Copper Handbook

Commodities and Export Projections Division
Economic Analysis and Projections Department

CONVERSION FACTORS

Product	Cu Content
Copper ores	0.5 - 6.0%
Copper concentrates	20 - 40%
Copper blister	96 - 99%
Refined copper	99.0 - 99.99%

Metric tons = 1,000 kilograms = 2,204.62 lb.

Short ton = 907 kilograms = 2,000 lb.

Long ton = 1,016 kilograms = 2,240 lb.

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I. THE CHARACTERISTICS OF COPPER

A. Physical Properties and Uses

1. Copper is one of the most useful and versatile metals and has been used by mankind longer than any other metal except gold. Use of copper dates back at least 6,000 years. It has been used both in pure copper form and in alloy with a variety of other metals, especially tin (in bronze) and zinc (in brass). Chemical symbol for copper is Cu. It has a hardness of 2.5-3.0, a melting point of 1,083°c, a boiling point of 2,595°c, a density of 8.89, and an electrical resistivity at 20°c of 1.71. Its electrical conductivity in cross section is surpassed only by silver and by weight only by aluminum respectively. 1/

2. High electrical and thermal conductivities, good resistance to corrosion, good ductility and malleability, high strength, lack of magnetism, and a pleasing red color are properties of copper that are the basis for the vast industrial applications. Copper and its alloys can be joined easily by welding, brazing and soldering. It can be finished by plating and lacquering.

3. The three tradi ional copper-based alloys, i.e., brass (with zinc), bronze (with tin) and nickel-silver (zinc and nickel, with 52-80% Cu), contain no less than 40% copper. Nickel copper, which is used for acid-resistant castings and bearing bronzes, contains 60% Ni, 33% Cu, 3.5% manganese and 3.5% iron. Copper is also used in many other alloys where it is not the major component.

1/ The first three paragraphs are based on:

(a) Donald A. Brost and Walden P. Pratt (eds.), United States Mineral Resources (Washington, 1973); and

(b) H.J. Schroeder and James H. Jolly, "Copper" in U.S. Bureau of Mines, Mineral Facts and Problems, 1980 edition.

4. Because of its easy malleability, strength in alloyed form, thermal conductivity and corrosion resistance property, copper has long been used for a variety of housenold and industrial purposes. Bronze and brass have been used extensively for over 2,000 years. Since the middle of the last century, however, as the use of electricity has developed, copper's superiority in electrical conductivity has resulted in a spectacular growth of its application in electrical uses. Copper is also used for coinage and in production of chemicals (e.g., paint pigments).

5. Statistical information on the end-uses of copper consumption is limited to major consumers among the industrialized market economies. Copper consumption is spread over a large number of sectors which have different characteristics in terms of the factors affecting consumption. Tables I.1 and I.2 show copper consumption in the United States, Japan and Europe, by type of semi-manufacture and by end-use industry respectively.

6. The pattern of consumption by type of semi-manufacture has shown little change in the last decade or so. Wire is the most important product in all the countries shown in Table I.1, and the product for which demand has grown most rapidly. Then, two categories, i.e., "rods, bars and sections" and "sheets, strips and plates" are the important groups. These are followed by "tubes." In terms of use by industry sector, in Western Europe and Japan the electrical and electronic products sector accounts for more than 50%, while in the United States, the electrical industry is less important as a copper user. Construction, transportation, and industrial equipment are important copper consuming sectors in all the countries shown.

B. World Copper Reserves and Resources

7. /1 In contrast to iron and aluminum, copper is a geochemically scarce element. While iron and aluminum are estimated to constitute 5.80% and 8.00%,

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1/ Information in this paragraph and the next is based on R.F. Mikesell, ibid, p. 45.

Table I-1: APPARENT COPPER CONSUMPTION BY TYPE OF SEMI-MANUFACTURE, ANNUAL AVERAGE 1973-75

Countries	Distribution by type (thousand tons)									
	Wire (thousand tons)	(%)	Rods, bars & sections (thousand tons)	(%)	Sheets, strips & plates (thousand tons)	(%)	Tubes (thousand tons)	(%)	Total consumption (thousand tons)	(%)
Copper										
France	270.4	75.8	12.0	3.4	17.5	4.9	56.7	15.9	356.6	100
F.R. of Germany	389.0	74.8	26.2	5.0	40.8	7.9	62.1	11.9	518.1	100
Japan	748.7	82.1	20.3	2.2	67.5	7.4	75.2	8.3	911.6	100
U.S.A.	1,169.4	70.7	57.0	3.4	126.8	7.7	299.8	18.2	1,653.1	100
Copper Alloy										
France	10.6	5.6	114.5	60.3	52.5	27.7	12.3	6.4	189.8	100
F.R. of Germany	28.2	9.0	133.4	42.6	78.0	24.9	50.4	16.1	290.0	100
Japan	30.8	7.3	193.8	46.2	157.3	37.6	37.5	8.9	419.4	100
U.S.A.	(0.7)		356.8	44.0	378.1	46.7	76.1	9.4	810.3	100

Source: World Bureau of Metal Statistics, *World Metal Statistics*, November 1976.

Table I-2: COPPER CONSUMPTION BY END-USE SECTOR

	U.S.A. 1974	W. Europe 1975	Japan 1975
Electrical and electronic products	46.3	54.3	52.0
Building construction	15.9	15.5	8.8
Transportation	10.1	10.7	17.1
Industrial equipment	18.8	14.0	15.0
Consumer products	8.9	5.5	7.1
TOTAL	100.0	100.0	100.0

Source: Commodities Research Unit, London New York

Reproduced from: Wolfgang Gluschke, Joseph Shaw and Bension Varon, Copper: The Next Fifteen Years (D. Reidel Publishing Co., 1979), p. 30.

respectively, of the earth's continental crust, the continental crust contains only 0.0058% copper. Economically relevant iron ore deposits contain 20-65% iron, and bauxite deposits 22-29% aluminum. In contrast, economically relevant copper deposits contain only 0.5-6% copper. What all this means is that the copper in a copper deposit must be between a hundred and a thousand times more concentrated than the crustal average, whereas iron and aluminum need to be only three to ten times as concentrated. Thus, copper is indeed a localized zone in the earth's crust that contains copper-bearing minerals in unusual quantities.

8. Copper occurs in three different types of mineralizations - sulfides, carbonates and silicates. Sulfides are by far the most important and silicates are the least important. Sulfides consist of copper, sulfur and iron. Since copper metal is more easily extracted from the carbonate and sulfide minerals, mining companies have a preference for exploiting these ores.

