/3 of iron's. When it is alloyed with iron, nickel, or other metals, it gives rise to powerful magnetism. In chemical characteristics, cobalt resembles iron and nickel. When finely powdered cobalt is heated in air, it gives off flames and oxidizes. However, cobalt ingots are not corroded by oxygen or water below about 300°C, differing from the characteristics of iron and nickel on this point. Alloys are made by combining cobalt in various proportions with iron, nickel, manganese or chrome.

II. The History of Cobalt

Cobalt has been known since ancient times more as a pigment that imparted a blue color to items such as pottery and glass than as a metal. Cobalt salts give a blue color to pottery and when combined with nickel, chrome, or manganese compounds, items with any shade of blue or green color are possible.

The cobalt used nowadays was first extracted from the ore in 1742 by the Swedish scientist, Brandt. He gave it the name "Cobalt", which is said to come from the Greek word "Cobalos", meaning a mine.

In the first half of the 19th century, cobalt was produced in Germany, Hungary, Norway, and elsewhere. Cobalt ore containing large amounts of silver was discovered in Canada's Ontario Province in 1903. In 1920, the Union Miniere du Haut Katanga (nowadays' the Gecamines Corp.) was established in the Belgian Congo (now, Zaire) and in 1924 first began to extract cobalt from copper-cobalt ore. Few years later this company became the world's largest producer of cobalt. Even now, Zaire is the world's largest producer of cobalt.

III. Types of Cobalt Minerals

The average amount of cobalt in the earth's crust is 10 to 25 ppm. The rocks with the highest concentration of cobalt are ultra basic rock (270 ppm) and basic rock (40 ppm).

Over 70 varieties of cobalt minerals are known, but in only a few of these cobalt is the main element. Most of them are minerals of iron, nickel, copper, zinc, etc. that contain some cobalt. The main minerals that are economically important are carollite, linnaeite, cobaltite, smaltite, skutterudite, and heterogenite. Reference Table A-1 shows the main cobalt minerals.

IV. Extractive Metallurgy of Cobalt

Extractive metallurgy of cobalt may be classified into the following:

a. Cobalt recovery from copper cobalt sulfide and oxide ores;
b. Cobalt recovery from material recovered during nickel refining;
c. Cobalt recovery from cobaltferous pyrite (as is carried out by the Outokumpu Oy of Finland);

Method a. produces cobalt and copper together but the ore used has few impurities and it is easy to separate the copper and the cobalt. About 60% of the world's cobalt is produced in Zaire and Zambia using this refining method.

Method b. comprises high-level technology and complicated refining techniques made necessary by the extraordinarily close resemblance of the chemical characteristics of nickel and cobalt. There are many ramifications developed within this method. Nickel and cobalt are produced together; about 30% of the world's cobalt is produced with this method.

1. Cobalt recovery from Copper-Cobalt Sulfide and Oxide Ores

Cobaltferous copper oxides and sulfide ores are concentrated through floatation. The average grade of concentrates is 24.0% copper and 2.0% cobalt for oxides and 43.0% copper and 2.5% cobalt for sulfides. Oxide concentrates have a higher proportion of cobalt. Copper-cobalt sulfide concentrate is roasted into oxides in a fluidized roaster. These calcined oxides and the copper-cobalt oxide concentrate are loaded into a leaching tank and the copper-cobalt is leached out with spent copper electrolyte and sulfuric acid. The product solution is separated from the leaching residue and sent to the copper electrolysis step where copper is electrowon.

Some of the spent copper electrolyte is sent to the leaching tank. Most of it is sent to the next purification step, where aluminum, iron, copper and other metals are removed. Pure cobalt hydroxide is separated from the purified solution using lime. This cobalt is dissolved with the spent cobalt electrolyte to form cobalt sulfate from which cobalt is extracted electrolytically. Reference Fig. A-1 is a flowsheet of this process.

2. Cobalt Recovery from Material Recovered during Nickel Smelting

2.1 Sherritt Gordon Process

This process uses techniques developed by Canada's Sherritt Gordon Mines Ltd. Company mainly to separate and recover nickel and cobalt from byproducts of nickel smelting. Besides the Sherrit Gordon Mines Ltd., this process is now employed by the Amax Company of the United States and the Outokumpu Oy of Finland.

The main raw materials are mixtures of nickel-cobalt oxides and sulfides produced when the cobalt impurities are removed during nickel smelting and refining steps. The nickel-cobalt mixed sulfides are dissolved with pressure oxidative leaching and the nickel-cobalt mixed oxides are dissolved with sulfuric acid solution using reduction agents to form a mixed nickel-cobalt sulfate solution. The iron impurities in the solution are removed as hydroxides through pH adjustment with ammonia. The copper and zinc impurities are removed as sulfides with hydrogen sulfide. After the impurities are removed, ammonia is added to the nickel-cobalt sulfate solution to form complex ammonia salts of nickel-cobalt which are then pressure oxidized with air in an autoclave. After this, sulfuric acid is added and the nickel is separated from the cobalt as complex nickel salt crystals. Cobalt powder is added to the nickel free solution and after the cobalt in the solution has been converted to the cobaltous iron, it is pressure reduced with hydrogen gas in an autoclave to form cobalt powder. Reference Fig. A-2 is a flowsheet of this process.

2.2 Solvent Extraction Methods

2.2.1 The Sumitomo process

The Sumitomo Metal Mining Co., Ltd. of Japan takes as the main raw material mixed nickel-cobalt sulfide arising when the Marinduque Mining and Industrial Corp. of the Philippines extracts nickel from laterite ore and lesser quantities of the nickel-cobalt precipitate produced through its own nickel refinery. The mixed nickel-cobalt sulfide is slurried in water. Then it is turned into nickel-cobalt sulfate solution with pressurized air in the autoclave. Next, in the purification stage, the manganese and iron impurities are removed as precipitate by utilizing the nickel-cobalt precipitate produced in Sumitomo's nickel refinery as oxidant. Copper and some zinc are removed as sulfides hydrogen sulfide.

The purified mixed sulfate solution is converted into an nickel-cobalt mixed chloride solution by a solvent extraction method that uses tertiary carboxylic acid as an organic extractant. This is because the nickel and cobalt can be separated more thoroughly in a chloride solution. The mixed chloride solution is separated into nickel chloride solution and cobalt chloride solution with a solvent extraction method that uses tertiary amine as an organic extractant. Cobalt and nickel are electrowon from their respective chlorides solutions. The chlorine released during electrolysis is reproduced as hydrochloric acid and recycled to the solvent extraction process. Reference Fig. A-3 is a flowsheet of this process.

2.2.2 The Nippon Mining process

The Nippon Mining Co., Ltd. of Japan produces cobalt and nickel by processing mixed nickel-cobalt sulfide produced during refining of nickel from laterite ore at the Greenvale mine in Australia. The mixed nickel-cobalt sulfide is slurried. Then mixed nickel-cobalt sulfate solution is formed by pressurized air in an autoclave. Next, in the purification step iron is removed as precipitate by oxidizing with air, and the copper is removed as copper sulfide with sodium hydrosulfide, and also the zinc is removed with a solvent extraction method that uses D2EHPA as an organic extractant.

