Nickel Handbook

Commodities and Export Projections Division
Economic Analysis and Projections Department

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I. THE CHARACTERISTIC OF THE PRODUCT

A. Nickel Properties and Nickel Alloys

1. Nickel shares some properties with iron: high melting p nt, strength, hardness and magnetism. However, nickel is superior to iron in its a ility to resist corrosion and oxidation and in its great strength at elevated temperatures. Ft thermore, when alloyed with other metals, nickel provides a variety attractive qualities preferable to those of other materials in a number of applications. Hence, about 85% of total nickel consumption is in the form of alloys, with most of the remainder going to electroplating, for which nickel is a basic material.

2. Alloying nickel with iron (between 36 and 46% nickel) produces the "invar," a material which expands very little under sharp changes in temperature. It is in fact similar to platinum in its expansion characteristics, but can be produced at much cheaper cost. The use of iron/nickel alloys in electric bulk making and in chronometers and accurate measuring tapes has been growing. By rising the nickel content to 78.5%, a new nickel/iron alloy is produced which is less susceptible to magnetism; its use is expanding in transatlantic cables. This alloy can increase the speed of transmission ıvefold. 1/

3. Nickel/chromium alloys (80% nickel) can withstand great stress at high temperatures. A number of these alloys, known as the "nimonic" series, which were developed during the Second World War, are essential for jet turbine engines. Nickel/molybdenum alloys (70% nickel) are particularly resistant to corrosion and are also strong. Both types of alloys are increasingly being used in the chemical and petroleum industries.

1/ In addition, nickel cast iron has been in use since 1925. The amount of nickel can be as low as 3%, yet the alloy still has exceptional hardness and resistence to corrosion. It has been used increasingly in the manufacture of crushers and ball mills for cement, gold ores and coal.

4. The nickel/copper alloys provide "monel," a natural alloy in that it is two parts nickel and one part copper, the proportion found in many ores in Canada (such a mixed ore could be smelted directly). Monel, when modified with a slight addition of aluminum and titanium, has not only twice the strength of mild steel, but also heat-resistant and non-magnetic qualities. It is, therefore, widely used in the parts of airplanes near the compass and also has a significant number of marine and mine-sweeping applications. Cupro-nickels have high electrical resistance at a wide range of temperatures; thus different combinations of both metals are particularly attractive for condenser tubes, pipelines carrying sea water, coinage, telephone exchanges, etc.

B. Intermediate Uses of Nickel

5. Nickel enters intermediate uses through a variety of nickel processes. In the steel industry, nickel is used in the making of stainless and heat-resistant steels, alloyed steels and iron and steel castings; this industry accounts for more than 60% of total world market economies' consumption. Nickel electroplating uses about 14%. A number of nickel alloys (those not related to the steel industry), along with nickel salts and oxides, account for the remainder (Table I-1).

6. The rate of growth of nickel use in stainless and heat-resistant steels was faster than that for nickel consumption overall, thus raising the share of stainless in total world nickel consumption from 33% in 1960 to about 44% in 1976. The main types of stainless are the designated 300-series

Table I-1: NICKEL - WORLD CONSUMPTION BY USES: VOLUME, STRUCTURE AND GROWTH /a

	Volume ('000 metric tons, nickel content)				Structure (% of total)				Growth (% annual rate)			
	1960	1970	1974	1976	1960	1970	1974	1976	1960-1970	1971-1974	1960-1974	1960-1976
Stainless, Heat Resistant Steel	72	184	243	215	33	41	44	44	9.8	7.2	9.1	7.6
Electroplating	33	59	78	70	15	13	14	14	5.9	7.2	6.3	5.2
Supernickel Alloys	33	62	72	65	15	14	13	13	6.5	3.8	5.7	4.7
Alloyed Steels	28	50	61	55	13	11	11	11	5.9	5.1	5.7	4.6
Iron-Steel Castings	26	41	39	35	12	9	7	7	4.6	(-1.1)	2.9	2.0
Cupro-Nickel Alloys	9	15	16	15	4	3	3	3	5.2	1.6	4.2	3.3
Other Uses	18	41	45	38	8	9	8	8	8.5	2.4	6.8	5.1
Total	219	452	554	493	100	100	100	100	7.5	5.2	6.8	5.5

/a Excluding centrally planned economies.

Notes: Data for 1970 and 1974 were taken from sources (1) to (4) with a slight adjustment to include consumption in the developing world, not included in the original sources; this adjustment was made for consistency with Appendix Table II.1. For 1960, consumption of nickel is distributed among uses by applying the percentage structure in 1961 as obtained from source (2).

Sources: (1) International Nickel Company of Canada, Ltd., Annual Press Statement, various years.

(2) Bankers Trust Company, London, Nickel - Changing Pattern of Production and Consumption, November 1974, p. 4.

(3) Central Marketing Steven, Global Nickel Projections 1980 and 1985, April 1975, Annex I.

(4) Hoogovens I. Jmuiden BV, Study of the Future Nickel Market, October 1970, p. 1.

and 400-series. 1/ Each series contains a large number of alloys of different composition, but most of the nickel in stainless steel is in the 300-series (it ranges from 6 to 22%). While accurate data on the relative ratio of nickel in the two series are lacking worldwide, the 300-series accounts for about three-quarters of steel output in the US, and the share of the 300-series in total stainless steel seems to be rising.

7. Several factors account for the rapid growth of nickel use in stainless. Technological developments in the manufacture of stainless, particularly the adoption of argon oxygen decarbonization (AOD) 2/ have facilitated the use in steel making of both inferior quality scrap and nickel products with lower nickel content, particularly ferronickel. Such nickel products are used mainly in the cooling medium. Besides cost advantage, the greater availability of ferronickel since the latter part of the 1960s has contributed to the growth of nickel use in making stainless.

1/ Based on conversations with various experts in the stainless steel industry, the following may represent (total nickel use) for stainless steels:

Series	Carbon Content	Nickel Content	Chromium Content	Other - usually small amounts of:
200	about .15%	3-6%	16-19%	manganese
300	under .15%	6-22%	16-26%	molybdenum, titanium
400	.12-1.2%	.6-2.5%	11-18%	molybdenum
600	.06-.07%	3-8.5%	15.5-18%	copper, aluminum

What is usually called austenitic (or chromium-nickel) stainless are a combination of varieties falling within series 200 & 300. Ferritic (or straight chromium) is basically in series 400. Martensitic (or cutlery grade) is also included in special varieties of stainless under series 400. Series 600 stainless develops significant hardness properties when the molten is cooled quickly.

2/ In addition, but to a lesser extent, the electroslag and vacuum processes of remelting along with the Witten-process, have permitted the use of furnace charges containing many more impurities than could be tolerated previously.

8. A second factor in the rise of nickel use in stainless is the favorable welding characteristics and anti-corrosive quality of nickel-bearing stainless steel (mainly the 300-series), compared with chromium-bearing ones (mainly the 200-series). In particular, nickel-stainless is preferred for piping for the chemical and petrochemical industries, for automobile-making and in a number of cryogenic applications (i.e. applications requiring very low temperatures). Potential for future expansion in nickel-bearing stainless lies in the field of nuclear energy and in the transport and storage of natural gas.

9. Use in alloyed steels 1/ account for about 11% of total nickel consumption; nickel is the favored alloying element in the structural steel industry, where nickel is used to increase the hardness of structural steel. However, since the 1960s, the use of nickel in alloyed steels has expanded at a slightly lower pace than that of nickel consumption overall. Future growth in this intermediate use will depend on the development of the liquefield natural gas market.

10. Nickel is also used in iron and steel castings (about 7% of total nickel consumption). The growth of this intermediate use had been decelerating in the past, and indeed a decline in absolute volume was experienced in the 1970s. Ironically, however, such a decline helped another nickel-bearing sector, that of alloys with higher chromium content, which provide better resistance to corrosion. The slow growth in nickel use in castings has thus been accompanied by an increasing use of nickel in the more lucrative category of supernickel alloys. This is but one small example of the sometimes complex interrelatedness of nickel to other metals and among its own different end uses.

1/ Steel may be divided into three categories: carbon, stainless and alloyed. The first contains .04 to .06% carbon. Stainless is an alloyed steel that must have chromium among its constituent elements so that the stainless quality may be developed. Alloyed steels (as used in this paper) are those to which alloying elements - other than carbon and manganese, and excluding stainless steels - are added to develop specific properties. These alloying elements may include one or more of nickel (which makes a category of alloyed steel that is not "stainless"), molybdenum, tungsten, cobalt, titanium and aluminum.

11. Nickel electroplating accounted for about 14% of total nickel consumption in 1976. Most nickel consumption for plating is in the automobile industry (e.g. for bumpers). The use of plating in a number of applications in most durable and cheaper stainless categories is expected to decrease, while aluminum and plastics in particular are likely to increase (depending upon relative future prices).