9. Copper mineral deposits are found only in special geological conditions and hence their geographical distribution tends to be concentrated. A copper containing deposit is classed as a reserve if the copper-bearing minerals are sufficiently concentrated to be extracted economically. 1/ Since the

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1/ The terms reserves and resources as used in this note are based on Gluschke, Shaw and Varon, ibid., and reflect the common elements of prevalent definitions. Resources comprise all concentrations of elements in the earth's crust, including the oceans, in such a form that a usable mineral commodity can be extracted at present or in the future. They include known (identified) deposits as well as undiscovered (hypothetical, speculative) resources which will require exploration to be found and evaluated, both within known and as yet unknown copper-bearing areas. Reserves are here defined as that portion of the identified resources from which a usable mineral commodity can be technologically, economically and legally extracted at the time of determination. The term "legally" is introduced to take into account restrictions such as those imposed by existing laws and regulations governing, for example, pollution standards or the exploitation of deposits in areas designated as national parks. Reserves are distinguished from resources by greater accuracy of knowledge on the size and quality of the deposits and by their greater economic viability. The latter is a function of mining, processing, and transport technology and costs, on the one hand, and price, on the other.

classification depends on the prices and production costs of copper, copper reserves could increase materially if copper prices rise substantially in relation to costs. The results of a recent United Nations survey of world copper reserves are reproduced in Table I.3.

10. Both as a result of a change in the price-cost relationship and of exploration activities, total volume of copper reserves changes over time. One interesting question often asked with respect to reserves is: How long would the present reserves last? Table I.4, again reproduced from the Gluschke-Shaw-Varon study, shows: Between 1960 and 1976, (a) how the volume of world reserves changed; and (b) how the "lifetime" of reserves changed. In short, it appears: (i) the total reserves increased; and (ii) the lifetime of these reserves increased under both static and dynamic assumptions. In other words, under the assumption that the consumption level were to remain constant in the forthcoming years, the existing reserves in 1976 would last for 59 years as opposed to 37 years for the reserves as of 1960. If consumption were to rise at 2, 3, 4 and 5 percent per annum in the "future" the existing reserves as of 1976 would last for 40, 35, 31 and 28 years, respectively.

11. It is extremely difficult to determine the volume of resources, as opposed to reserves, and the authoritative UN study shies away from showing any any specific estimates of copper resources, but the study gives some indications of probable sizes of resources both overland and in the oceans. 1/

12. Scrap is an important source of supply for refined copper. There are two kinds of scrap in copper - i.e., new scrap and old scrap. New scrap is the waste material "produced" in fabricating plants. This kind of scrap is usually clean and does not need to be refined again to be used. It is simply remelted and used without refining. Old scrap, on the other hand, comes from used and worn goods such as transmission cables, transformers, generators, old plumbing and radiators. This scrap must be refined before it is put to use.

1/ Gluschke, Shaw and Varon, ibid., pp. 58-60.

Table I-3: WORLD COPPER RESERVES BY CATEGORY AND AVERAGE GRADE: SURVEY A2

	I. Producing mines[b]		II. Under construction		III. Other known deposits		Total (I + II + III)	
	Copper content (thousand tons)	Average grade (%)	Copper content (thousand tons)	Average grade (%)	Copper content (thousand tons)	Average grade (%)	Copper content (thousand tons)	Average grade (%)
Canada	16,500	0.70	500	1.21	7,400	0.48	24,400	0.62
United States	69,400	0.71	6,300	1.21	13,400	0.63	89,100	0.71
Mexico	11,700	0.60	5,900	0.75	5,800	0.72	23,400	0.67
Panama	—	—	—	—	12,000	0.60	12,000	0.60
Others	800	0.8	—	—	2,300	0.75	3,100	0.76
North and Central America	89,400	0.69	12,700	0.94	40,900	0.60	143,000	0.68
Peru	9,400	1.07	6,800	0.68	11,100	0.88	27,300	0.93
Chile[c]	58,500	1.11	3,300	1.70	18,000	0.84	79,800	1.07
Argentina	—	—	—	—	4,200	0.59	4,200	0.59
Others	—	—	—	—	1,900	1.10	1,900	1.10
South America	67,900	1.10	10,100	0.85	35,200	0.82	113,200	0.99
Zaire	30,900	3.90	4,300	5.02	6,400	4.1	41,600	4.05
Zambia	26,500	3.06	800	2.22	--	—	27,300	3.02
South Africa	4,000	0.71	1,000	0.8	—	—	5,000	0.73
Others	2,900	1.8	—	—	—	-	2,900	1.8
Africa	64,300	2.70	6,100	2.47	6,400	4.1	76,800	2.80
Philippines	9,400	0.55	3,200	0.44	3,300	0.46	15,900	0.50
Papua New Guinea	4,100	0.47	—	—	2,400	0.85	6,500	0.61
Australia	5,400	2.58	—	—	800	2.69	6,200	2.59
Iran	—	—	5,200	1.2	1,300	0.65	6,500	1.09
India[d]	2,300	1.4	—	--	2,300	1.3	4,600	1.35
Others	6,100	1.13	—	—	1,400	0.88	7,500	1.08
Asia	27,300	0.77	8,400	0.72	11,500	0.74	47,200	0.75
Europe[e]	6,300	0.73	1,700	0.43	—	—	8,000	0.67
Centrally planned economy countries[fg]	36,700	1.57	16,300	1.72	10,000[d]	1.5[d]	63,000	1.60
World[h]	292,000	1.03	55,300	1.04	104,000	0.77	451,200	0.96

a Individual deposits with less than 100,000 tons copper content were generally not considered.

b As not all deposits in producing mines could be surveyed, a correction factor is included in the tonnage data. This factor is the ratio of the surveyed capacity to the total capacity of a country in 1976 and varies between 85 and 100 per cent; for the world, an average of 95 per cent of copper reserves in producing mines was surveyed.

c After compilation of this table new official calculations became available which place proven and probable reserves about 10 per cent higher.

d Estimates.

e Excluding centrally planned economy countries, but including Yugoslavia.

f Estimates by Stolberg Ingenieurberatung GmbH, Stolberg, Federal Republic of Germany.

g Bulgaria, Hungary, Poland, Romania, USSR.

h Excluding China.

Source: United Nations Centre for Natural Resources, Energy and Transport.

(Reproduced from: Gluschke, Shaw and Varon, Copper: The Next Fifteen Years, A United Nations Study, (D. Reidel Publishing Co., 1979).

Table I-4: LIFETIME OF COPPER RESERVES AS OF 1960 AND 1976

	1960	1976
Reserves (millions of tons)	154	451
Static Life Index (years)	37	59
Dynamic Life Index (years) at a growth rate of production of:		
2 per cent per year	28	40
3 per cent per year	25	35
4 per cent per year	23	31
5 per cent per year	21	28

Sources: 1960 reserves, United States Department of the Interior, "Copper," Mineral Facts and Problems, Washington, D.C., 1960; 1976 reserves, United States Centre for Natural Resources, Energy and Transport (Survey A in Table I-3).