The cobalt is extracted from final purified solution with a solvent extraction process that uses alkyl-phosphonic acid as an organic extractant and stripped into cobalt sulfate solution. After the cobalt is separated, the nickel is extracted as a nickel sulfate solution from the raffinate with a solvent extraction method that uses L1X64N as organic extractant. Cobalt and nickel are electrowon from their respective sulfate solutions. Reference Fig. A-4 is a flowsheet of these process.

3. Cobalt Recovery from Cobaltferous Pyrite

The Outokumpu Oy smelts cobalt at its Kokkola refinery using iron-cobalt concentrate produced from cobaltferous pyrite from its own mine, blast furnace residue that is a byproduct of German Democratic Republic copper smelting, and cobalt precipitate from nickel refining as the raw materials.

Blast furnace residue [1] is converted into ferrous sulfate through the combined processing of weak acid leaching, alkaline leaching and strong acid leaching. Iron cobalt concentrate and the ferrous sulfate are sulfate roasted in a fluidized roaster, then leached with water. After the iron is removed from the leached solution by the Jarosite process and the copper and zinc are removed with hydrogen sulfide, the nickel-cobalt is all precipitated from the solution with hydrogen sulfide as a mixture of nickel-cobalt sulfides.

The mixture of nickel-cobalt sulfides, along with the cobalt precipitate from nickel refining, is pressure leached in an autoclave, to obtain a nickel-cobalt sulfate solution. Subsequent refining uses the Sherrit Gordon process.

V. Standards for Cobalt Products

The standards of the major cobalt producers are shown in Reference Table A-2. There are standards for shapes such as electrolytic cobalt, granules, briquettes and powders. As for chemical components, 99% minimum cobalt is general.

There are standards for compounds such as cobalt oxide (black or gray), cobalt hydroxide, cobalt sulfate, cobalt carbonate, and cobalt chloride. They contain from 20 to 76% cobalt.

There is also a cobalt intermediate product, cobalt-nickel mixed sulfide, which is a raw material for cobalt producers in Canada, Finland, Japan, and elsewhere. The producers of this mixture and its composition are:

	Nickel	Cobalt	Iron	Copper	Sulfur
Marinduque (the Phillipines)	25%	12%	2.6%	1.5%	25%
Greenvale (Australia)	37	15	0.8	0.7	34

There are no national or international standards for cobalt.

1) Blast furnace residue: A by-product of copper smelting, i.e., a cobalt-containing deposit of which the main constituent is the iron produced in the bottom of copper blast furnaces.

VI. Uses for Cobalt

1. Heat and Corrosion Resistant Alloys

Heat and corrosion resistant alloys are divided into cobalt alloys, nickel alloys, iron alloys, and chromium alloys. Because each family of alloys has superior physical and chemical properties, they are used as materials in gas turbines, aircraft engines, thermal power and atomic-power generations. Some representative cobalt-containing alloys are stellite (42-66% cobalt), multimet (20% cobalt), and hastelloy (2.5% cobalt).

2. Hard Metal and Abrasion Resistant Alloys

Because cobalt bonds metal carbides such as tungsten carbide, titanium carbide, and tantalum carbide, it is mixed with these metal carbides in proportions ranging from 4 to 30%. These alloys are primarily used for abrasion and corrosion resistant components of cutting tools, mining tools, engines and so on.

3. Magnetic Alloys

The magnetic materials used in the electric and electronic industry are classified into those composed mainly of cobalt and nickel and those in which cobalt is an additive. The cobalt-based permanent magnets are the alnico series cast magnets (6-42% cobalt), the rollable iron-cobalt-chromium series magnets (15-20% cobalt), and the rare earth-cobalt series magnets (65-80% cobalt) that revolutionized magnetic properties. As the coercive force of magnetic materials is raised by adding cobalt for high-density recording, such materials are used as magnetic tape.

4. High-Speed Steel

In the high-speed steel field, cobalt is added to steel mainly to increase heat resistance. There are molybdenum type and tungsten type alloys, with a cobalt content of 4 to 20%. Because their cutting capacity is extremely superior, they are used as tool steel. The alloy appropriate to the use is selected.

5. Others

Cobalt is used as a component of desulfurizing catalyst for heavy oil along with nickel, molybdenum. Cobalt is also used as dryer in ink and paint, as pigment for cosmetics and pottery, and as material for plating and animal feed, etc.

Reference Table A-1 A List of the Main Cobalt Minerals

Mineral	Chemical Formula	Co %	SC	Notes
Sulfides				
cobaltite	CoAsS	28.0~32.4	6.3	Fe max. 10%, commonly in high-temperature deposit; Canada
linnaeite	Co_3S_4	40.0~58.0	4.5~4.8	Cu, Ni, Fe contents common; Sweden, Congo, USA
siegenite	$(Co,Ni)_3S_4$	20.0~26.0	4.5~4.8	polymorph of violarile and polydymite
carrollite	Co_2CuS_4	35.0~38.0	4.5~4.8	rare mineral; Maryland USA, Zaire, Zambia
Arsenides				
safflorite	$(Co,Fe)As_2$	13.0~19.0	6.9~7.3	in mesothermal vein; Germany, Sweden, Canada, Morocco
skutterudite	$(Co,Ni)As_3$	11.0~21.0	6.5+0.4	Sudbury Canada, USA, Germany
smaltite	$(Co, Ni)As_{3-x}$	13.0~24.0	6.5+0.4	Canada, Chile
glaucodot	(Co,Fe)AsS	17.0~31.0	6.0	Sweden, Norway, Australia, USA
badenite	$(Co,Ni,Fe)_3(As,Bi)_4$?		7.1	rare mineral; Romania
Oxides				
asbolane(earthy	cobalt) +Co	0.5~5.0	2.8~4.4	kind of wad
heterogenite	(Co,Cu)O.OH	54.0~64.1	3.1	Zaire, Zambia
cobaltcalcite	$CoCO_3$	43.8~63.0	4.1	Zaire, USA, Germany, Italy
earthrite	$(Co,Ni)_3(AsO_4)_2 \cdot 8H_2O$	18.7~26.8	3.1	secondary mineral; Canada, USA
stainierite	CoO(OH)	64.1	4.4	secondary mineral; Zaire, Nevada USA
bieberite	$CoSO_4 \cdot 7H_2O$	21.0	1.9	secondary mineral; Zimbabwe, Chile, USA
Others				
pyrrhotite	$(Fe,Ni,Co)_{1-x}S$	~1.0	4.6	Sudbury Canada
pentlandite	$(Ni,Fe,Co)_3S_4$	~1.5	4.6~5.0	Sudbury Canada
pyrite	$(Fe,Co)S_2$	~14.0	5.0~5.1	Uganda, Canada
sphalerite	(Zn,Co)S	~0.3	3.9~4.0	
arsenopyrite	(Fe,Co)AsS	~12.0	5.9~6.2	Canada