12. Among the remaining uses, nickel is an element in a number of super alloys (these account for 13% of total nickel consumption). It is used particularly in the civil and military aerospace industries, the making of furnace elements and parts, nuclear power generation, and a number of applications in the chemical and petrochemical industries. Cupro-nickel alloys account for a further 3% of total nickel consumption, but these face strong competition from titanium alloys. The remaining 8% of total nickel consumption covers a wide variety of uses: in coins, as catalysts or in the form of salts and chemicals.

C. Classes of Nickel Product

13. The commercial forms of primary nickel fall into two classes. Class I products are essentially pure, with a nickel content between 99% - 100%, and can generally be used without constraints for many applications. True Class I products include electrolytic cathodes (99.9% nickel) and carbonyl pellets (99.7% nickel); briquets, rondels and nickel 98 are also accepted as Class I products, although their use is slightly restricted.

14. Class II products have a moderate range of residual elements; the nickel content ranges widely from 1% to 96%. They are usually suitable for specific limited applications. Class II products include the various grades of ferronickel (40-50% nickel in the US, but 20-38% outside the US) and nickel oxide sinter (either 76% or 90%). A new product, incomet (94-96% nickel), introduced in 1974, is replacing the oxide in sinter commercial form. Nickel salts, also included under Class II products, contain 20-25% nickel.

15. The proportion of nickel consumed as Class I or Class II products differs widely among intermediate uses and various markets. At present, slightly over half the nickel output is consumed in "pure" form -- Class I. Ferronickel and nickel oxides, both Class II, account for about 33% and 13% respectively of total world nickel consumption. The shares of Class I and Class II in Japan, however, are about 25% and 75%, reflecting the dominance of the steel industry as a user of nickel, while in Europe and the US the ratio is about 65%:35%. 1/

16. In the future, ferronickel's share of total nickel demand is expected to rise rapidly. It is likely to make major inroads in the stainless steel sectors and in the iron and steel castings category. The cost of ferronickel is low compared with Class I nickels, and it was successfully applied in the AOD steelmaking process in the mid-1960s. Such a development would particularly benefit the developing world. Nearly all the future increments in worldwide market economies' nickel production will come from the developing countries as well as Australia. Almost all new projects in the developing countries are designed to process the ore into ferronickel, since it is technically feasible to process it from the kind of ore found there -- laterite -- which also requires a less sophisticated technology than that for making pure nickel products.

D. Nickel Ores and Resources

17. Nickel resources can be classified as either sulfide or oxide; the latter are also called nickeliferous laterite deposits. The largest concentration of sulfide ores is in the Sudbury district of Ontario in Canada. Some sulfide deposits also exist in the USSR and South Africa. Oxide deposits are formed by laterization over long periods of weathering and erosion. They

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1/ Hess, Guy C. and M. James Martin, Nickel Industry Study: Detailed Quantification of Supply-Demand Outlook, Cavanest House, Ontario, Canada, April 1975, pp. 23-24.

are found near the surface, can be worked by open-pit methods and exist mainly in tropical areas, i.e. mostly in the developing countries. In contrast to sulfide deposits which accounted, in the late 1960s, for almost two-thirds of the nickel mined in the world, today oxides or laterites constitute the major portion of identified world reserves. Such laterite deposits are of two types: those in which silicates are predominant, and those with an iron base. Silicate ores (also called garnierite) 1/ which comprise most of the New Caledonia deposits, are richer in nickel content than sulfide ores, usually exceeding 1.5%. The second type of laterite deposits, nickeliferous iron laterites, while rich in iron (45 to 50%), contains a low level of nickel, about 1%. Most of the deposits in Cuba, Philippines, Indonesia and other developing countries are this type of laterite deposit.

18. The laterite ores are more difficult to treat compared with sulphide ores, although the mining itself is not so difficult. They are usually of low grades, however, and the capital cost per ton of capacity for producing nickel from laterite sources (i.e. cost of mining and processing taken together) is roughly about 170-180% that of producing nickel from sulfide sources. Further, obtaining nickel from laterite is relatively labor-intensive. After the increase in energy costs in 1974, nickel production from laterite sources has become more costly.

19. There have, however, been factors which have increased the cost of production in sulfide mines. Some of the world's sulfide nickel deposits, notably in Canada, have been in production for a long time, and require deeper digging and usually involves lesser grade of ore. The rising cost of mining sulfide was further boosted in 1975 by the increased taxes imposed by provincial and federal governments. Oxide ores (or laterites) could not be concentrated sufficiently for economic refining before

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1/ Named after Jules Garnier, the French geologist who discovered New Caledonia's silicate ores in 1867.

mid-1960s, at which time that problem was overcome. Concurrently, the technological breakthrough enabling the use of ferronickel in stainless steelmaking took place (as noted, most oxide ores are rich in iron). With the marked rise in the price of nickel in real terms from the mid-1960s, the mining of laterite ores accelerated rapidly.

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II. THE LOCATION OF THE INDUSTRY

A. Production

1. The pattern of nickel production has changed significantly over the last quarter of a century in terms of the geographical sources of the ore. Between 1950 and 1977, world nickel mine production increased at over 6% per year to reach about 780,000 tons in 1977. During that same period, output in the industrialized countries expanded more slowly than in the rest of the world, at 4.2%. Thus their share of world total output declined from 76% in the early 1950s to 47% in 1977, while that of the developing countries rose substantially from 4% to 29%; the share of the centrally planned economies registered small change to reach 24% in 1977 (Table II-1).

2. Among the industrialized countries, Canada's position declined significantly. It provided over 90% of market economies' mine output in early 1950s but now accounts for only about one-third of market economies' production. The remarkable growth of production in two other industrialized countries - Australia and Greece - has not compensated fully for the slowdown in Canada's production. Australia's output rose from negligible amounts ten years ago to about 86,000 tons in 1977, and Greece, a non-producer in 1965, produced 10,000 tons in 1977.

3. The outstanding rise in the developing countries' share of world mine production was not only the result of the sharp expansion of nickel mining production in New Caledonia, but also of the emergence of a number of new producers. Over the last 25 years, New Caledonia's output growth averaged 12% annually, to account for about 15% of world production at present - a level equivalent to that of the USSR (125,000 tons in 1975/76). The Philippines, Dominican Republic and Botswana, which were non-producers in the early 1970s, contributed 37,000, 25,000 and 12,000 tons respectively in 1977. In addition, Indonesia, which produced a very small volume in the mid-1960s, now produces about 16,000 tons.

Table II-1: NICKEL - MINE PRODUCTION

('000 metric tons nickel content)

	Average 1950-51	Average 1960-61	Average 1970-71	1974	1975	1976	1977	Structure (% of total) 1950-51	1977	Growth (% annual rate) 1950-51 to 1977
Developed Countries	120.7	218.7	345.4	371.7	372.7	380.8	396.7	76	47	4.2
of which:										
Canada	118.7	203.0	372.3	269.1	242.2	240.8	235.4	75	30	2.6
USA /a	0.7	10.8	14.2	12.8	13.0	11.9	10.5	-	1	
Australia	-	-	32.7	45.9	75.8	32.5	85.7	-	11	
South Africa	1.0	2.9	12.2	22.1	20.8	22.4	22.0	-	3	
Greece	-	-	9.6	15.1	14.8	16.4	9.6	-	1	
Developing Countries	5.9	54.4	172.2	201.2	206.4	206.6	223.8	4	29	14.4
of which:										
Asia	0.3	0.6	12.9	16.4	24.2	29.1	53.0	-	7	
of which:										
Philippines	-	-	-	0.3	9.5	15.2	36.8	-	-	
Indonesia	-	-	12.8	16.0	14.6	13.8	16.1	-	-	
Burma	0.3	-	.1	0.1	0.1	0.1	0.1	-	-	
Africa	0.1	0.3	11.4	14.5	18.8	28.8	25.0	-	3	
of which:										
Botswana				2.6	6.3	12.6	11.8	-	-	
Latin America	-	0.1	3.2	33.5	30.1	29.8	30.3	-	4	
of which:										
Dominican Republic	-	-	.1	30.5	26.9	24.5	24.5	-		
Brazil	-	0.1	3.1	3.0	3.2	5.3	5.5	-		
New Caledonia /b	5.5	53.4	144.7	136.8	133.3	118.9	115.5	4	15	11.9
Centrally Planned Economies	31.6	84.1	155.8	163.9	173.9	179.3	184.5	20	24	6.8
of which										
USSR	31.0	66.5	110.0	120.0	125.0	130.0	135.0	20	17	5.6
Cuba	-	16.3	36.6	33.9	37.3	36.8	36.5	-	5	
TOTAL										
World (excl. CPEs)	126.6	273.1	517.6	572.9	579.1	587.4	593.5	80	76	5.9
World (incl. CPEs)	158.2	357.2	673.4	736.8	753.0	786.7	778.0	100	100	6.1

/a Recovered nickel content. This may differ slightly from nickel content of ores mined.
/b Ni and Co content of the mining production to 1961, and only Ni content thereafter.
\- Nil

Source: Metallgesellschaft AG, Metal Statistics, various issues.