Reproduced from: Gluschke, Shaw and Varon, ibid., p. 58.

Roughly speaking, new scrap remelted and recycled often within the fabricating plants is estimated to be as large as 20-25% of annual world refined copper consumption. Refined copper produced from old scrap accounts for 15-17% of market economies' refined copper consumption.

C. The Chain of Production Stages

12. The four principal stages of copper production are: (a) mining, in which ore (containing 0.4-2.0% Cu) is extracted from the ground either by underground operations or from open pits; (b) milling (concentrating), which includes crushing and grinding the ore and removing the bulk of the waste material to produce concentrates (containing 12-40% Cu); (c) smelting, which involves feeding the concentrate into furnances which produce molten material called blister (containing 96-99% Cu); and (d) refining either by electrolytic

process or by a pyrometallurgical process to produce electrolytic refined copper and "fire refined" copper (containing over 99.5% Cu). The last two stages have been combined in new chemical smelting-refining processes using leaching techniques. 1/

14. Figure I.1 illustrates the basic steps in the chain of copper production from the ore in the ground to refined copper. Figure I.2 is an attempt to illustrate the technological alternatives in addition to the basic steps of production.

1/ Raymond F. Mikesell, The World Copper Industry, Structure and Economic Analysis (The Johns Hopkins University Press, 1979), pp. 16-17, pp. 60-63.

Figure I-1: BASIC STEPS: COPPER SULFIDE ORE TO FINISHED PRODUCT

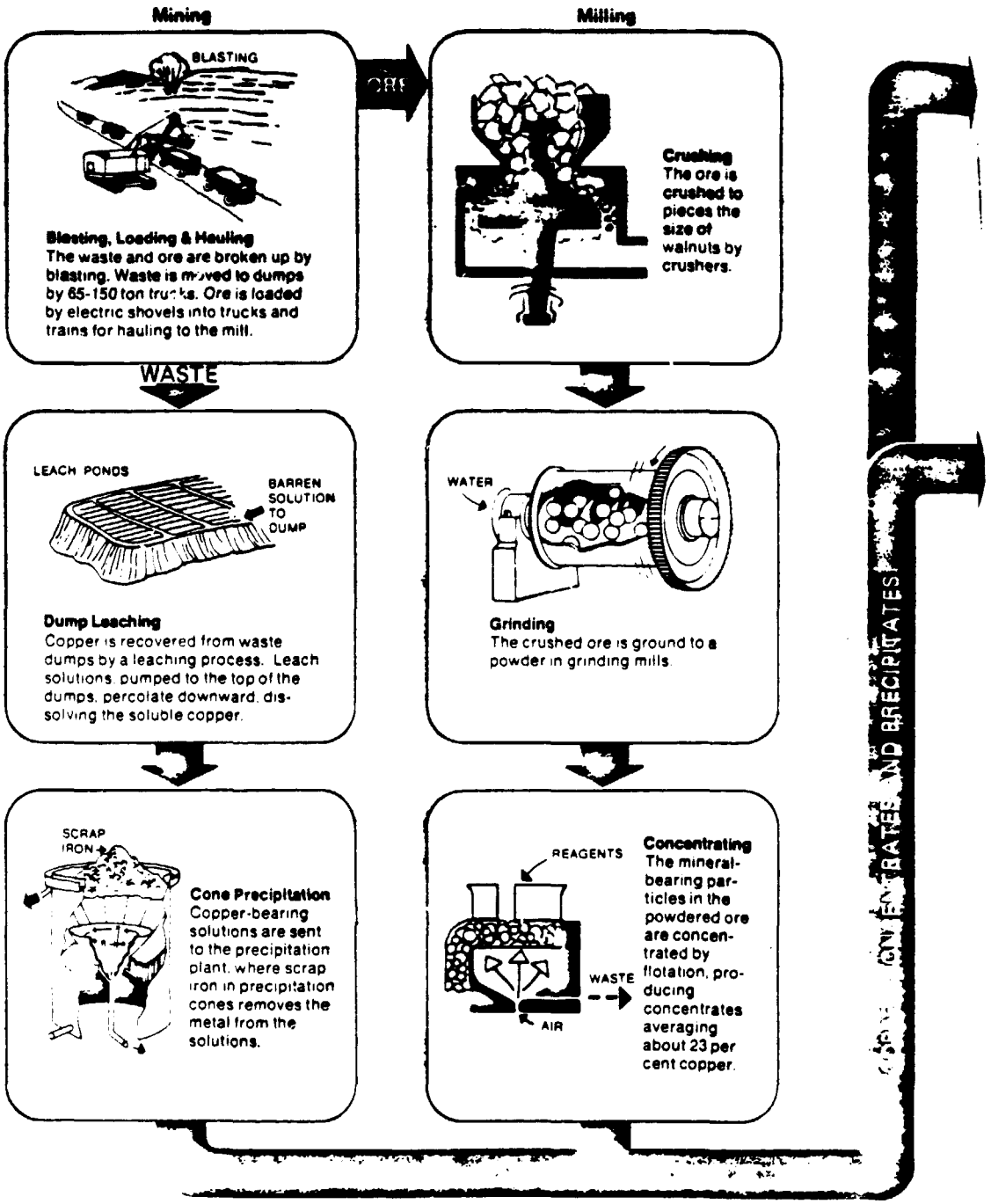
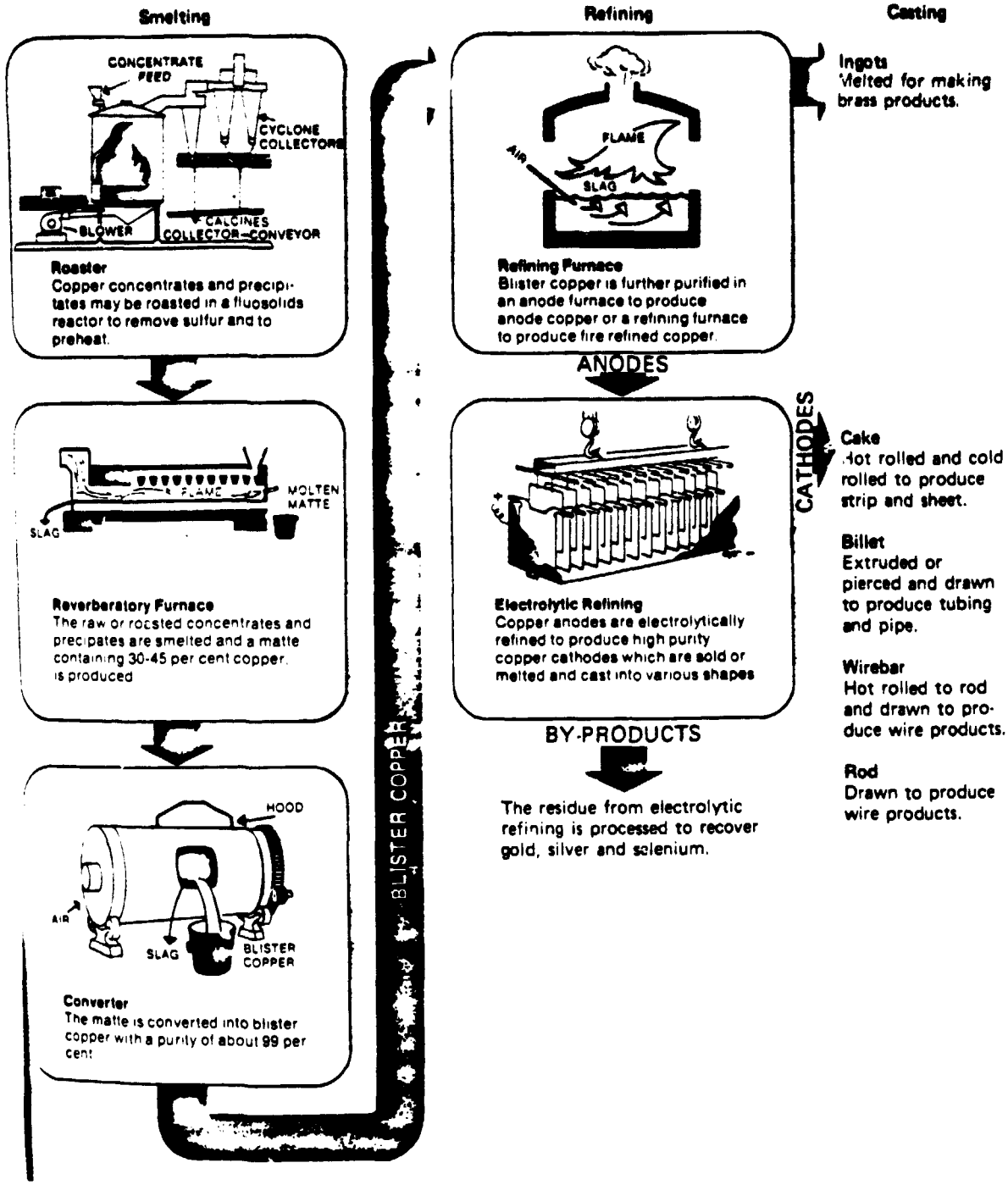
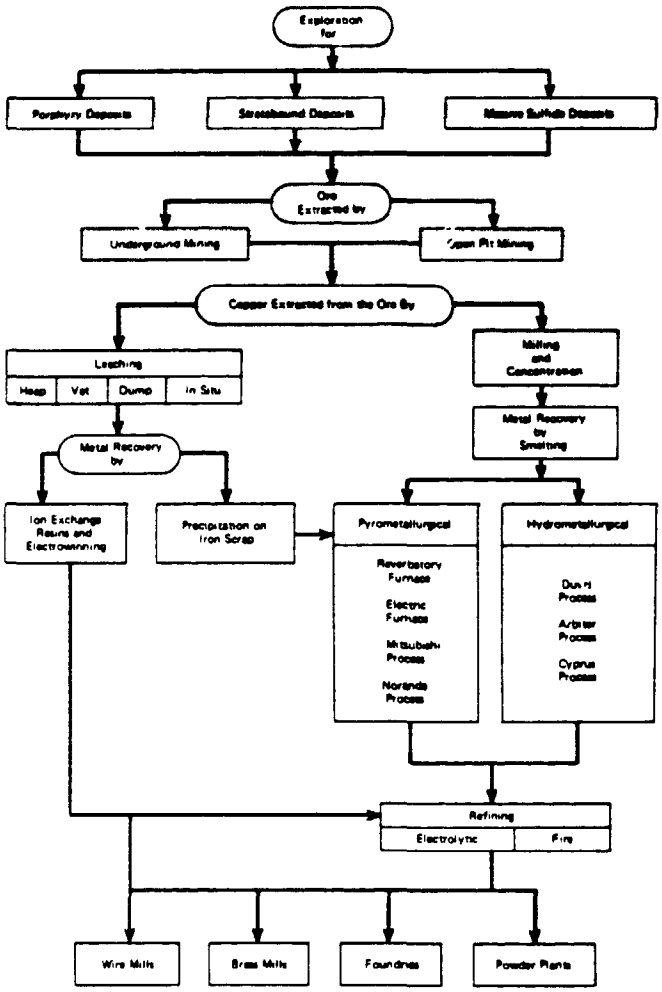