Reference Table A-2 Product Standards of Main Cobalt Products

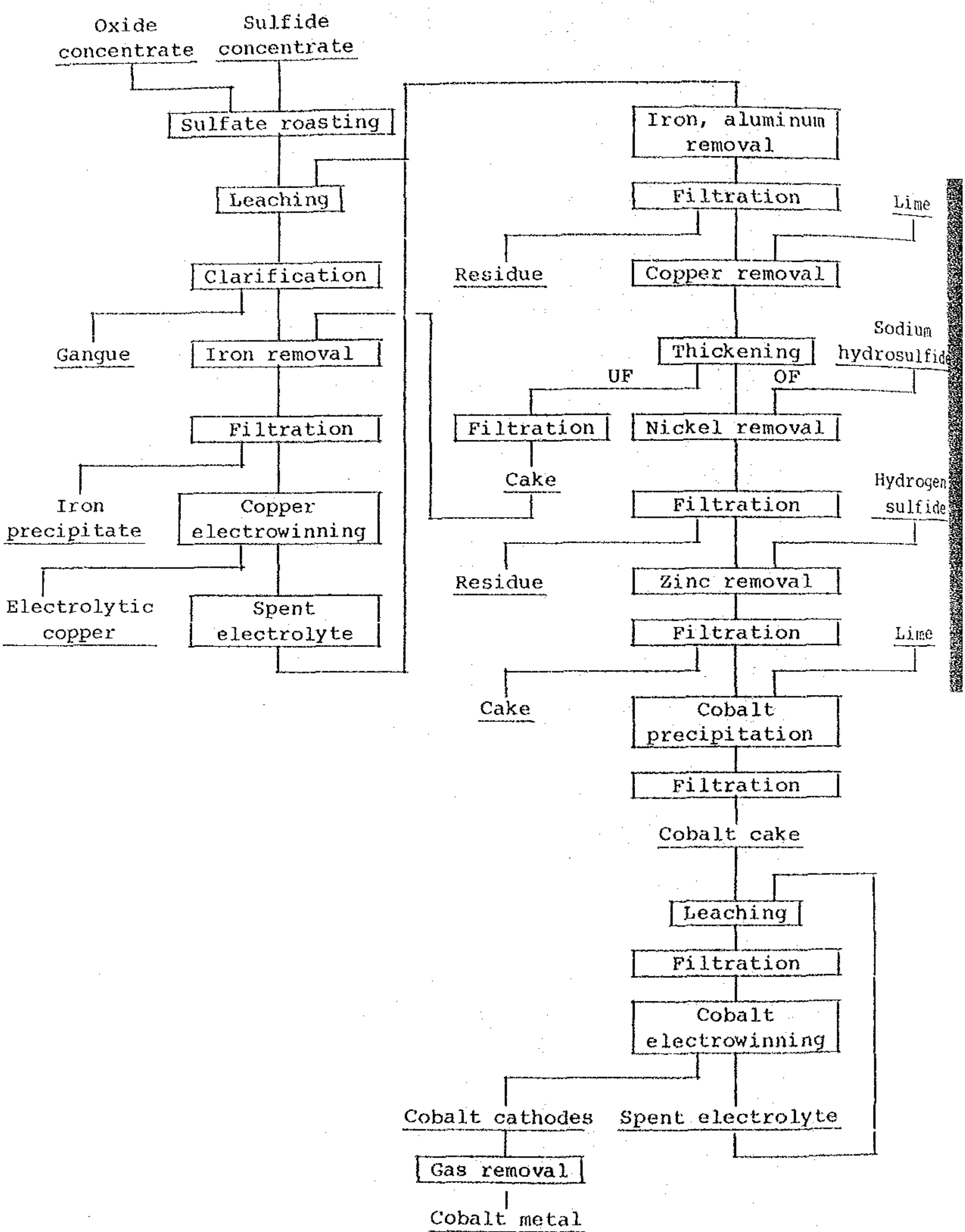
(Cobalt metal)

Producer	Country	Type	Co	Ni	Fe	Mn	Cu	Pb	Zn	Si	S
Gecamines	Zaire	Electro(Typical)	99.90	0.040	0.004	0.0007	0.0015	0.0003	0.0030	0.0010	0.0010
		Granules(Typical)	99.50	0.15	0.14	0.013	0.015	< 0.001	0.005	0.025	0.007
M.H.O.	Belgium	Powder (Typical)	99.85	0.045	0.020	0.001	0.002	0.001	0.005	0.004	0.008
Outokumpu	Finland	Powder (Typical)	99.8	0.08~0.12	0.001	0.0001	0.001	0.0002	0.001	-	0.03
Starck	Germany, FR	Powder (Typical)	99.75	<0.6	< 0.05	<0.01	<0.01		< 0.01	<0.03	<0.01
Puk	France	Powder (Typical)	99.8	< 0.02	< 0.01				< 0.50		
Sherritt	Canada	Powder (Typical)	99.9	0.10	0.15		0.002				0.005
		Briquettes (Typical)	99.9	0.10	0.15		0.002				0.030
Nihon Kogyo	Japan	Electro(Typical)	99.98	0.02	0.002		0.001	0.0001	0.0001		
ZCCM	Zambia	Electro(Typical)	99.5	<0.4	0.002	<0.002	0.0015	0.0005	0.0015	<0.001	0.0015
Sumitomo	Japan	Electro(Typical)	99.95	0.04	0.0020	0.0001	0.0040	0.0001	0.0020	0.0003	0.0010