4. Smelter is less concentrated than mining. About one-fifth of world refined output is produced in Canada, as against one-third of world mine production. Another one-fifth is produced in Western Europe from Canadian and New Caledonian sources, while Japan refined 13% of world's total from imported ores.

5. Negligible amounts of concentrate were smelted in the developing countries in the early 1950s. However their share at present amounts to 13% of total world refined output and most of it comes from New Caledonia and the Dominican Republic. The developed countries still dominate the world picture, refining over 60% of world's total (Table II-2).

B. Reserves

6. Known world reserves 1/ (Table II-3) are estimated at just under 60 million metric tons. At historical rate of consumption growth of about 6% per annum, they are sufficient to run well beyond the middle of the next century. However half the world reserves are found in the developing countries which account for 29% of current mine production. New Caledonia and Indonesia together account for 40% of world reserves and the Philippines another 9%. Among the developed countries Canada and Australia have the largest reserves of over 26% of the world's total. Furthermore about 80% of known reserves constitute of costly-to-exploit laterite ores against a ratio of some 35% in current output (see also pp. 7-9 of Section I of this handbook). These factors, and the potential of mining nickel from the sea, indicate that nickel production in the next decade or two is likely to witness significant structural changes with regard to the sources of supply.

1/ Reserves include only "measured" and "indicated" quantities expressed in metal content.

Table II-2: NICKEL - SMELTER AND REFINED PRODUCTION /a

('000 metric tons nickel content)

	Average 1950-51	Average 1960-61	Average 1970-71	1974	1975	1976	1977	Structure (% of total) 1950-51	1977	Growth (% annual rate) 1950-51 to 1977
Developed Countries	122.8	243.0	421.9	461.7	430.9	465.2	429.8	79	61	4.7
of which:										
Canada	67.1	127.3	191.7	197.0	178.0	176.4	155.7	43	22	2.5
USA	17.8	11.4	14.1	12.6	19.9	30.8	34.4	11	5	2.4
Japan	0.1	20.9	96.2	104.6	78.0	94.8	93.9	-	13	28.9
Australia	-	-	7.5	20.5	32.9	39.9	37.4	-	5	
UK	22.5	36.2	37.7	35.7	38.8	36.0	23.2	14	3	
Norway	10.6	31.3	40.2	43.2	37.1	32.7	38.2	7	5	4.9
Greece	-	-	9.6	15.1	14.8	16.4	9.6		1	
Developing Countries	0.8	12.4	39.3	93.3	104.3	96.7	95.1	1	13	19.4
of which:										
New Caledonia /b	0.8	12.4	30.1	48.5	52.8	38.2	28.3	1	4	14.1
Dominican Republic	-	-	.1	30.5	26.9	24.5	24.5		3	
Brazil	-	-	2.5	2.3	2.2	2.2	2.5		..	
Philippines	-	-	-	-	9.4	15.2	21.9		3	
Indonesia	-	-	-	-	-	3.4	4.9		1	
Centrally Planned Economies	31.7	87.1	152.2	161.1	174.1	182.1	186.6	20	26	6.8
of which:										
USSR	31.0	66.5	125.0	134.5	143.0	151.0	155.0	20	22	6.1
Cuba	-	16.3	18.1	14.9	18.5	15.0	18.0	-	3	
TOTAL										
World (excl. CPEs)	123.6	255.4	461.2	555.0	535.2	561.9	524.9	80	74	5.5
World (incl. CPEs)	155.3	342.5	613.4	716.1	709.3	744.0	711.5	100	100	5.8

/a Smelter and refined production includes primary nickel and nickel contained in ferronickel, nickel oxide sinter and monel smelter directly from ores.

/b As of 1972, only nickel content; until 1971, nickel and cobalt content.

- nil
.. less than .5%

Source: Metallgesellschaft AG, Metal Statistics, various issues.

Table II-3: NICKEL RESERVES,[a] 1979

	Ore ('000 metric ton)	% of World Total
Developed Countries	15,400	26.7
USA	200	
Canada	9,600	16.7
Australia	5,600	9.7
Developing Countries	30,700	53.3
Dominican Republic	1,100	
Colombia	900	
Guatemala	300	
Brazil	200	
Indonesia	7,800	13.5
New Caledonia	15,000	26.0
Philippines	5,400	9.4
Centrally Planned Economies	11,500	20.0
Cuba	3,400	5.9
USSR	8,100	14.1
WORLD TOTAL	57,600	100.0

/a Reserves include only "measured" and "indicated " quantities expressed in metal content.

Sources: US Bureau of Mines, Mineral Commodity Summaries, 1979, and further details obtained from the US Bureau of Mines, US Department of the Interior, Washington, D.C.

C. Secondary Sources

7. Nickel scrap is derived from two sources. The first is the scrap produced in fabricating plants from metal machined away in the process of manufacturing final nickel-bearing products; they take the form of cuttings of stainless steel, nickel alloys and ferro scrap. Such "new scrap" is consumed either directly as "run-around" scrap in plants producing superalloys and stainless steel 1/ or as "prompt industrial" scrap in the nickel smelters and refineries and steel mills. (This scrap is reused in a 6-8 month cycle.) The second source - "old scrap" - is obtained from obsolete nickel-bearing materials (the cycle is 15-20 years).

8. Nickel scrap is a significant component of total supply. Except for the US, no data are available about its magnitude, as nickel scrap is usually included without identification in the statistics on refined nickel output. US data, however, suggest that nickel scrap accounts for about one-quarter of output and consumption. The same ratio probably applies worldwide.

D. Consumption

9. From 1950 to 1977 the pattern of nickel consumption among the main world regions changed very slightly. The industrialized countries at present account for almost seventy percent of world nickel consumption, centrally planned economies 28%, and developing countries 3% (from negligible amounts in the early 1950s). However, in the industrialized countries, a notable structural change took place. The two most mature economies - the US and the UK - increased their nickel consumption slowly, at about 2% per annum each, and Germany, France and Sweden also recorded higher than average growth in nickel consumption (Table II-4).

1/ In the case of superalloys, separating its constituent elements is technically difficult and expensive; hence such scrap is only used when the ratio of the component elements is known within fairly close limits. Further, while the amount generated in scrap is significantly higher in the making of nickel alloys than most of other materials, the loss in recycling is also high. See, e.g., John D. Corrick, "Nickel", Mineral Facts and Problems, U.S. Department of the Interior, 1975 edition, p. 742.

Table II-4: NICKEL CONSUMPTION /a

('000 metric tons nickel content)

	Average 1950-51	Average 1960-61	Average 1970-71	1974	1975	1976	1977	Structure (% of total) 1950-51	Structure (% of total) 1977	Growth (% annual rate) 1950-51 to 1977
Developed Countries	123.5	220.3	417.6	540.9	394.3	475.0	444.4	79	69	4.9
of which:										
USA	84.7	102.8	141.2	194.5	132.0	152.7	146.0	54	23	2.0
Japan	0.8	19.2	90.5	115.9	83.3	1[illegible]5.0	97.3		15	19.4
Germany	5.3	22.5	37.6	61.2	42.8	56.2	54.2	3	8	8.9
France	5.2	17.7	34.1	40.5	31.9	33.5	35.8	3	6	7.4
UK	17.6	27.2	34.3	33.5	27.0	30.5	30.5	11	5	2.1
Sweden	3.1	8.8	21.1	31.9	22.0	24.0	17.5	2	3	6.6
EEC-9	30.4	76.7	128.7	161.3	124.1	147.6	147.3	20	23	6.0
Europe	34.5	91.8	161.4	209.3	160.6	187.7	184.8	22	28	6.4
Developing Countries	0.3	2.0	6.5	13.0	14.7	18.4	21.9	..	3	17.2
of which:										
Asia	0.1	1.0	2.9	5.4	4.9	6.9	8.9		1	18.0
of which										
India			2.1	2.8	3.3	3.5	5.6		1	
Africa /b	-	-	.6	1.0	1.2	[illegible].2	1.2		..	
Latin America	0.2	1.0	3.0	6.6	8.6	10.3	11.8		2	16.3
of which:										
Brazil			1.6	4.2	3.8	4.7	6.0		1	
Mexico			.6	0.7	3.0	4.0	3.5		..	
Centrally Planned Economies	32.0	84.5	127.5	153.3	165.5	376.7	182.4	21	28	6.7
of which:										
USSR				105.0	115.0	121.0	125.0		19	
TOTAL										
World (excl. CPEs)	123.8	222.3	424.1	553.9	409.0	493.4	466.3	79	72	5.0
World (incl. CPEs)	155.8	306.8	551.6	707.2	574.5	670.1	648.7	100	100	5.4

/a Including nickel content in ferronickel, fonte and nickel oxide sinter.
/b IBRD estimates.

.. less than 0.5%
\- nil

Source: Metallgesellschaft AG, Metal Statistics, various issues.

10. The share of developing countries in world consumption has increased since the beginning of the 1970s, but still represents only 3% of the total. Mexico, Brazil and India, experiencing rapid industrialization, account for almost all the increment in the developing countries' nickel consumption. Between the mid-1960s and 1976, the use of nickel in Mexico, Brazil and India increased by 45%, 16% and 13% respectively, though from an admittedly low base.