Figure I-1: BASIC STEPS: COPPER SULFIDE ORE TO FINISHED PRODUCT (Cont'd.)



Source: Reproduced from Coopers and Lybrand, Financial Reporting and Tax Practices in Nonferrous Mining, 5th edition (New York, 1976), pp. 26-27.

Figure I-2: TECHNOLOGY OF PRIMARY COPPER PRODUCTION



Source: Raymond F. Mikesell, The World Copper Industry (Johns Hopkins University Press, 1979), p. 72.

GLOSSARY

Mine: Mines are the source of copper-bearing material found near the surface or deep in the ground. Most copper mines are open pits, where ore is removed from the surface rather than from underground workings.

Ore: There are two primary types of copper ores: sulfide ore, the most common, which is a copper-iron-sulfur compound and silicate and oxide ores, which are silicon or oxygen compounds rather than a sulfide compound.

Waste: This is material which overlies ore in open pit mines and may be encountered underground. It must be removed before ore can be mined.

Dump Leaching: This is the recovery of soluble copper by allowing specially treated water to filter through waste material. As the water percolates through the waste, small amounts of copper are dissolved and carried in a solution, which is treated in a precipitation plant to recover the copper.

Precipitation Plant: A facility which processes the copper-bearing solution recovered from dump leaching. Treating the solution with iron in a precipitation cone produces cement copper. This cement-like sludge, containing a high percentage of copper, is shipped to a smelter or sold.

Concentrator: The processing plant where copper sulfide ore is separated into concentrates of copper, other metals, and reject material through processes such as crushing, grinding, and flotation. Concentrates are shipped to a smelter.

Smelter: Following mining and concentrating, smelting produces blister and anode copper, which are sent to a refinery for further processing. Fire-refined copper, also produced by the smelter, is shipped directly to fabricators.

Blister Copper: After passing through a reverberatory furnace and a converter, the resulting copper—98.5 per cent pure—is cast. "Blisters" that form on the surface give it its name.

Anode Copper: Blister copper undergoes further refinement to remove impurities. In an anode furnace, the blister copper is blown with air and natural gas to upgrade its purity to 99.6 per cent copper. It is then cast into keystone shaped slabs that are shipped to an electrolytic refinery.