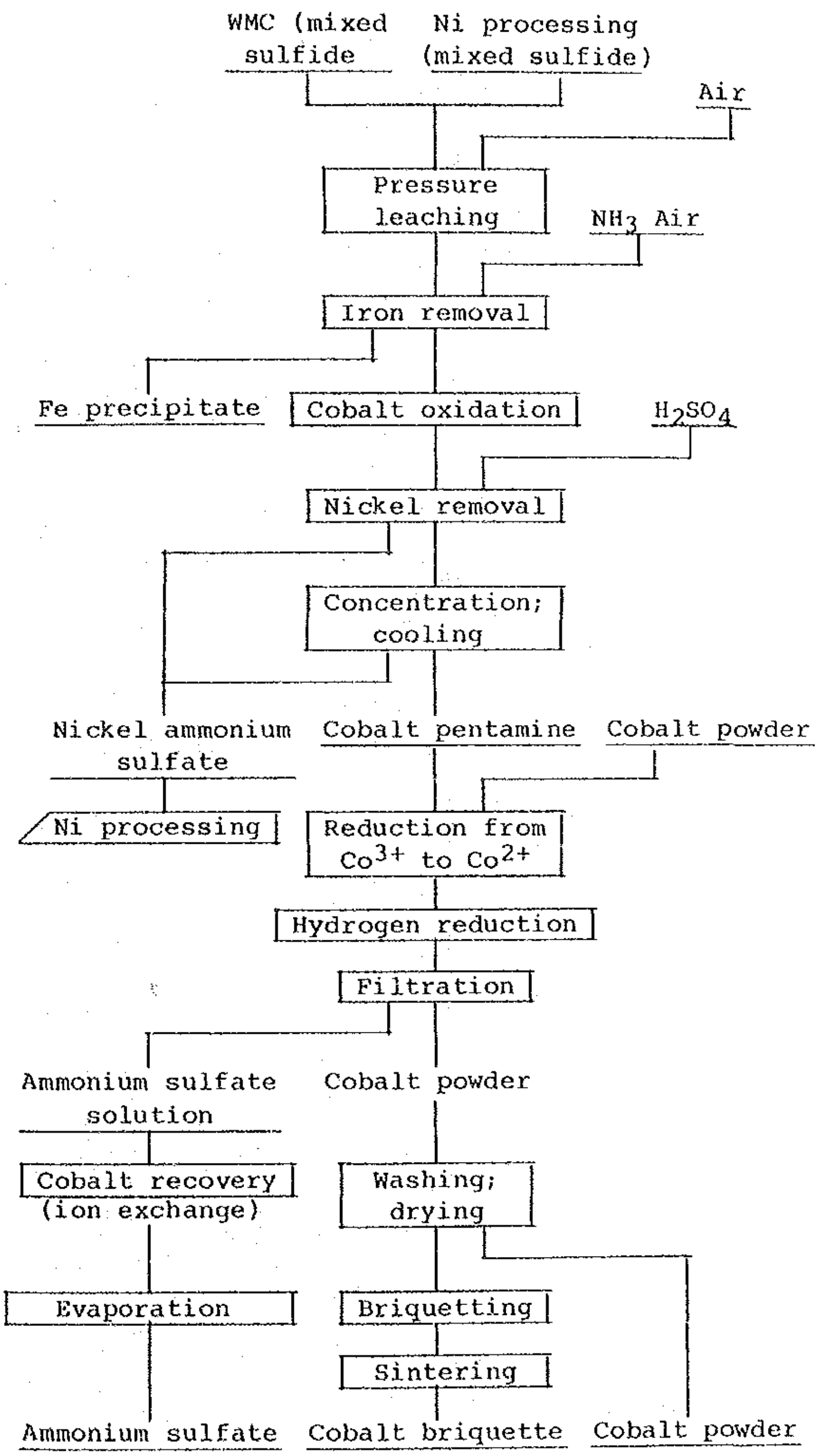
(Cobalt compounds)

Producer	Country	Type	Co	Ni	Fe	Mn	Cu	Pb	CaO	SiO_2	MgO	S
M.H.O.	Belgium		71	0.1	0.08	0.02	0.003	0.01	0.03	0.09	-	0.04
			75~76	0.25	0.05	0.02	0.001	0.003	0.02	0.08	-	0.05
			61	0.2	0.01	0.02	<0.001	0.01	0.04	0.10	0.35	0.20
			24	0.08	0.001	0.003	< 0.001	0.001	0.03	0.004	0.03	0.015
			45~47	0.12	0.02	0.01	< 0.001	0.001	0.25	0.17	0.04	0.18
			24~25	0.01	0.005	<0.001	< 0.001	< 0.001	0.010	0.002	0.001	0.005
			20	0.03	< 0.001	<0.001	< 0.001	< 0.001	0.003	<0.001	0.004	0.002
			21	0.05	0.001	0.002	< 0.001	< 0.001	0.08	0.002	0.07	-
INCO	Canada		71.6	0.8	0.2	0.04	0.012	0.006	0.097	0.063	-	0.076

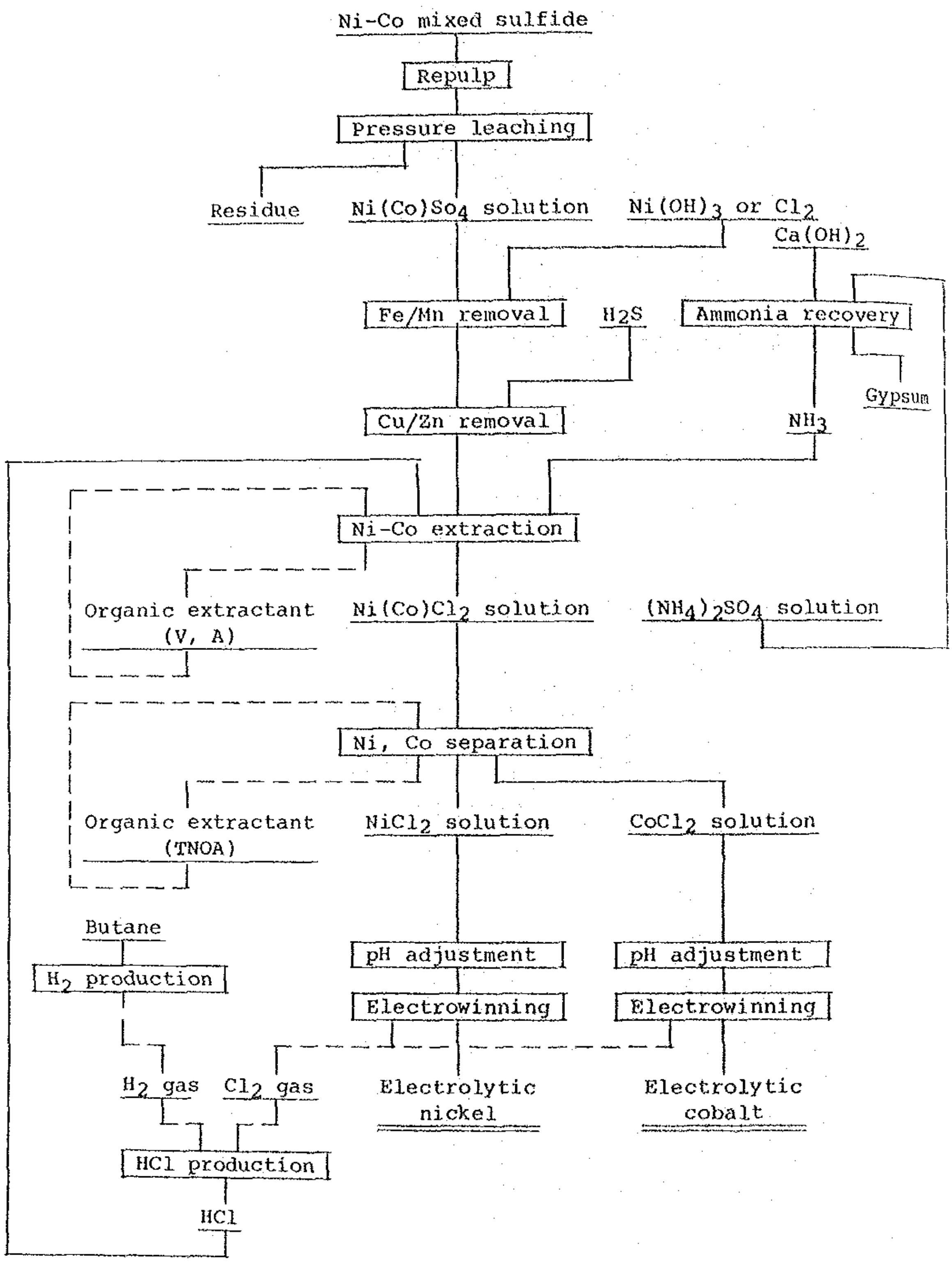
Reference Fig. A-1 Extraction Cobalt from Sulfide or Oxide Ore (Gecamines - Luilu plant)