11. The nickel consumption in market economies rose annually by 5.6% in the 1950s; between 1960 and 1974 the rate increased to 6.8%. Thus the average over the 1950-1974 period was 6.5% per annum. With the slowdown of economic activities that followed, the growth of nickel consumption averaged less than 3% per annum between 1975 and 1979; most of the recovery occurred within the last two years. The major part of the increment took place in the use of nickel in the steel industry (stainless and heat resistance steels, alloyed steels and steel castings), which accounts presently for more than 60% of total nickel consumption. On the other hand, nickel electroplating (14% of total nickel consumption) has been facing strong competition from alternative materials, mainly aluminum, plastics and cheaper stainless categories; these are expected to continue replacing nickel, particularly in the automobile industry.

12. Consumption of nickel by intermediate uses was detailed under Section I of this manual (paras. 5-12). The steel industry accounts for 60% of world market economies' consumption (stainless and heat resistence steels, alloyed steels, and iron and steel castings), nickel electroplating 14% and non-steel nickel alloys, nickel salts and oxides (26%).

E. Trade

13. Nickel materials are heavily traded (Table II-5), and total trade flows approximate total annual production. The centrally planned economies

are self-sufficient in nickel as a group; consumption usually equals production and very little trade takes place with the market economies. Among market economies, the developing countries raised their share of total exports from 17% in 1960 to 35% in 1977. This reflects the sharp expansion of the developing countries' nickel mining output since late 1960s.

14. The trading pattern for nickel involves two categories - raw material (SITC-283) and nickel products and alloys (SITC-683). The first includes ore, concentrates and matte, while the latter comprises ferronickel, nickel oxide and all categories of Class I nickel. The raw material nickel category makes up about one-third of the market economies' total trade, a ratio unchanged over time. The same ratio also applies to the developing countries' nickel exports. However, within the raw material nickel category of the developing countries, the share of ores and concentrates rose from 6% to 14% of the total market economies' total exports between 1960 and 1977, while that of matte declined from 26% to 20%. This is explained mainly by the fact that a significant amount of the exports of New Caledonia, the major developing country producing nickel, was sent to Japan. Japan insisted, until recently, on importing nickel in raw form (mainly ores and concentrates) to feed its large refining capacity. Two other developing countries export their nickel in raw form. Botswana ships its output to the parent company's (AMAX) refineries in Port Nickel, Louisiana, while Indonesia's production goes to Japan, also in ores and concentrates form. On the other hand, the remaining developing countries - the Dominican Republic, Brazil and the Philippines - refine their output to ferronickel. They are, however, new to the mining of nickel and have either just started production or extended their output significantly in the early 1970s. This increase in the latter countries did not outweigh the rise in nickel raw material exports from New Caledonia, Botswana and Indonesia; hence the ratio of raw material to nickel products exports in the developing countries did not change over time.

Table II-5: SUMMARY OF NICKEL EXPORTS

	1960 Amount ('000 tons)	Structure		1977 Amount ('000 tons)	Structure	
Developing Countries						
Ores and Concentrates	19	6%	] 32%	69	14%	] 34%
Matte	11	26%		24	20%	
Products and Alloys	22		68%	80		66%
	52		100%	173		100%
Industrialized Countries						
Ores and Concentrates	0		0	0		0
Matte	66		26%	76		24%
Products and Alloys	183		74%	246		76%
	249		100%	322		100%
World Total						
Ores and Concentrates	19	6%	] 32%	69	14%	] 34%
Matte	77	26%		100	20%	
Products and Alloys	205		68%	326		66%
	301		100%	495		100%
Shares of:						
Developing Countries	52		17%	173		35%
Industrialized Countries	249		83%	322		65%
	301		100%	495		100%

Sources: Tables II-6 to II-9.

Table II-6: NICKEL EXPORTS, BY COUNTRIES

('000 metric tons metal content)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Developed Countries	249	294	261	262	299	318	310	312	341	291	380	379	383	429	447	373	378	322
of which:																		
Canada	178	220	190	188	216	234	225	221	236	191	267	258	246	272	256	214	208	175
Norway	28	30	28	24	34	32	31	29	31	36	37	40	40	43	44	30	34	21
UK	27	28	26	30	35	35	34	40	53	43	45	44	45	51	61	42	40	37
France/a	6	6	8	11	6	8	11	11	8	6	13	14	23	25	39	39(E)	39(E)	39(E)
Developing Countries	52	55	32	41	61	62	76	83	111	131	149	148	129	145	170	172	165	173(E)
of which:																		
New Caledonia	52	55	32	40	59	59	73	79	106	126	138	132	98	102	126	123	105	100
Brazil	-	-	-	1	1	1	1	1	1	1	2	2	2	3	2	2	3	3(E)
Dominican Republic	-	-	-	-	-	-	-	-	-	-	-	-	15	25	25	22	22	22(E)
Botswana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4	10	9(E)
Indonesia	-	-	-	-	1	2	2	3	4	4	9	14	14	15	15	14	13	14(E)
Philippines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	12	25(E)
World Total/b	301	349	293	303	360	380	386	395	452	422	529	527	512	574	617	545	543	495

/a 1970-77 includes ferronickel; data on ferronickel were not available for previous years.
/b Excluding centrally planned economies.
(E) = Estimate

Sources: UK Institute of Geological Sciences, Mineral Resources Division, Statistical Summary of the Mineral Industry, various issues;
UN Yearbook of International Trade Statistics, various issues;
Institut de Mission d'Outre-Mer, Le Nickel en Nouvelle-Caledonie en 1977, New Caledonia;
Ministry of Natural Resources, Ontario, Canada, Towards a Nickel Policy for the Province of Ontario, 1977.

Table II-7: NICKEL EXPORTS BY PRODUCT

('000 metric tons of metal content)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Ores and Concentrates																		
Developing Countries:	19	20	12	12	23	20	24	33	54	65	90	92	57	64	76	76	72	69
New Caledonia	19	20	12	12	22	18	22	30	50	61	81	78	43	49	59	58(E)	49(E)	46
Botswana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4	10	9(E)
Indonesia/a	-	-	-	-	1	2	2	3	4	4	9	14	14	15	15	14	13	14(E)
World /b	19	20	12	12	23	20	24	33	54	65	90	92	57	64	76	76	72	69
Matte																		
Developed Countries:																		
Canada	66(E)	81(E)	70	66(E)	71(E)	75	74(E)	74(E)	85(E)	70	88	106	104	91	85	84	73	76(E)
Developing Countries:																		
New Caledonia	11	12	9	13	13	14	15	12	15	15	15	15	16	18	20	21(E)	23(E)	24
World/b	77	93	79	79	84	89	89	86	100	85	103	121	120	109	105	105	96	100
Products and Alloys																		
Developed Countries:/c	183	213	191	196	228	242	236	238	256	221	292	273	279	338	362	289	304	246
of which:																		
Canada	112(E)	139(E)	120	122(E)	145(E)	159	151(E)	147(E)	151(E)	121	179	152	142	181	171	130	135	99(E)
Norway	28	30	28	24	34	32	31	29	31	36	37	40	40	43	44	30	34	21
UK	27	28	26	30	35	35	34	40	53	43	45	44	45	51	61	42	40	37
France/d	6	6	8	11	6	8	11	11	8	6	13	14	23	25	39	39(E)	39(E)	39(E)
Developing Countries/e	22	23	11	16	25	29	37	38	42	51	44	41	56	63	74	75	70	80
New Caledonia	22	23	11	15	24	28	36	37	41	50	42	39	39	35	47	44(E)	33(E)	30
Brazil	-	-	-	1	1	1	1	1	1	1	2	2	2	3	2	2	3	3(E)
Dominican Rep.	-	-	-	-	-	-	-	-	-	-	-	-	15	25	25	22	22	22(E)
Philippines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	12	25(E)
World/b	205	236	202	212	253	271	273	276	298	272	336	314	335	401	437	364	374	326
Total World Nickel Exports/b	301	349	293	303	360	380	386	395	452	422	529	527	512	574	617	545	543	495

/a Includes Matte.
/b Excludes centrally planned economies.
/c Includes other developed countries.
/d 1970-77 includes ferronickel; data on ferronickel were available for previous years.
/e Exclusively ferronickel.
(E)- estimate

Note: Totals may ... 'd due to rounding

Sources: UK Institute of Geological Sciences, Mineral Resources Division, Statistical Summary of the Mineral Industry, various issues;
UN, Yearbook of International Trade Statistics, various issues;
Institut de Mission d'Outre-Mer, Le Nickel en Nouvelle-Calédonie en 1977, New Caledonia;
Ministry of Natural Resources, Ontario, Canada, T... ards a Nickel Policy for the Province of Ontario, 1977.