Electrolytic Refining: Copper anodes are placed alternately with refined copper sheets in a tank through which a copper sulfate solution and sulfuric acid are circulated. A low voltage current is introduced, causing copper to transfer from the anodes to the pure copper sheets, producing 99.9 per cent pure copper cathodes. Impurities, often containing precious metals, settle to the bottom of the tanks.

Cathode: Copper cathodes are produced by the electrolytic refining process. They are sold or melted and cast into cakes, billets, wirebars, or rods.

(Reproduced from: E.C. Janson, J.A. MacLean and D.T. Wright, Financial Reporting and Tax Practices in Nonferrous Mining, Coopers and Lybrand, 1976).

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6. Schroeder, H.J., and James H. Jolly, "Copper", a chapter from Mineral Facts and Problems, 1980 Edition. Preprint from Bureau of Mines Bulletin 671. United States Department of the Interior, 1980.

II. THE LOCATION OF THE INDUSTRY

A. Mine Production

1. Mine production of copper is shared by developing countries, industrialized countries and centrally planned economies (CPEs) (Table II.1). Of world production in 1979, developing countries account for 45.6%, industrialized countries 31.5% and the CPEs 22.9%. The largest eight producers in the market economies are (in descending order): The United States, Chile, Canada, Zambia, Zaire, Peru, Philippines and Australia, which together accounted for 83% of the market economies' production in 1979. Other significant producers are Mexico, South Africa, Papua New Guinea and Yugoslavia. Among the CPEs, USSR and Poland are the most important producers.

2. On the whole, during the last two decades, world mine production of copper has increased at 4.1% per annum. 1/ Production in CPEs appears to have grown much faster than the world average, at 6.2% per annum, while production in industrialized countries has grown at the below-average rate of 3.2% and production in developing countries has grown at about the world average rate. As a result of these differential rates of growth among the three economic regions, there have been some changes in their shares in world mine production. Over the last two decades, the share of developing countries has not changed much (Table II.1). Comparing the situations in 1970 and 1979, one gets the impression that the share of industrialized countries has declined in the last decade. However, this is partly due to the fact that there were widespread production cutbacks and mine closings in the United States and Canada from the fall of 1977 to the spring of 1979 in order to cope with the extremely depressed market conditions prevailing then. One should also bear in mind that, in 1980, there was an estimated production loss of some 400,000 tons in the United States as the result of an industry-wide strike.

1/ The growth rates in this paragraph refer to the least squares trend rates based on 1960-1977.

Table 5: COPPER - MINE PRODUCTION, BY ECONOMIC REGIONS AND MAIN COUNTRIES

	Actual							Growth Rate	Shares			
	1960	1965	1970	1975	1977	1978	1979	1960-77	1960	1970	1979 (A)	1979 (B)
	('000 tons)											
Developing Countries	1,949	2,192	2,605	3,279	3,730	3,655	3,620	4.1	46.0	41.1	45.6	59.1
Latin American & Caribbean	784	840	974	1,100	1,495	1,498	1,576	3.1	18.5	15.4	19.8	25.7
Chili	532	585	686	828	1,056	1,036	1,061	3.5	12.6	10.8	13.4	17.3
Mexico	60	55	61	78	90	87	110	3.6	1.4	1.0	1.4	1.8
Peru	182	177	206	181	341	366	397	2.0	4.3	3.2	5.0	6.5
Other	10	23	21	13	8	9	8	e -1.1	0.2	0.3	0.1	0.1
Africa	985	1,123	1,283	1,464	1,456	1,372	1,286	2.9	23.2	20.2	16.2	21.0
Zaire	302	289	387	495	482	424	400	3.9	7.1	6.1	5.0	6.5
Zambia	576	696	684	677	656	643	588	1.2	13.6	10.8	7.4	9.6
South Africa	48	61	144	179	205	209	203	9.9	1.1	2.3	2.6	3.3
Other	59	77	68	113	113	96	95	e 3.9	1.4	1.1	1.2	1.6
Asia and Africa	60	76	174	499	576	585	587	13.2	1.4	2.7	7.4	9.6
Indonesia	0	0	0	64	57	58	56	n.a.	-	-	0.7	0.9
Iran	0	0	0	4	6	6	3	n.a.	-	-	-	-
Philippines	44	63	160	226	273	263	297	12.4	1.0	2.5	3.7	4.8
Papua New Guinea	0	0	0	173	182	199	171	n.a.	-	-	2.2	2.8
Other	15	13	14	32	58	59	60	e 8.3	0.4	0.2	0.8	1.0
Southern Europe	121	154	174	217	203	200	171	2.2	2.9	2.7	2.2	2.8
Industrialized Countries	1,652	1,949	2,536	2,443	2,555	2,441	2,504	3.2	39.0	40.0	31.5	40.9
Western Europe	73	64	88	123	128	130	122	4.5	1.7	1.4	1.5	2.0
United States	980	1,226	1,560	1,282	1,364	1,358	1,444	2.3	23.1	24.6	18.2	23.6
Canada	399	461	610	734	759	659	644	4.8	9.4	9.6	8.1	10.5
Australia	111	92	158	219	222	222	235	6.1	2.6	2.5	3.0	3.8
Japan	89	107	120	85	81	72	59	-1.0	2.1	1.9	0.7	1.0
Market Economies	3,601	4,141	5,140	5,722	6,285	6,096	6,124	3.7	85.0	81.0	77.1	100.0
Centrally Planned Economies	637	924	1,205	1,626	1,696	1,778	1,818	6.2	15.0	19.0	22.9	
WORLD TOTAL	4,238	5,065	6,345	7,348	7,981	7,874	7,942	4.1	100.0	100.0	100.0	

/a All growth rates in this column are based on least-squares trend-fitting, except for those marked 'e', which are based on end-points.

Source: World Bureau of Metal Statistics.

B. Smelter Production

3. The role of developing countries in world smelter production is much less than its role in mine production. The share of developing countries in the market economies' smelter output in 1979 was 47%, compared with their share in mine production of 59% in the same year (Table II.2). The share of developing countries in market economies' smelter output appears to have remained fairly constant at least over the last fifteen years or so (compare 1979 and 1965 in Table II.2).

4. Smelting of sulfide copper ores and concentrates is a highly polluting activity with sulphuric and other chemical emissions. As the concern with industrial pollution in industrialized countries has intensified, pollution control standards in these countries have been sharply tightened. As a result, although the developing countries are insisting on similarly stringent pollution control standards, the political climate in developing countries has been more conducive to the growth of smelting capacity there than in densely populated industrialized countries.

C. Refined Copper Production

5. Table II.3 shows world production of refined copper by economic regions and by main producers for some benchmark years. Currently, it appears that roughly one half of world production takes place in industrialized countries while developing countries and CPEs each account for one quarter of world production.