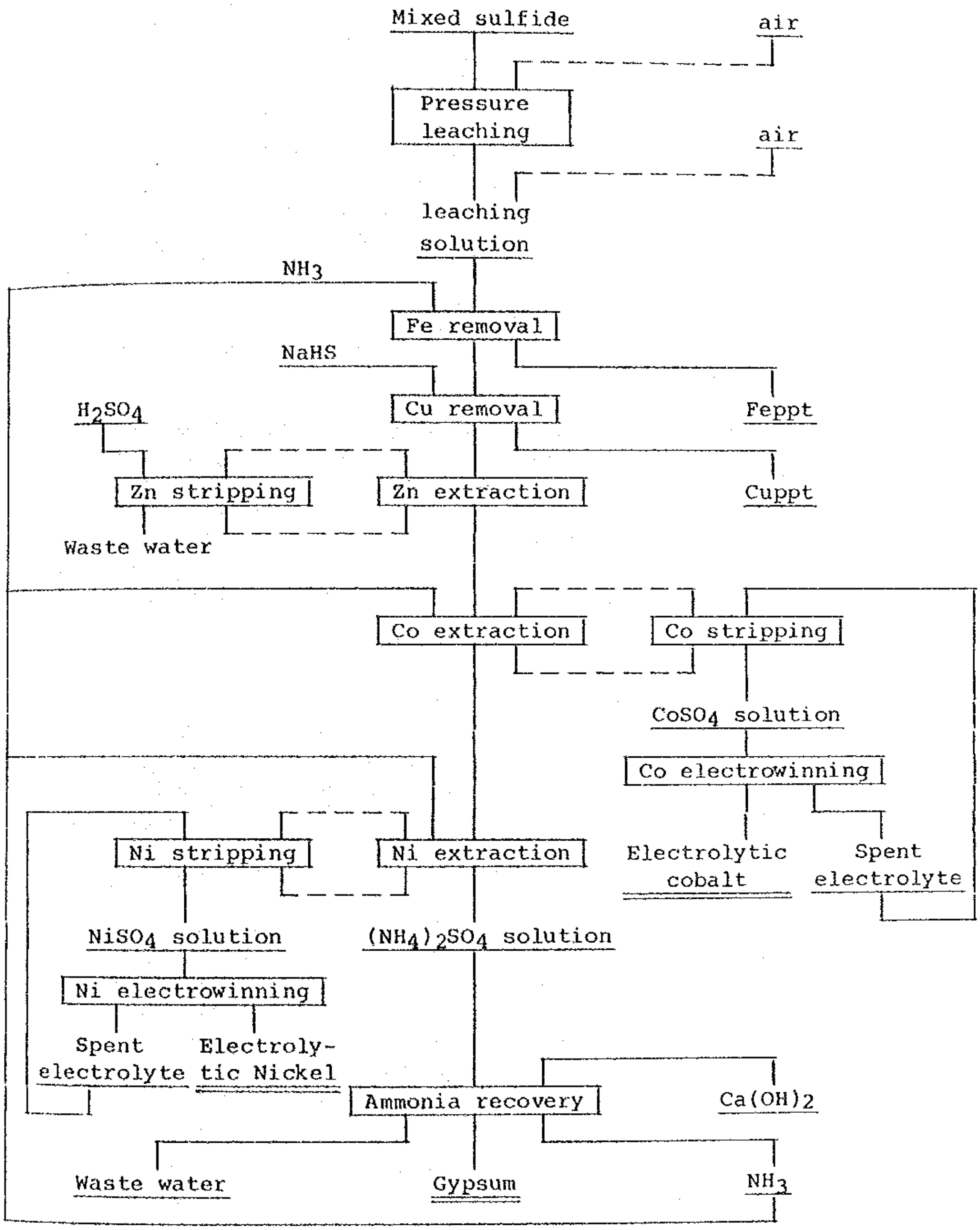
Reference Fig. A-2 Sherrit Gordon Process