Table II-8: NICKEL IMPORTS, BY COUNTRIES

('000 metric tons metal content)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Developed Countries	280	332	311	313	350	380	391	402	409	400	490	500	483	501	560	470	460	480
of which:																		
France	8	8	8	8	12	12	13	14	14	13	18	17	20	17	23	26	24	24
Norway	31	32	30	28	25	30	31	27	39	35	48	50	43	45	47	40	36	36
Japan	26	29	20	19	35	29	38	59	53	68	95	97	92	105	126	94	100	112
UK	66	72	53	57	72	72	80	70	71	56	84	98	60	58	64	73	60	65
US	72	106	106	97	92	112	102	103	102	94	110	95	119	118	135	109	113	116
Developing Countries	4	5	5	4	5	5	4	6	7	6	8	9	8(E)	7(E)	8(E)	10(E)	12(E)	18(E)
World Total /a	284	337	316	317	355	385	395	408	416	406	498	509	491	508	568	480	472	498

/a Excluding centrally planned economies.

Sources: UK Institute of Geological Sciences, Mineral Resources Division, Statistical Summary of the Mineral Industry, various issues;
UN Yearbook of International Trade Statistics, various issues.

Table II-9: NICKEL IMPORTS, BY PRODUCT

('000 metric tons metal content)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Ores and Concentrates																		
Developed Countries	28	30	20	20	32	28	36	47	50	62	84	88	80	90	107	86	88	100
Japan/a	26	28	18	18	31	26	34	45	48	60	82	86	78	88	105	84	86	98
France/a	2(E)	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2(E)
World	28	30	20	20	32	28	36	47	50	62	84	88	80	90	107	86	88	100
Matte																		
Developed Countries	70	74	65	69	62	72	69	66	77	66	96	99	82	76	79	83	72	76
Norway	31	32	30	28	25	30	31	27	39	35	48	50	43	45	47	40	36	36
UK	39(E)	42	35	41	37	42	38	39	38	31	48	49	39	31	32	43	36	40
World	70	74	65	69	62	72	69	66	77	66	96	99	82	76	79	83	72	76
Refined and Alloys																		
Developed Countries/b	182	228	226	224	256	280	286	289	282	272	310	313	321	335	374	301	300	304
of which:																		
U.S	72	106	106	97	92	112	102	103	102	94	110	95	119	118	135	109	113	116
France	6	6	6	7	11	10	11	11	12	12	16	16	18	15	21	24	22	22(E)
Japan	-	1	2	1	4	3	4	14	5	8	13	11	14	18	21	10	14	14(E)
UK	27(E)	30	18	16	35	30	42	32	32	25	36	49	21	27	32	30	24	25(E)
Developing Countries	4	5	5	4	5	5	4	6	7	6	8	9	8(E)	7(E)	8(E)	10(E)	12(E)	18(E)
World/c	186	233	231	228	261	285	290	295	289	278	318	322	329	342	382	311	312	322
World Total																		
Nickel Imports/c	284	337	316	317	355	385	395	408	416	406	498	509	491	508	568	480	472	498

/a Includes Matte.
/b Includes other developed countries, which are estimated.
/c Excludes centrally planned economies.

Sources: UK Institute of Geological Sciences, Mineral Resources Division, Statistical Summary of the Mineral Industry, various issues;
UN, Yearbook of International Trade Statistics, various issues;
Institut de Mission d'Outre- er, Le Nickel en Nouvelle-Caledonie en 1977, New Caledonia;
Ministry of Natural Resources, Ontario, Canada, Towards a Nickel Policy for the Province of Ontario, 1977.

15. The flow of nickel is basically from the producing areas to the refineries, which are mainly owned by the parent-producing companies, and from the refineries to the main nickel-consuming countries in Western Europe and the US. New Caledonia and Indonesia ship ores, concentrates and matte to Japan, which also imports some concentrates from Australia. SLN production in New Caledonia goes to France. A significant amount of INCO's Canadian nickel output is refined in the UK, Falconbridge's in Norway. Further, some matte from Canada is sent to the US. This pattern is likely to continue in the future but with more ferronickel, and perhaps other refined forms of nickel, exported from the developing countries.

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3. UN Yearbook of International Trade Statistics, various issues.

4. Institut de Mission d'Outre-Mer: Le Nickel en Nouvelle-Caledonie en 1977, New Caledonia (on New Caledonia's data).

5. Ministry of Natural Resources, Ontario, Canada, Towards a Nickel Policy for the Provence of Ontario, 1977 (on national Canadian data).

III. THE STRUCTURE OF THE INDUSTRY

A. Degree of Integration; Control

1. The ownership of nickel production is highly concentrated, one of the most concentrated among the major metals. The industry as a whole has a significant degree of vertical integration. While most of the integration is from mining of ore through refining of metal, the International Nickel Company of Canada (INCO) is integrated from mining to the fabrication of metal products. On the other hand, nickel producers in Japan import all their ore and matte. Furthermore the industry is almost totally privately owned.

2. In the early 1950s, one company, INCO, alone controlled about 85% of total world output. The company currently operates a large number of mines, ore concentrates, smelters and refineries in Canada and also refines a significant amount of production in Clydach, Wales. INCO's dominance began to erode in the mid-1950s when it refused to participate in the US government's plan to build up a stockpile of nickel under the General Services Administration. This left a vacuum which was soon filled by new companies assured of a market for their products because of the stockpiling operation. INCO's share of total market economies' production declined gradually to about 35% by 1976.

3. At present, three of the companies which have traditionally dominated the industry still account for half the total world market economies' nickel output (Table III-1). They are INCO, Société Metallurgique Le Nickel (SLN) and Falconbridge Nickel Mines Ltd. SLN operates mines and smelters in New Caledonia and produces nickel rondelles at Le Havre, France; it contributes about 12% of world output. 1/ Falconbridge owns a number of mines and smelters in Canada and refines the larger part of its output in Kristiansand, Norway; it provides about 6% of total current world production.

1/ The original company (Société Anonyme Le Nickel) experienced severe financial difficulties in 1973. It changed its name to Imetal in 1974 and sold 50% of its New Caledonian nickel interests to SNPA (Société National des Petroles S'Aquitaine). The new company is now called Société Metallurgique Le Nickel (SLN). Imetal has interests in a number of other metal companies: Penarroya (European lead/zinc company), Nippon Nickel (Japan), Morro de Niquel (Brazil). SLN is involved with Penamax and Amaxim in joint ventures.

Table III-1: CORPORATE STRUCTURE OF THE WORLD /a NICKEL INDUSTRY

(% of total deliveries)

	1955	1965	1970	1974	1976
International Nickel Co. Ltd.	67.1	61.1	43.9	39.1	35.0
Societe Metallurgique Le Nikel	5.1	8.7	10.8	9.6	11.5
Falconbridge Nickel Mines Ltd.	9.4	9.0	7.1	6.4	6.1
Sherritt Gordon Mines Ltd.	6.5	3.3	1.9	2.1	2.1
Hanna Mining Co., Inc.	4.1	3.1	2.2	2.2	2.0
Western Mining Co., Inc.	-	-	3.4	7.2	8.0
Other Producers /b	7.8	14.8	30.7	33.4	35.3
TOTAL	100.0	100.0	100.0	100.0	100.0

/a Excluding centrally planned economies.

/b Largely independent Japanese in New Caledonia.

Sources: Bankers Trust Company, London, "Nickel - Changing Patterns of Production and Consumption," 1974, p. 5 - for 1955, 1965 and 1970 data; estimates based on various reports and data obtained from the US Bureau of Mines for nickel delivery in 1974 and 1976.

4. These three companies had contributed over 80% of total world deliveries in 1955, but accounted for only 53% in 1976 - or an estimated 60% of total world capacity (both shares refer to data for world market economies). These figures still suggest a higher degree of concentration than in any other major natural resource. For example, in mid 1970s, even in aluminum it takes the six largest companies and in petroleum all the "seven sisters," to account for 60% of world productive capacity in aluminum and petroleum respectively. 1/

5. About 40 other companies account for remaining world nickel production: their share of the market is likely to expand in the future. Among the newcomers is Western Mining Corporation Limited of Australia, which probably produces 8% of current world output, and a number of independent Japanese mining companies whose share as a group has been rising rapidly

6. In such an oligopolistic structure, the three major producers, and particularly INCO, were the price-setters for the world nickel market. Their policy has been to maximize their profits by weighing the impact of their production strategies on market prices. Other producers, the price-takers, tended to increase their production as long as their marginal revenue exceeded marginal cost, thus leaving to the major companies the task of balancing supply and demand. During the last few years, the oligopolistic structure of the nickel market has been eroding slowly, particularly as excess supplies have been rising rapidly. Since a year ago, the three major companies have abandoned their previous policy of quoting comparable prices for similar categories of nickel. Further, most of the increment of future output is expected to come from the non-major companies. The market for nickel is likely to be relatively more competitive in the future.

1/ T.H. Moran, The International Political Economy of Cuban Nickel Development, a paper prepared for the International Conference on the Role of Cuba in World Affairs, University of Pittsburgh, November 1976, pp. 3-4.