6. Over the last two decades, the share of developing countries and CPEs in world refined production appear to have steadily increased at the expense of the share of industrialized countries. Thus, while the share of developing countries rose from 19% to 26% between 1960 and 1979, the share of industrialized countries declined from 65% to 49% (Table II.3).

D. Consumption

7. World consumption of refined copper has been growing at 3.8% per annum in the last two decades. For the market economies, however, the growth rate for the same period works out to be somewhat lower, at 3.6% per annum.

Table II.2: COPPER - MINE, SMELTER AND REFINERY PRODUCTION IN DEVELOPING COUNTRIES IN 1965, AND 1979

('000 tons copper content)

	1965			1979		
	Production	Smelter Output	Refinery /a Output	Mine Production	Smelter Output	Refinery /a Output
Developing Countries	2,192	1,993	1,212	3,620	2,963	2,963
Chile	585	557	289	1,061	947	780
Mexico	55	47	46	110	83	100
India	9	9	9	33	22	15
Indonesia	-	-	-	56	-	-
Iran	-	-	-	3	0.7	3
Panama	-	-	-	-	-	-
Papua New Guinea	-	-	-	171	-	-
Peru	180	159	41	397	371	231
Philippines	63	-	-	297	-	-
Zaire	289	289	152	400	370	103
Zambia	696	696	522	588	595	564
South Africa	61	56	16	203	182	152
Southern Europe	154	110	114	129	244	308
Other Ore Producers	100	65	15	171	72	32
Other Non-Ore Producers /b	-	5	8	1	76	125
Industrialized Countries	1,949	2,140	3,832	2,504	3,344	4,628
Market Economies	4,141	4,133	5,044	6,124	6,307	7,041

/a Refinery production includes secondary copper.
/b Includes Brazil, Republic of South Korea and Taiwan.

Source: World Bureau of Metal Statistics.

Table II.3: REFINED COPPER PRODUCTION BY ECONOMIC REGIONS AND MAIN COUNTRIES, 1960-1979

	1960	1965	1970	1975	1977	1978	1979	Shares in Total 1960	1970	1979
	1,000 metric tons							percent		
Developing Countries	949	1,210	1,657	2,006	2,287	2,382	2,421	19.0	21.9	25.9
of which, Chile	226	289	465	535	676	749	780	4.5	6.1	8.3
Mexico	28	46	54	70	79	83	100	.6	.7	1.1
Peru	30	41	36	54	188	186	231	.6	.5	2.5
Zaire	145	152	190	226	99	103	103	2.9	2.5	1.1
Zambia	403	522	581	629	649	628	564	8.1	7.7	6.0
South Africa	12	16	75	88	146	153	152	.2	1.0	1.6
Southern Europe	89	114	187	296	339	317	308	1.8	2.5	3.3
Industrialized Countries	3,249	3,834	4,511	4,256	4,558	4,544	4,627	65.0	59.4	49.4
of which, U.S.	1,643	1,942	2,035	1,610	1,677	1,832	1,980	32.9	26.8	21.2
Canada	378	394	493	529	509	446	397	7.6	6.5	4.2
Japan	248	366	705	819	934	959	984	5.0	9.3	10.5
W. Europe	896	1,110	1,132	1,106	1,253	1,132	1,092	17.9	14.9	11.6
Australia	84	93	146	192	185	175	174	1.7	1.9	1.9
Market Economies: Total	4,198	5,044	6,168	6,262	6,845	6,926	7,048	84.0	81.3	75.3
Centrally Planned Economies	800	1,015	1,415	2,075	2,220	2,275	2,309	16.0	18.7	24.7
WORLD TOTAL	4,998	6,059	7,583	8,337	9,065	9,201	9,357	100.0	100.0	100.0

Source: World Bureau of Metal Statistics, World Metal Statistics various issues.

The growth in the 1970s was distinctly slower than in the 1960s, reflecting the slower overall economic growth in the market economies in the 1970s than in the 1960s. The single most important factor affecting the growth of demand for copper is overall economic growth trends (especially in industrialized countries).

8. Table II.4 shows world consumption of refined copper by economic regions and by main consuming countries for the selected benchmark years in the last two decades. Industrialized countries are the most important consuming region. While these countries' share has been falling, especially since the early 1970s, these countries still account for over two-thirds of world consumption. Developing countries have been steadily increasing their share in world consumption.

E. The Pattern of Trade

9. Developing countries account for almost two-thirds of world copper exports. Since copper consumption in these countries is still relatively small, the bulk of production is exported. A crude estimate of the "export dependence" for the group as a whole is about 90% (Tables II.1 and II.5). The major mine producers are usually the major exporters; namely, Chile, Peru, Zambia, Zaire, Philippines, Papua New Guinea and South Africa. Table II.5 shows world exports of copper by economic regions and by main countries for the selected benchmark years. The figures refer to gross exports combining ores/concentrates, blister and refined copper in metal content terms.

10. Among the industrialized countries, Canada is the major exporter. Although to a much lesser extent, Australia is also a significant exporter. There is a fair volume of intraregional trade within Western Europe, which explains the fairly high volume of exports shown in Table II.5. Despite being a large primary producer, the United States is a small exporter in gross terms, but it really is a significant net importer.

11. Table II.6 shows the world flow matrix of copper in 1979, compiled by the World Bureau of Metal Statistics. It shows for major producing countries, from the top down: mine production, where it is exported to in ores and concentrate form, smelter production, where it is exported to in blister form,

Table II.4: COPPER CONSUMPTION BY ECONOMIC REGIONS AND MAIN COUNTRIES

	Actual							Shares		
	1960	1965	1970	1975	1977	1978	1979	1960	1970	1979
	('000 tons)							(%)		
Developing Countries	303	432	525	773	975	955	1,095	6.4	7.2	11.2
South Africa	26	32	35	65	52	60	69	0.5	0.5	0.7
Southern Europe	108	141	216	271	324	308	312	2.3	3.0	3.2
Other Developing	169	259	273	437	599	587	714	3.6	3.7	7.3
Industrialized Countries	3,527	4,620	5,279	4,682	5,895	6,262	6,414	74.4	72.4	65.4
United States	1,245	1,844	1,860	1,397	1,986	2,193	2,168	26.3	25.5	22.1
Western Europe	1,805	2,036	2,263	2,158	2,468	2,461	2,544	38.1	31.0	26.0
Japan	304	428	821	828	1,127	1,241	1,330	6.4	11.3	13.6
Other Industrialized	173	312	335	300	314	366	372	3.6	4.6	3.8
Market Economies	3,830	5,052	5,803	5,455	6,870	7,217	7,509	80.8	79.6	76.6
Centrally Planned Economies	912	1,166	1,486	2,018	2,160	2,232	2,291	19.2	20.4	23.4
WORLD TOTAL	4,742	6,217	7,289	7,473	9,030	9,449	9,800	100.0	100.0	100.0

Source: World Bureau of Metal Statistics.