Reference Fig. A-3 Sumitomo Process



Reference Fig. A-4 Nippon Mining Process



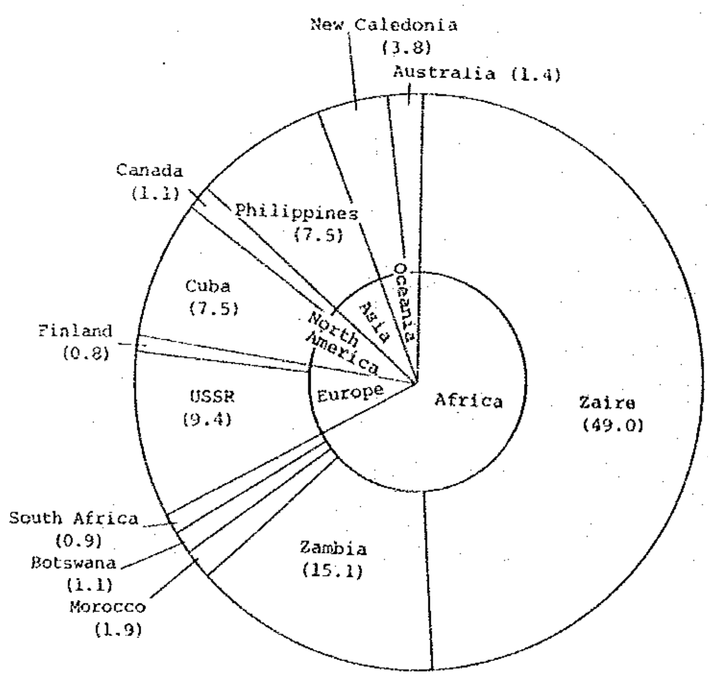
B. GEOGRAPHIC DISTRIBUTION OF RESOURCES AND TRENDS IN MINE PRODUCTION

I. Resources and Reserves

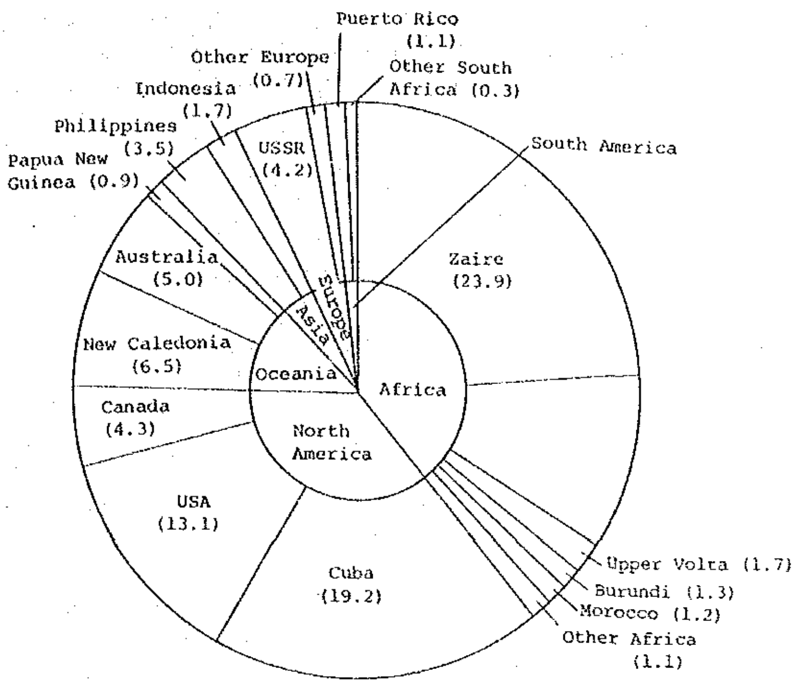
Cobalt is primarily contained in copper and nickel deposits but because it is of minor grade and minor value, its precise grade is not known. Reference Table B-1 contains estimates of cobalt resources based on the 1980 edition of the U.S. Bureau of Mines' Mineral Facts and Problems, and some additional information from other sources.

According to this table, world cobalt resources were estimated at 5.9 million tonnes (excluding manganese nodules on the seabed). About 40% of these resources, i.e. 2.4 million tonnes, are cobalt reserves that can be recovered with current mining and ore processing technology. Looking at the distribution of these 2.4 million tonnes, 64% of them are found in the Copper Belt of Central Africa (Zaire and Zambia). 19% of the cobalt reserves are in laterite nickel deposits in Cuba, the Philippines and New Caledonia. Adding to this the USSR's 11% of reserves gives 94% of the world's reserves. The uneven distribution of cobalt reserves is easy to see. A pair of figures below show the distribution of cobalt resources and reserves by region and by country.

(a) Cobalt Reserves (2,408,500 tonnes)



(b) Cobalt Resources (5,893,900 tonnes



The recovery rate of cobalt that is a recovered as byproduct of copper or nickel ores is low. It is said that only half of the cobalt in the copper dominating deposits in Zaire and Zambia is recovered. Much of lateritic nickel ore, because of the ratio of nickel to iron constituents in it, is used as raw material for ferronickel, in which case cobalt is not recovered as cobalt metal. Thus, of the cobalt reserves, about one half of it, i.e., 1.2 million tonnes, is actually recoverable as cobalt metal.

At first glance, cobalt reserves seem adequate, but if one takes into consideration the low recovery rate, the uneven distribution of producing regions, and the way in which cobalt is dominated by the elements copper and nickel because they are the main constituents in cobalt ore, then it is no longer safe to say that cobalt is necessarily a secure mineral resource.

II. Reserves by Mine and Mine Production by Country

Reference Table B-2 shows the reserves as broken down according to operating mines. This table lists only those mines of which reserves and grade of the cobalt ore is known.

Reference Table B-3 shows mine production by country. The volume of mining production reached a peak of 35,000 tonnes in 1980. Of this, Zaire produced 44.1%; zambia, 12.5%; Australia, 9.2%; New Caledonia, 6.4%; Canada, 4.6%; and the Philippines 4.3%. Add to this USSR's 6.1% and these seven countries accounted for 87.2% of the world total.

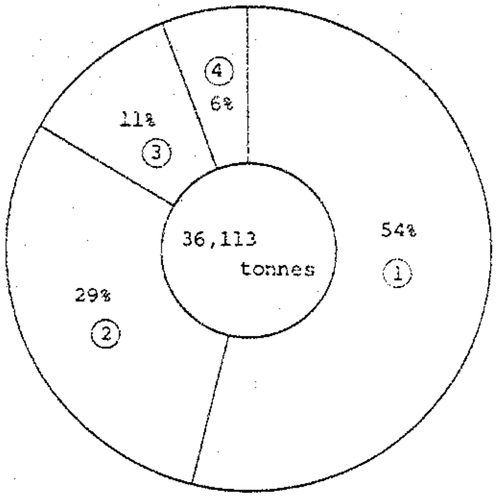
III. Production Results and Reserves by Deposit Type

Classifying cobalt deposits by origin gives the following types:

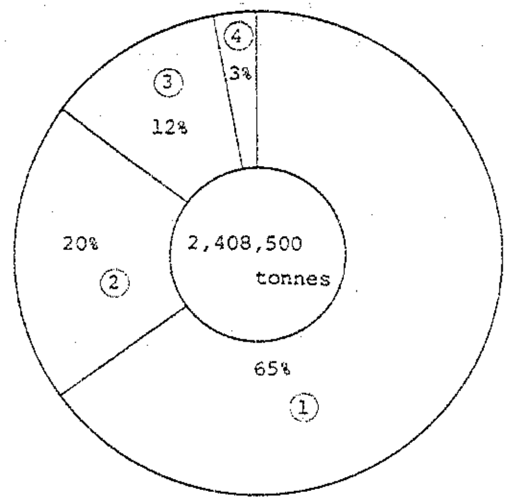
a. sediment-hosted stratiform deposit;
b. lateritic nickel deposit;
c. orthomagnetic deposit; and
d. others, such as volcanogenic massive sulfide deposit, hydrothermal deposit, contact metasomatic deposit.

The following figure shows a breakdown by deposit type: (a) the amount of cobalt mined in 1979; (b) 1979-cobalt reserves; (c) shares of cobalt reserves and resources in 1979.

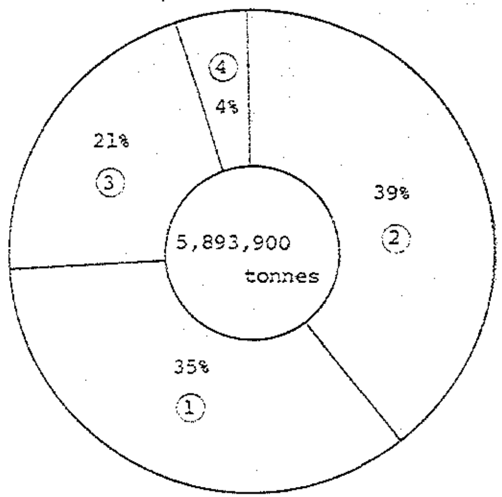
(a) Volume of Cobalt Mine Production by Deposit Type (cobalt metal content)



(b) Volume of Cobalt Reserves by Deposit Type (cobalt metal content)



(c) Volume of Cobalt Resources by Deposit Type (cobalt metal content)



① Sediment-hosted stratiform deposit
② Lateritic nickel deposit
③ Orthomagnetic deposit
④ Volemogenic massive sulfide deposit; hydrothermal deposit; contact metasomatic deposit

Reference Table B-1 Resources and Reserves by Country (cobalt metal content)

	Resources (tonnes)	Reserves (tonnes)
North America		
Canada	254,000	27,200
Cuba	1,134,900	181,400
USA	771,100	0
Subtotal	2,159,000	208,600
South America		
Brazil	4,000	0
Guatemala	16,000	0
Puerto Rico	81,500	0
Subtotal	101,500	0
Europe		
Albania	12,000	0
Finland	22,700	18,200
USSR	249,500	226,800
Yugoslavia	8,000	0
Subtotal	292,200	245,000
Africa		
Botswana	31,700	27,200
Burundi	73,000	0
Morocco	68,100	45,400
South Africa	27,200	22,700
Uganda	8,000	0
Upper Volta	100,000	0
Zaire	1,406,100	1,179,300
Zambia	589,700	362,900
Subtotal	2,303,800	1,637,500
Asia		
Indonesia	101,000	0
Philippines	204,100	181,400
Subtotal	305,100	181,400
Oceania		
Australia	294,800	45,300
New Caledonia	385,500	90,700
Papua New Guinea	52,000	0
Subtotal	732,300	136,000
Total	5,893,900	2,408,500

Notes : 1) Mineral Facts and Problems, 1980 edition data plus data from the information system of Sumitomo Metal Mining Co. Ltd.