B. Barriers to Trade

7. There is little barriers to trade in nickel and tariffs if any are nominal. The following tariff structure on nickel products in the US as of January 1, 1981 is typical of most countries:

Table III-2: TARIFF STRUCTURE ON NICKEL IN THE UNITED STATES

Item	Number	Most Favored Nation (MFN) 1/1/81	1/1/87	Non-MFN 1/1/81
Nickel ore and concentrates	601.36	Free	Free	Free
Nickel oxide	419.72	Free	Free	Free
Ferronickel	607.25	Free	Free	3¢/lb.
Unwrought nickel	620.03	Free	Free	3¢/lb.
Waste and scrap	620.04	Free	Free	3¢/lb.
Nickel powders	620.32	Free	Free	3¢/lb.
Nickel flakes	620.30	4.4¢/lb.	Free	14¢/lb.
Other, over 10% nickel	603.60	Free	Free	Free

Source: U.S. Bureau of Mines

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IV. ECONOMIC PARAMETERS USED IN THE MARKET ANALYSIS OF THE INDUSTRY

A. Demand Elasticities

1. The income and price elasticities of demand for nickel (estimated for the six major consuming countries using a single equation procedure) are of the following order of magnitudes:

	Income elasticity /a	Price elasticity /a
USA	1.58*	-0.93*
Germany, Fed. Rep.	2.13*	-0.85*
France	1.72*	-0.55*
UK	1.71*	-0.87*
Sweden	2.78*	-0.28
Japan	2.22*	-1.03

/a estimated using the following functional specification:

$$\ln C_t = \alpha + \beta \ln GNP_t + \gamma \ln P_t$$

where:

C = consumption of nickel, GNP = real gross national product and P = deflated price of nickel.

* estimates significant at the 95% level or above.

2. Nickel demand appears to be quite income elastic. The value of the price elasticity of demand is uniformly less than 1. Given the probable biases in the estimates, these values can only be taken as broadly indicative. The nickel intensity, defined as the volume of nickel used by producers of semi-fabricated products (i.e. "consumed" by them) per unit of GNP, is falling in industrialized countries where industrialization has already reached a mature stage. Evidently, a sharp rise in nickel consumption per unit of GNP usually accompanies the early stages of industrialization - countries such

as Mexico and Brazil fall in this category. This reflects two factors: the establishment of heavy and basic industries with their increasing requirements of metal intensive investment goods, and the sharp rise in the demand for metal intensive consumer durables - all being relatively heavy users of nickel. A rapid advancement in nickel application technology explains the exceptionally sharp increase in nickel consumption in Japan since the mid-1950s. In the more advanced phase, seen in mature economies, nickel consumption growth has tended to match that of GNP. The reason is that the pattern of demand changes in favor of services using less metals, and in favor of goods with high value added but relatively low metal content (including nickel), e.g. computers and electronics; therefore, nickel intensity levels off at that stage, and then the nickel intensity would eventually decline.

B. Supply Elasticities

3. No econometric study on nickel supply elasticities is available. However, the analysis of some components of cost may be of particular interest. The components of cost may be divided into three main categories: operating, depreciation and amortization (which depend on capital cost); and lastly the normal return on capital (i.e. the opportunity cost of capital). The available data on production costs have been extracted from the financial statements of some of the nickel producing companies. There are inherent pitfalls in using cost figures. Not only do they depend on the scale of production, the grade of ore mined, and the basis for calculating the value of associated by-products (traditionally the latter are usually computed at their realized selling price), but variations in accounting methods and techniques could also alter the outcome.

4. While nickel production from sulfides is labor-intensive, that from laterite is relatively energy-intensive. About two-thirds of the required

energy is used at the mining and primary processing stage. For laterites, energy accounts for between 40% and 60% of total operating costs, which include, besides energy, labor, material and overhead. The range relates to the source of energy; the lower ratio tends to apply where hydroelectric power is the main source of energy (e.g. in some operations in New Caledonia), the higher ratio where oil is used (e.g. Dominican Republic, Philippines, Australia and Indonesia). Until 1973, the operating production cost of nickel from laterites was about 40% more expensive than that from sulfides. The differential has widened further since the hike in the price of energy in 1973.

5. The remaining part of the total operating cost is generally divided between labor, material and overheads in the ratio of 2.5:1:1 respectively for production of nickel from sulfide ores and 1:1.5:1 respectively for obtaining nickel from laterite ores.

6. In addition to operating costs, capital requirements to produce a ton of nickel from laterites are generally about 70-80% higher than those for producing nickel from sulfides.

7. Given those difficulties and limitations in cost estimates, an attempt to construct a supply schedule relating supplies at various ranges of unit production cost per pound of nickel in 1976 is made (Table IV-1) using data obtained from an Australian mineral study. 1/

C. Price Determination Mechanisms

8. In addition to supply and demand elasticities, etc., the following factors are of particular interest:

1/ Australian Mineral Economies, Nickel Survey, Analysis and Outlook, 1977, p. 29.

Table IV-1: APPROXIMATE BREAKDOWN OF WORLD /a NICKEL PRODUCTION CAPACITY BY UNIT PRODUCTION COST, 1976

('000 tons per year, metal content)

Production Cost /b Per Pound (US cents)	Producer	Capacity	Total capacity in each unit range	Cumulative Tons Per Year (% of total)
100	WMC (Kambalda Mines)	43		
	INCO (low cost mines)	120	163	25
130	Hanna (Oregon)	15	15	27
140	WMC/Shell (Windarra)	12		
	Dominican Republic	30		
	INCO (high cost mines)	125		
150	Rhodesia	15		
	New Caledonia	140	155	76
160	Larco (Greece)	15		
	Metals Explorations (Greenvale)	20	35	81
170	Other Australian (Sulfide Mines)	12		
	Falconbridge (Canada & Norway)	45	57	90
180	Marinduque (Philippines)	20	20	93
210	Botswana	20	20	96
	Total Capacity for above		625	
	TOTAL WORLD CAPACITY /c		653	100

/a Excluding centrally planned economies.

/b Defined as: operating costs plus selling and administrative costs; excluding depreciation, amortization and interest costs.

/c Excluding capacity in South Africa and Finland where nickel is produced as a byproduct.

Source: Based on Australian Mineral Economics, Nickel Survey, Analysis and Outlook, 1977.

In the short run:

(i) Most of the transactions are based on producer prices. Given the oligopolistic structure of the industry, INCO, in particular, is the main price setter (details in section III). The major three companies (INCO, Le Nickel and Falconbridge) balance supply and demand. Most of the new smaller producers have been able to produce to near capacity during the recent turn down of economic activities.

(ii) Nickel stocks play a major part in price determination in the short-run. Stocks reached as high as four times trade requirements in 1977/78. Interest rates fluctuated widely in recent years and had a strong influence on producers' policies regarding stocks. This in turn influences prices.

(iii) Perhaps second to the copper industry, strikes are not unusual in the nickel industry and could last for a prolonged period. For example, labor strikes closed down INCO's Canadian operations between September 1978 to June 1979.

In the long-run:

In the longer term, the shape of the industry cost curve affects decisevely price trends. A few considerations on this subject may be of general interest:

(i) Most of the new land based nickel mines would produce the metal from laterite ores, a significantly dearer source.

(ii) A rising proportion of total supply is expected to come from marine sources. The cost of producing nickel from nodules would be an important factor in price determination.

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3. Hilmy, Joseph, "Old Nick" - An Anatomy of the Nickel Industry and its Future, World Bank Commodity Note No. 13, 1979, pp. 34-39, 50-56 and Appendix I, pp. 62-63.

4. Kellogg, Herbert H., "Sizing up the Energy Requirements for Producing Primary Materials," Engineering and Mining Journal, April 1977.

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V. MARKET PRICES

1. The three main producers - INCO, SLN and Falconbridge - act as price-setters, with their posted prices closely aligned; INCO usually takes the lead in changing the posted prices. 1/ By far, most transactions in the market take place at such producers' prices (Tables V-1 and V-2) although since 1974 discounts have been granted occasionally, their magnitude is not precisely known. There is also a free market where very small amounts of refined nickel products, mainly from Cuba and the USSR, are traded. It is not an organized market, but price quotations attributed to it have been published in the Metal Bulletin since 1966. The quotations have irregular dates and give a wide range of prices; they are reported to be based on contracts with metal dealers but do not indicate quantities traded at such prices. It is notable that some of the free market quotations have remainded unchanged for prolonged periods. The INCO price for electrolytic cathodes (99.7% nickel) FOB shipping point was selected as the benchmark price.

2. Prices of the remaining categories of nickel are usually established according to staple differentials. Since 1972, the prices of ferronickel, incomet and sinter 75 have been lower than the price of nickel cathode by about 6%, 10% and 15% respectively.