Table II.5: COPPER - WORLD EXPORTS BY ECONOMIC REGIONS AND MAIN COUNTRIES

	Actual							% Share in World Total		
	1960	1965	1970	1975	1977	1978	1979	1960	1970	1979
	('000 tons)							(percent)		
Developing Countries	1,748	1,941	2,383	2,825	3,393	3,198	3,228	59.1	60.9	64.4
Asia and Pacific	44	66	155	449	555	545	545	1.5	4.0	10.9
Papua New Guinea	-	-	-	170	182	195	172	-	-	3.4
Philippines	42	63	150	212	282	258	292	1.4	3.8	5.8
Indonesia	-	-	-	61	60	59	56	-	-	1.1
Other	2	4	4	5	31	33	25	-	0.1	0.5
Africa	930	1,087	1,244	1,312	1,414	1,218	1,213	31.4	31.8	24.2
Zaire	274	289	370	493	489	440	366	9.3	9.5	7.3
Zambia	560	683	689	635	655	576	647	18.9	17.6	12.9
South Africa	50	58	136	119	189	133	138	1.7	3.5	2.8
Other	46	58	50	65	81	69	62	1.6	1.3	1.2
Latin America and Caribbean	722	731	905	961	1,348	1,341	1,391	24.4	23.1	27.8
Chile	515	522	669	788	1,005	978	1,004	17.4	17.1	20.0
Peru	168	181	217	150	330	355	382	5.7	5.6	7.6
Mexico	35	9	6	14	10	5	4	1.2	0.2	0.1
Other	4	19	14	9	3	3	1	0.1	0.4	-
Southern Europe	51	57	80	104	76	94	79	1.7	2.0	1.6
Industrialized Countries	1,139	1,113	1,358	1,510	1,481	1,454	1,396	38.5	34.7	27.9
Canada	295	260	428	634	574	530	509	10.0	10.9	10.2
United States	409	314	264	167	96	123	127	13.8	6.8	2.5
Western Europe	384	500	548	540	643	648	593	13.0	14.0	11.8
Other Industrialized	52	39	118	168	168	153	167	1.8	3.0	3.3
Market Economies	2,887	3,055	3,741	4,335	4,874	4,652	4,624	97.5	95.7	92.3
Centrally Planned Economies	73	121	168	323	378	383	386	2.5	4.3	7.7
WORLD TOTAL	2,960	3,176	3,910	4,658	5,252	5,035	5,510	100.0	100.0	100.0

Source: World Bureau of Metal Statistics.

WORLD BUREAU OF METAL STATISTICS
WORLD FLOW OF UNWROUGHT COPPER — 1979

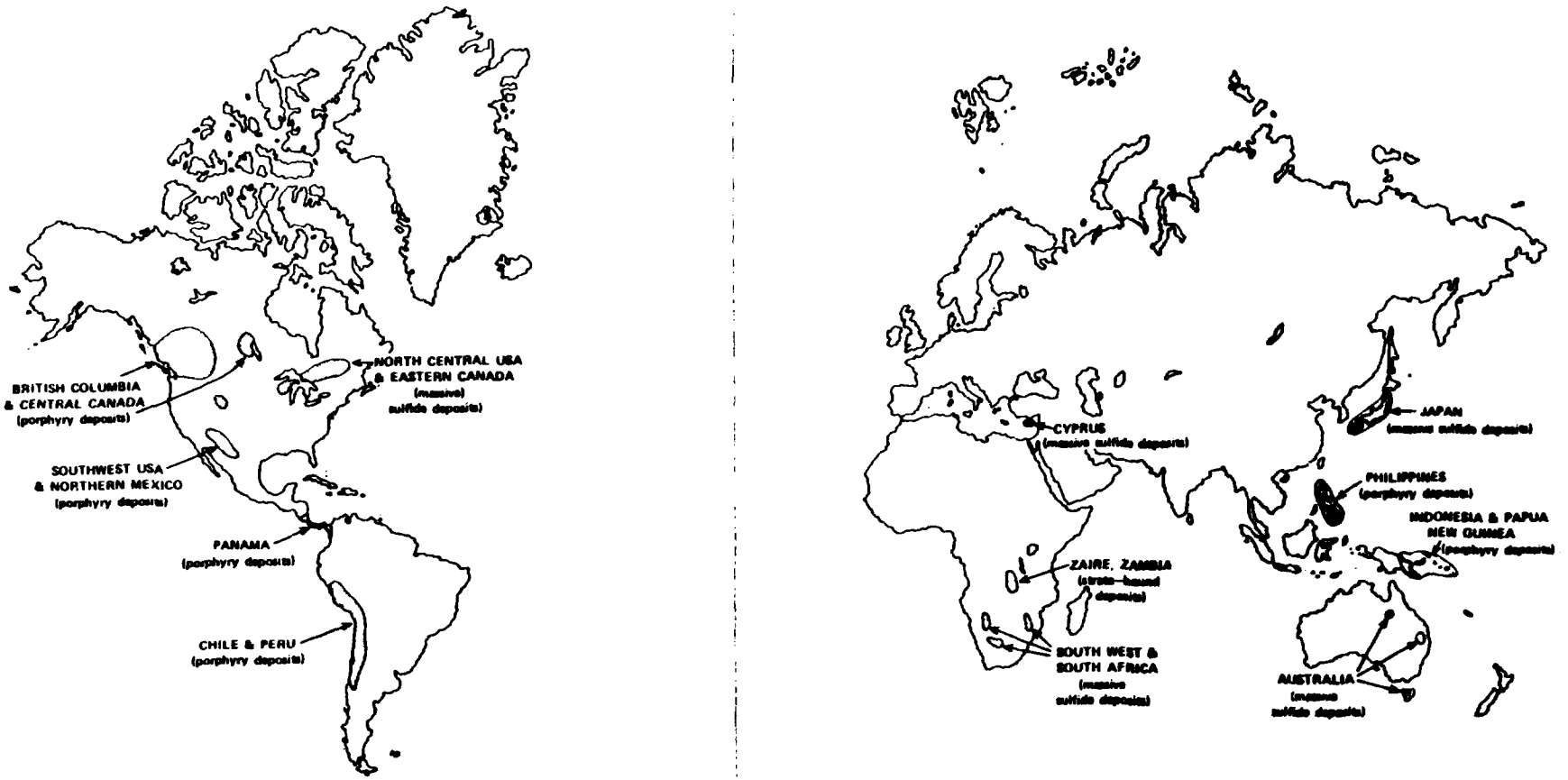
EAU OF METAL STATISTICS
OF UNWROUGHT COPPER — 1979