2) Reserves: that portion of resources recoverable with current mining and ore processing technology

Source: The U.S. Bureau of Mines

Reference Table B-2 Reserves in Operating Mines

Country	Mine	Ore	Type*	Amount of ore (thousand tonnes)	Co (%)	Co (tonnes)	Ni (%)	Cu (%)	Production capacity (thousand tonnes/year)
Albania	Kukes	Ni, Co	L	20,000	0.06	12,000	1.00	-	1,000
Australia	Agnew	Ni, Co	O	35,000	0.10	35,000	2.20	-	500
	Green Vale	Ni, Co	L	26,691	0.11	29,360	1.28	-	2,000
Botswana	Pikwe Selebi	Cu, Ni, Co	O	37,890	NA		0.096	1.05	2,000
Canada	Falconbridge -Sudbury	Ni, Cu, Co	O	71,815	NA		1.49	0.93	3,000
	Falconbridge								
	Lockerby								
	Strathcona								
	Fraser								
	INCO	Ni, Cu, Co	O	455,414	NA		1.533	0.916	15,000
	Frood Stobie								
	Little Stobie								
	Creighton								
	Coppe Cliffs								
	Garson								
	Levack								
	Coleman								
	Birch Tree								
	Pipe								
	Soab								
Cuba	Moa Bay	Ni, Co	L	50,000	NA		1.45	-	1,500
	Nicaro	Ni, Co	L	300,000	NA		1.35	-	1,600
	Pinar Del Rio	Ni, Co	L	24,000	NA		1.30	-	NA

Reference Table B-2 (cont'd.)

Country	Mine	Ore	Type*	Amount of ore (thousand tonnes)	Co (%)	Co (tonnes)	Ni (%)	Cu (%)	Production capacity (thousand tonnes/year)
Finland	Outokumpu (Keretti)	Cu, Zn, Co, Ni	V	11,000	0.24	26,400	0.12	3.80	450
	Stormi (Vammala)	Ni, Cu, Co	V	6,600	0.025	1,650	0.44	0.71	400
	Vuonos	Cu, Zn, Ni, Co	V	NA	NA		NA	NA	500
	Luikonlamti	Cu, Zn, Co	V	NA	NA		-	NA	450
Philippines	Surigao Nonoc	Ni, Co	L	67,118	0.10	67,118	1.23	-	2,600 3,000
Yugoslavia	Pazanovo	Ni, Co	L	134,000	0.006	8,040	0.90	-	NA
USSR	Talnakh	Ni, Cu, Co	O	NA	0.12		3.20	3.00	
	Burukhtal	Ni, Co	L	NA	0.08		0.88	-	
Zaire	Kamoto (U/G)	Cu, Co	S	82,300	0.35	88,050	-	5.30	
	Kipushi	Cu, Zn, Co	S	16,000	NA			4.50	
	Tenke-Fungrume	Cu, Co	S	59,240	0.41	42,884	-	5.70	
Zambia	Broken Hill	Pb, Zn, Co	S	1,928	NA			-	
	Chibulma	Cu, Co	S	6,800	0.160	10,880	-	4.77	
	Luansha-Baluba	Cu, Co	S	128,000	0.081	03,680	-	2.44	
	Rhokana-Nkana	Cu, Co	S	117,988	0.140	65,183	-	2.35	

* O: Orthomagnetic deposit; L: Lateritic deposit; V: Volcanogenic deposit;
S: Sediment-hosted stratiform deposit

Reference Table B-3 Mine Production by Countries

(Amount of cobalt: tonnes)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Australia	469	311	770	775	1,078	2,708	3,393	3,409	3,393	3,357	3,245
Botswana	0	0	0	6	33	81	150	165	261	294	226
Canada	2,069	1,961	1,520	1,517	1,564	1,354	1,355	1,507	1,234	1,640	1,603
Finland	1,270	1,270	1,270	1,270	1,270	1,401	1,279	1,326	1,296	1,139	1,035
Indonesia	0	0	0	0	0	0	0	91	NA	NA	431
Morocco	604	978	1,602	1,421	1,626	1,961	862	1,561	1,134	961	838
New Caledonia	NA	NA	NA	1,723	1,916	2,053	4,145	4,199	4,172	4,172	2,239
Philippines	0	0	41	41	30	106	514	1,084	1,192	1,370	1,514
South Africa	0	0	0	0	0	0	0	0	91	200	254
USA	316	0	0	0	0	0	0	0	0	0	0
Uganda	0	0	0	0	0	0	0	0	0	0	0
Zaire	13,955	11,998	13,109	15,049	17,628	13,995	10,975	10,521	13,300	15,000	15,500
Zambia	2,399	2,080	3,344	4,299	3,837	2,382	2,177	2,268	3,741	4,280	4,400
Cuba	1,542	1,542	1,542	1,633	1,633	1,633	1,633	1,633	1,600	1,700	1,700
USSR	1,542	1,587	1,633	1,678	1,723	1,769	1,814	1,814	1,950	2,000	2,150
Total	23,850	21,726	24,830	29,412	30,879	30,838	28,296	29,578	33,364	36,113	35,135

Note : Differences arise in calculations due to conversion from pounds to tonnes.

Source: The U.S. Bureau of Mines, Minerals Yearbook, 1980; others

C. PRODUCTION TRENDS AND THE CURRENT SITUATION

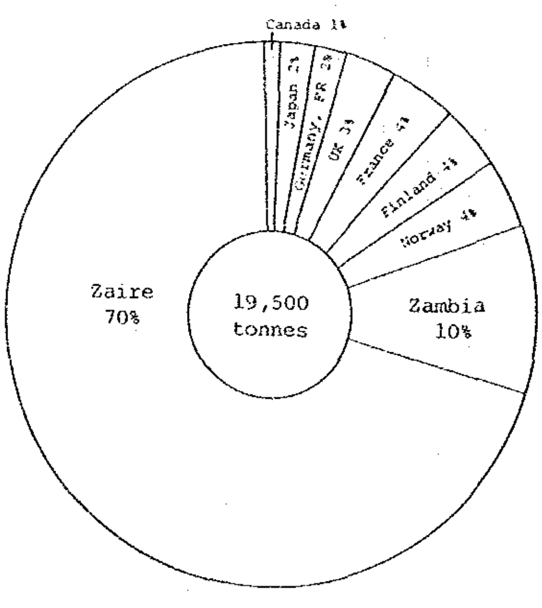
I. Production Trends

Total free world cobalt production increased from 15,450 tonnes in 1965 to 26,500 tonnes in 1980, i.e. 1.7 times the 1965 figure. However, along with the sales decrease that was caused by substitution due to 1979's skyrocketing prices and by stagnant demand due to the prolonged global recession, the 1981 production fell 19% from the previous year to 21,500 tonnes.