1/ A challenge to INCO's leadership took place in the early 1970s. For example, in 1974 Falconbridge took the initiative in May of increasing its ruling price from US$1.62 per lb. to US$1.85, and INCO followed 6 weeks later. In October 1974 SLN increased its list price to US$2.05 and Falconbridge followed quickly, but INCO delayed until December its announced new price of US$2.01, which the others followed (notwithstanding the subsequent substantial discounting from this price). Again in September 1976 Falconbridge tried to lift the list price from US$2.20 to US$2.53 but had to fall in with the US$2.41 announced soon after by INCO (again notwithstanding the discounting). See Australian Mineral Economics Pty. Ltd., Nickel Survey, Analysis and Outlook, December 1977, p. 89.

Table V-1: NICKEL - INCO'S PRICES

($/kg)

	Current $
1960	1.63
1961	1.71
1962	1.76
1963	1.74
1964	1.74
1965	1.74
1966	1.74
1967	1.94
1968	2.08
1969	2.36
1970	2.85
1971	2.93
1972	3.08
1973	3.37
1974	3.83
1975	4.57
1976	4.97
1977	5.20
1978	4.61
1979	5.99
1980	7.53

Commodity Specification: Nickel - Canadian Nickel, electrolytic cathodes, Ni 99.97%, shipping point.

Source: Engineering and Mining Journal, various issues.

Table V-2: OTHER NICKEL MARKET PRICES

	Germany (FR) Nickel, refined[1]) Average	United Kingdom Nickel, refined[2]) Average	Free Market refined 1 ton and over cif Europe[3]) Average	United States of America Nickel, Electrolytic Cathodes[4]) Average
	RM/DM per 100 kg	£ per long ton (1016,047 kg)[5])	£ per long ton[6]) (1016,047 kg)	cents per lb. (453,592 gs)
1946	246,000	192,50000		35,000
1947	246,000	192,50000		35,000
1948	285,880	205,08065		36,534
1949	334,750	251,20109		[illegible]
1950	439,615	360,05833		54,792
1951	524,875	434,00000		54,000
1952	550,000	454,00000		56,500
1953	579,039	482,07051		59,888
1954	584,410	486,68182		60,453
1955	623,000	519,00000		65,500
1956	629,389	524,68421		65,165
1957	715,000	600,00000		74,000
1958	715,000	600,00000		74,000
1959	715,000	600,00000		74,000
1960	715,000	600,00000		74,000
1961	718,750	630,00000		77,653
1962	722,999	649,17391		79,895
1963	712,500	642,00000		79,000
1964	712,500	642,00000		79,000
1965	712,500	642,00000		78,673
1966	725,417	652,00000	1155,33—1330,36	78,900
1967	810,000	737,24711	1397,57—1533,66	87,774
1968	870,000	902,77778	1561,78—1659,57	95,000
1969	972,500	1007,93750	3431,41—3741,45	105,417
1970	1092,500	1210,296	2053,05—2247,87	128,985
1971	1087,917	1233,649	1,23—1,34	133,000
1972	1041,00	1254,42	1,30—1,39	139,667
1973	941,00	1395,16	1,45—1,53	153,000
1974	1025,00	1651,44	1,93—2,07	173,500
1975	1127,00	2045,42	1,80—1,93	207,333
1976	1259,50	2754,99	2,02—2,14	225,250
1977	1181,42	[7]) 3169,31	1,95—2,[illegible]2	[8]) 240,186
1978	867,50	–	1,81—1,96	[9]) 2,091
1979	1026,60	2848,71	2,43—2,71	2,715

[1]) Until July 13th, 1949 official maximum price; beginning July 14th, 1949 price for imported nickel of the major producers.
[2]) Until 1964 based on quotations published by "Daily Commercial Report", as from 1965 according to "Metal Bulletin".
[3]) Averages based on quotations published by the Metal Bulletin calculated by us.
[4]) According to the "Engineering and Mining Journal" and from January 1st, 1967 Metals Week.
[5]) Beginning 1970 £ per metric ton.
[6]) Beginning 1971 $ per lb.
[7]) January – July.
[8]) January – July; December 208,00 US-c lb.
[9]) $ per lb.

Source: Metallgesellschaft Aktiengesellschaft: Metal Statistics, 67th Edition, Frankfurt Am Main, 1980, p. 378.

3. Historically, despite large fluctuations in the demand for nickel, its price has shown stability, though there was a slight rise until 1967. It is suspected that INCO has, without damaging itself financially, intentionally kept prices low enough to prevent potential newcomers from entering the nickel industry. Producers' prices increased sharply over the 1967-72 period. This may have been the result of three factors: the prolonged strike in Canada in 1967-68 and the resultant shortages of supplies, the fact that demand for nickel is inelastic in the short term, and the marked rise in the cost of production which took place at that time. In particular, a new and substantially higher wage contract was adopted following the strike. It coincided with a surge of nickel output from laterites (a significantly dearer source of nickel as compared with traditionally cheaper sulfide ores). Since 1975, prices were artificially kept high despite large producers' stocks and notably low operating capacity. However, discounts were commonplace. In October 1977, INCO stopped posting prices, but quotations resumed shortly thereafter, at a lower price, and discounts were not permitted anymore. INCO's quotations were reintroduced shortly after. Reflecting a 10% decline in world nickel consumption in 1980 with the ensuing rise in inventories, INCO announced in November 1980 a 6% discount on its prices of nickel products. It also intends to close down its Guatemalan operations during the whole of 1981.

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For annual reviews of prices:

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For sources of price series:

Engineering & Mining Journal for INCO prices. Metallgesellschaft Metal Statistics for a number of other price series.

VI. SPECIAL ISSUES

A. Substitutes

1. Alternative materials to nickel could be used either at the intermediate stage - other metals can be used as alloying elements or at the end product stage - where non-nickel bearing products may be suitable. However, in most cases substitution of nickel-bearing material by other materials entails a sacrifice of physical or chemical attributes and sometimes involves an even higher cost. On the other hand, where corrosion resistance, high strength or special magnetic and electronic properties are emphasized, carbon steel clad with titanium along with plastic coating, can compete with nickel-bearing stainless steel, as these substitutes provide equal or superior corrosion-resistant qualities and in many instances are relatively inexpensive. Aluminum could compete with nickel/chromium in the automobile industry, and in some processing industries aluminum and stainless could replace each other. In all these areas substitution is price- and cost-sensitive. For example, in 1967-69, when there was a shortage of nickel and its price was high, some of these alternative alloys were commonplace. However, the amount of nickel used in most final products represents such an insignificant proportion of the cost of the product that nickel consumption is not too sensitive to its price. 1/

2. In other areas - such as the use of nickel in steel alloys and super-alloys - manganese, molybdenum, cobalt and titanium could be used as alternative alloying elements in various combinations. However, nickel is often used to make these alternative alloys, although in smaller proportions per unit produced.

1/ See, e.g., UNCTAD, The Effects of the Production of Nickel from the Seabed, with Particular Reference to the Impact on the Export Earnings of Developing Country Producers of Nickel, December 1974, p. 2.

3. Other areas where substitution is possible would entail significant sacrifice in performance. In nickel-based iron castings, manganese and molybdenum give the most competition. The combination of nickel/manganese/chromium with steel has made a small inroad in the stainless market, but the performance is still for nickel/chromium stainless on qualitative grounds. Indeed, the nickel content of stainless steel has been rising over the recent decade.

B. Processing

4. The processing chain for nickel could be considered to consist of the following steps:

	stage of production	output	
(a)	mining	ore (1-2% Ni)	
(b)	milling	concentrates (10-15% Ni)	'raw materials'
(c)	further concentrating	matte (50-75% Ni)	
(d)	smelting	ferronickel (25-50% Ni)	
(e)	refining (oxidation)	nickel oxides (75-90% Ni)	'processed'
(f)	smelting/refining (more treatment)	refined nickel (over 98% Ni)	

It is important to note that not all nickel mined goes through each step shown above

5. Almost all nickel production in the developing countries is exported. About 45% of total nickel production or exports of developing countries is in "processed" form; the major part is ferro-nickel (25-50% Ni) which is directly used in steelmaking without further "refining". "Raw material" nickel must be processed further to purer types - electrolytic

cathodes, pellets, briquets and rondelles - (reaching over 98% Ni in most cases). Almost nine tenths of developing countries' exports in "raw material" form are as nickel matter (50% Ni). Ores and concentrates are mostly confined to exports of laterite ores from New Caledonia and Indonesia to feed the ferro-nickel plants in Japan.

6. Since the early 1970s, new technology in the steel industry has made it possible to use nickel in the "fe Ni" state instead of pure nickel. At present about 80% of the "processed nickel" produced by developing countries is in the form of ferro-nickel, which has a low nickel content falling below the nickel content of nickel matte. The new technology has a cost advantage and is expected to raise the share of ferro-nickel in total nickel consumption from about 35% at present to cover over 50% by the end of this decade. Most of the new nickel projects under construction or in the pipeline in developing countries are for ferro-nickel production, because it is not technically feasible to concentrate laterite ores.

7. In the future, New Caledonia and Botswana would probably be the only raw material nickel producers among the developing countries with the share of ferro-nickel in New Caledonia's exports gradually rising. Similarly, Indonesia will be processing increasingly more of its output into either ferro-nickel or refined nickel form before exporting. However, the value added by processing nickel in matte into nickel metal is less than 15% of the value of nickel metal.

C. Nickel from Marine Sources

8. The discovery of a vast quantity of metal-bearing nodules on the seabed, whose mining is expected to commence in late-1980s, has added a new dimension to prospects in the nickel market. The nodules contain mainly manganese, nickel, copper and cobalt. The ratio of these four minerals is significantly different from the relative size of present or likely future

demand for each of them. Because of this and the different land-based reserve status of these metals, the accepted view is that the decision to mine the nodules and the level of production will be determined by the market prospects of nickel, whose sales are expected to yield almost 70% of gross revenues from most of the contemplated nodule mining operations. The extent of nodule development, therefore, will be dictated by the outlook for an increase in world demand for nickel 1/ and the degree of competitiveness between marine- and land-based sources of supply.

9. There are no definite data on the relative production costs and profitability of marine- and land-mined nickel. The handful of individual firms or consortia so far engaged in pilot seabed mining projects guard their information closely. Some estimates of profitability, based on confidential data in which individual companies are not identified, have recently become available. The estimate, while tentative in nature, indicates competitiveness of marine nickel mining ventures with land-based laterite, but not sulfide nickel mining operations.

10. There are a number of uncertainties regarding nodule mining at present. Prospects for technological progress in engineering, material and design, which would reduce production costs are uncertain. Furthermore, the design of the particular metallurgic process selected - e.g. whether additional stages of processing are included in the plant design - could determine whether certain minerals, particularly manganese, could be recovered, thus affecting profitability.

11. Another crucial determinant of costs and the quantity of marine-nickel output could be the regulations to be imposed by the International

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1/ In the very long run, if output from seabed mining is sufficiently large to depress the price of nickel to the level of copper, it may open to the former metal significant potential areas for substitution, causing a large expansion of seabed mining. This is, however, unlikely to happen in the 1980s.

Seabed Authority (ISA), 1/ whose creation was proposed at the UN Conference on the Law of the Sea. For example, proposals are currently under serious consideration to empower the ISA to impose levies on seabed mining; to authorize payment of compensation to countries with land-based mining whose revenues would be adversely affected; and to control development of seabed mining. 2/ The UN Secretary-General has also suggested to the Conference that the ISA employ a grid system demarking the areas of potential mining, impose limitations on the number of blocks auctioned in any one year and reserve part of the best nodule sites for future use. 3/ The most controversial topic in the negotiations regarding the Law of the Sea is the nature of the regime of seabeds beyond national jurisdictions, the seabeds where the nodules are found. The issue here is to what extent the private sector and "The Enterprise" - the operating arm of the ISA - should share in the exploitation of this new resource. Whatever international regulations are adopted, they will clearly affect the profitability of nodule mining, the volume of production and its impact on prices.

12. Within the uncertainties and limitations already mentioned, some tentative estimates of production costs were made recently by various

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1/ See, for example, UN Third Conference on the Law of the Sea, Economic Implications of Seabed Mineral Development in the International Area, Secretary-General's Report, May 1974, pp. 45-59 and pp. 79-86.

2/ A proposed formula based on limiting nodule output to specific percentages of future nickel increases in consumption seems to have gained support during the deliberations of the recent sessions of the UN Conference on the Law of the Sea. It was proposed that such restrictions continue until a commodity agreement entered into effect. The extent of the restrictions is currently under negotiation.

3/ Op. cit., UN Secretary-General's Report, pp. 89-91.

sources on the relative profitability of marine- versus land-based nickel. 1/ While the estimates are wide-ranging, they all indicate that marine nickel mining can compete seriously with land-based laterite nickel mining, but not with sulfide nickel operations. 2/ Most of the estimates, however, do not allow

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1/ See, for example, among others:

(i) Rebecca L. Wright, Ocean Mining - An Economic Evalution, A US Ocean Mining Administrative Study, Washington D.C., May 1976, pp. 7-18.

(ii) Daniel Nyhard and a team from the Massachusetts Institute of Technology University and the Sloan School of Management, A Cost Model of Deep Ocean Mining and Associated Regulatory Issues, Report No. MITSG78-4, Office of Marine Minerals, US Department of Commerce, March 1978 (currently in preliminary draft of a special run).

(iii) UN, Economic Implications of Seabed Mineral Development in the International Area, Op. cit., also published in the Third United Nations Conference on the Law of the Sea - Official Records, Volume III, pp. 29-32.

(iv) Richard Tinsley, "Economics of Deep Ocean Resources - A question of Manganese or No Manganese," Mining Engineering, Society of Mining Engineers, April 1975, pp. 32-33.

(v) Robert Sisselman, "Ocean Miners Take Soundings on Legal Problems, Development Alternatives," Engineering and Mining Journal, April 1975, pp. 78-79.

2/ The estimates assume metal contents from nodules similar to those used in this paper; capital costs ranging from $500 million to $790 million per mining/processing system providing about 3 million tons of dry nodules per year; operating costs ranging from about $100 million in the MIT/Sloan study to between $120-143 million in R. Wright Paper (using the low and medium estimates in the latter paper), all at 1975-76 prices. On the revenue side, the prices used are broadly in line with IBRD projections for the metals involved. Furthermore, taxation provisions similar to those applicable in the US on mining would provide a remunerative rate of return on capital invested in marine mining operations.

for the possible decrease of unit cost over time that might materialize with economies of scale, improvement in operating efficiency and further development of technology. The tentative nature of such estimates must, therefore, be emphasized, and they should be viewed with great caution.

13. Current technical coefficients about nodule mining may be summarized as follows:

(i) The initial generation of nodule miners will be able to obtain 95% metallurgical recovery. Although nodules vary in metal content and quality, a typical dry nodule will include about 1.6% nickel content by weight. Thus, one million metric tons of dry nodules will provide about 15,000 tons of nickel (Table VI-1). 1/ This figure has to be viewed cautiously, however. Defining what is a typical nodule for the purpose of projecting marine nickel output is difficult. The amount of nickel metal recoverable from a typical dry nodule differs between areas. 2/ In general, sources in the industry look for bodies containing over 1.4% nickel or over 3% combined nickel and copper. It is not currently known what sites would be exploited at the outset, nor what restrictions, if any, might be imposed by the proposed UN International Seabed Authority. However, these figures are widely accepted in the industry at present.

1/ Op. cit., UN Secretary-General's Report, pp. 27-28.

2/ For example, within the chemical composition of nodules, nickel averages between 0.16% to 2.0% in the Pacific, and between 0.31% to 0.54% in the Atlantic, John Mero, The Mineral Resources of the Sea, 1965, p. 180.

Table VI-1: ESTIMATED METAL PRODUCTION PER MILLION METRIC TONS OF HIGH GRADE NODULES

	Metal content per Weight of Dry Nodules	**Metal Production per Million Tons of Dry Nodules**
	---(percent)---	--(metric tons)--
Manganese (if recovered)	24.00	230,000
Nickel	1.60	15,000
Copper	1.40	13,000
Cobalt	0.21	2,000
Other Metals (including molybdenum, vanadium, zinc and silver)	0.30	2,500

Note: Estimates are based on various scientific data and information provided by geologists and other officials associated with the industry.

Source: UN Third Conference on the Law of the Sea, Economic Implications of Seabed Mineral Development in the International Area, report of the Secretary-General, May 1974, p. 28.

(ii) Optimum capacity for a mining rig will be between one and two million tons of dry nodules annually. However, in order to benefit from economies of scale at subsequent stages, most systems would most likely be geared to processing three to four million tons annually from two to three mining rigs.

Table VI-2: NICKEL - TECHNICAL COEFFICIENTS

	Ni content
Nickel Content:	
Ores	1 - 2%
Concentrates	10 - 15%
Class I	
Electrolytic Cathodes	99.9%
Carboyl Pellets	99.7%
Briquets / Rondels / Nickel 89 — above 99%	
Class II	
Ferronickel	40 - 50% in US, 20 - 38% outside US
Matte	50 - 75%
Nickel Oxide Sinter	either 76% or 90%
Incomet	49 - 96%
Nickel Salts	20 - 25%

Price Deferentials:

Price of INCO's Electrolytic Cathodes is the Benchmark.

Ferronickel is less than Cathodes by 6%.
Incomet " " 10%.
Sinter 75 " " 15%.

Weights

1 metric ton = 2204.62 lb. = 1000 kg.
1 short ton = 2000 lb. = .90718 metric ton.
1 long ton = 2240 lb. = 1.016046 " "
1 kilogram (kg) = 2.2046 lb.

Marine Nodules:

Metal content per weight of dry nodules:

Manganese	24%
Nickel	1.6%
Copper	1.4%
Cobalt	.21%
other metals (including molybdenum, vanadium, zinc & silver)	.3%

i.e. Nickel metal production per one million tons of dry nodules = 15,000 metric tons.

Source: Summarized from previous text material.

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