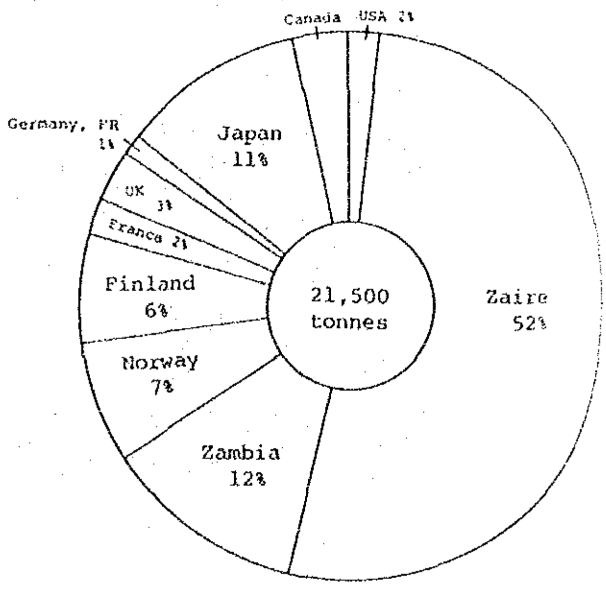
There are no totally reliable statistics to show national-by-nation production since 1965, but the Imetal statistics which are relatively reliable are given in Reference Table C-1.

As can be understood from the table, two African countries, Zaire and Zambia, have always shared among them over 60% of free world production since 1965. In 1974, these two countries' share reached 83%. Also in that year, cobalt production in Zaire peaked at 17,545 tonnes, but fell thereafter because of confusion caused by operation by Zaireans — which had previously been conducted under the guidance of Belgians — after the inauguration of President Mobutu in 1974, and because of problems with the transportation of fuel and supplementary materials due to closure of the Benguela Railway, thither to the shortest route, as a result of the internal strife in neighboring Angola in 1975. In the meantime, Japan entered the ranks of cobalt producers as a newcomer by separating nickel and cobalt from nickel-cobalt mixed sulfides with an excellent solvent extraction process. Presently, Japan's share of production has increased to a little over 10%. Below are shown the production shares for free world countries in 1975 and 1981.

1975



1981



There are no definite figures available for the centrally planned economies. Annual USSR production is estimated to be from 3,650 to 5,800 tonnes.

II. Production Capacity

Reference Table C-2 shows the world's production of cobalt by producing countries, and the capacity of production, kinds of product and locations of the main smelters. Some of the figures for production capacity include capacity to produce intermediary products. Because these intermediary products are turned into final products by other type of production capacity, simply adding up all the production capacity figures will not give the world production capacity. For example, all the nickel-cobalt mixed sulfide produced by the Marinduque of the Philippines is sold to Sumitomo Metal Mining Co., Ltd., which turns it into final cobalt products within its own capacity.

Adjusting for such production capacity that is counted twice, here is an estimate of the current condition of free world capacity to produce refined cobalt.

	Tonnes	Share of production capacity
Canada	1,000	3
USA	500	1
Finland	1,500	5
France	2,000	6
Germany, FR	500	1
Norway	1,500	5
UK	1,200	4
Zambia a)	5,700	17
Zaire b)	16,000	48
Japan	3,100	9
Others	100	1
Total	33,100	100

a) Includes a 2,000 tonne expansion scheduled to be finished in 1983.

b) Includes some Belgian and U.S. production.

Thus, Zaire and Zambia have 65% of the production capacity. Production capacity is concentrated to a high degree in one region - central Africa.

III. Production Cost

1. Summary

Little precise information concerning cobalt production costs is available, and further, since cobalt is usually recovered as a by-product of nickel or copper, the way the costs are imputed to cobalt and the main metal greatly changes the cost of the cobalt production. Estimating the production cost for cobalt is therefore very difficult.

However, we have dared to estimate the cobalt production costs as follows.

Production Cost (US$/lb of cobalt, 1981)

	Production from copper minerals	Production from nickel minerals	
		Laterite ore	Sulfide ore
	(Zaire, Zambia)	(The Philippines, Australia)	(Canada, Australia)
Energy	1.1	2.8	1.0
Chemicals, etc.	0.7	0.7	0.8
Labor costs	0.8	1.1	1.5
Direct costs total	2.6	4.6	3.3
Overhead costs	1.7	1.8	1.8
Total	4.3	6.4	5.1

Source: Estimate of the Working Group

2. Cobalt Production from Copper Ore

Cobalt production from copper ores is the least expensive method because cobalt in the ore can be concentrated by pre-treatment of ore processing and because separating cobalt and copper is relatively easy. Energy costs are said generally to be about 40% of the direct costs.

3. Cobalt Production from Nickel Ore

3.1 Laterite Ore

Smelting and refining cobalt from laterite requires complete pre-treatment such as drying, reduction, and leaching of all low-grade ore. The energy costs are particularly high. Again, production costs of cobalt are affected by the way the cost is shared with nickel. Here, the treatment costs are estimated to be the average cost of nickel treatment. Also, in refining cobalt from the concentrated cobalt precipitate, it needs further cost to separate the nickel and the cobalt. However, this method has the advantage of being able to produce high-grade cobalt products.

3.2 Sulfide Ore

Sulfide ores can be concentrated by dressing, so the energy cost is low, but on the other hand, labor costs are high, partly because the mine is operated by underground mining. However, cobalt is a byproduct of nickel and its cost is greatly affected by how costs are distributed. Here, cobalt is presumed to cost nearly the same as nickel even in nickel production process.

4. Production Costs for New Projects

The sections above gave the production costs for existing mines, but at this point of time, if a new project were to be implemented, the burden of repaying the investment and of paying interest would be enormous.

Suppose a new mine were developed in central Africa. Taking account of the depreciation and the interest on the capital, the production cost per pound of finished product is estimated to be about US$20 at 1980 price or US$24 at 1982 price, even if the income from the copper is credited. This production cost is based on the following premises:

Grade : Cobalt 0.10%, Copper 2.50%
Operation period: 20 years
Recovery rate : Cobalt 30%, Copper 75%

It is also said that the Noranda's Blackbird project in the United States needs cobalt prices of US$20 per pound at 1980 price to generate a 15% D.C.F. rate of return. In any case, it is clear that with today's low cobalt prices, projects to be newly undertaken will not pay.