Thousand metric tons

	EUROPE																	AMERICA
	Belgium	Denmark	France	Germany F.R.	Irish Republic	Italy	Nether-lands	United Kingdom	Total EEC Countries	Austria	Finland	Greece	Norway	Spain	Sweden	Switzer-land	Yugo-slavia	Argentina
MINE PRODUCTION			0.4	0.9	4.8	0.5			4.6		41.1		28.0	43.3	45.8		96.0	0.1
Exported to —																		
Belgium					1.1				1.1									
Germany F.R.	0.2				0.3				0.5				15.9				0.8	
Italy																		
Portugal																		
Finland					1.3				1.3				0.4		4.5			
Norway																		
Spain			4.2		2.1	0.4			2.7									
Sweden													6.3					
Yugoslavia																		
Canada																		
U.S.A.																		
Mexico																		
Namibia																		
Japan																		
South Korea																		
Taiwan																		
Turkey																		
Bulgaria																		
Germany Dem. Rep.															1.9			
U.S.S.R.																		
China																		
N. Korea																		
Markets unspecified																		0.1
TOTAL EXPORTS	0.2		0.2		4.8	0.4			5.6				22.6		6.6		0.8	0.1
TOTAL IMPORTS	0.4			127.0					128.0		6.0		20.6	47.0	13.6		2.2	
Stock Change Concentrates			0.2	-29.7		0.1			-29.4				-1.4		0.8			
Secondary Blister	65.2		8.0	92.5					152.7	11.1	7.5			18.0	12.9		12.6	
SMELTER PRODUCTION	55.4		8.0	260.7					311.1	11.1	64.8		27.4	108.3	64.5		110.0	
Exported to —																		
Belgium			4.0	3.1					7.1						0.8			
France	0.5								0.6									
Germany F.R.	0.2		1.8			0.1			2.1		1.0		6.2	0.2				
Italy				0.1					0.1									
United Kingdom				19.1					19.1		0.9							

[illegible]

Figure II.1: IMPORTANT COPPER PRODUCING REGIONS OF THE NON-COMMUNIST WORLD



Raymond F. Mikesell, The World Copper Industry, Figure 2-1, pages 48-49.

refined production, where it is exported to in refined form and refined copper consumption. Imports in various forms and stock changes at each stage are also provided in appropriate places.

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III. THE STRUCTURE OF THE INDUSTRY

A. Industry Concentration at the Mining Stage

1. The world copper industry established its oligopolistic nature in the first quarter of the 20th century as a result of the shift in extraction techniques from small scale vein mining for high grade ores averaging 10-15% copper content to large scale mining of much lower grade porphyry ores averaging 1-6% grade. With demand for copper rising explosively to serve electrical as well as building sectors, a handful of international enterprises were able to apply new techniques of open-pit and underground mining. These enterprises rapidly expanded their activities geographically around the world. According to a recent study for UNCTC, the principal barriers to the entry of competition were:

> "(a) exploration know-how (the use of increasingly sophisticated geological and geographical mapping techniques to locate and sample large ore-bodies, which replaced prospecting for copper veins); (b) engineering technology (the extraction and processing of low-grade ore); (c) scale of capital (the value of investments by Kennecott and Anaconda in Chile after the First World War, for example, ranged from $36 million to $113 million)." 1/

2. In the post-World-War-II period, the degree of corporate concentration in the copper industry began to erode. The share of the seven leading copper mining companies declined from 70% in 1948 to some 54% by 1966, and further decreased to a mere 23% by 1978 (Table III.1). According to Moran and Maddox, the following five factors were responsible for the erosion of the industry's concentration:

(a) A series of discoveries of new sources of copper;

(b) The diffusion of the large-scale mining technology required to work large low-grade ore-bodies;

(c) The availability of financing from the smelters, refiners and fabricators which desired to secure raw material supplies (e.g., Japanese smelters);

1/ Moran, Theodore and D.H. Maddox, (1980), p. 73. Notice that between 1966 and 1978, Newmont and ASARCO replaced the Roan-AMC Group and Union Miniere.

Table III.1: COPPER PRODUCTION OF LEADING COMPANIES

(thousand short tons)

	1948	1960	1966	1978
Kennecott	514	571	699	376
Anaconda	362	476	597	193
Phelps Dodge	247	234	284	346
Roan-AMC Group	134	241	368	-
Anglo-American Group	118	392	426	168
Union Minière	171	331	399	-
International Nickel	118	155	110	166
Total "The Seven"	1664	2400	2883	1730*
Percentage of World Production	70%	60%	54%	23%

* For 1978 the Roan-AMC Group and Union Minière have been replaced by Newmont (329,000 tons) and Asarco (359,000 tons).

Source: Moran, Theodore H. and D.H. Maddox, Structure and Strategy in the International Copper Industry (prepared for UNCTC, mimeographed preliminary draft, 1980), p. 74.

(d) The growing desires of natural resource companies involved in other minerals to diversify into copper mining;

(e) The emergence and growth of state-owned enterprises in several major copper producing developing countries, which took over mining operations in Zaire (1967), Chile (1967-1971), Zambia (1970) and so on. (By 1979, the state mining companies in Chile, Zaire and Zambia together accounted for over 24% of total mine capacity of the market economies.)

3. Table III.2 shows the importance of the largest 12 companies (including state-owned companies) in the mine capacity of the market economies as of the beginning of 1979. It is noteworthy that the largest three in terms of mining capacity were state-owned companies. It is also important to note that the industry concentration is still fairly high with the largest seven accounting for 43%, and the largest twelve accounting for 49.%.

B. Concentration and Vertical Integration at the Smelting, Refining and Semi-fabricating Stages

4. Concentration at the smelting and refining stages of the copper industry is high; at least, it is greater than at the mining stage. Table III.3 shows the twelve large companies with significant smelting and refining facilities as of 1979. It is found that the twelve companies together accounted for 51 and 40 percent of market economies' smelting and refining capacities, respectively. Another tabulation of copper refining capacity by producing unit (Table III.4) shows that the largest twelve producing units as of the end of 1977 acccunted for 65% of market economies' refining capacity, and that the largest 33 units accounted for 94%. Taking into account the interlocking ownership relationships among the companies that are not fully reflected in these tabulations above, it is fair to say that there is a significant degree of concentration in the copper smelting and refining sectors.

5. Moving further downstream in the processing chain of copper, it is reasonably clear that concentration in the semi-fabricating industry is more

Table III.2: MINE CAPACITY OF COPPER PRODUCERS 1979

(thousand metric tons, beginning of year)

	Producers	Capacity	Percentage of World Mine Capacity
1.	Codelco (Chile)	880	11.5
2.	Gecamines (Zaire)	537	7.0
3.	Zimco (Zambia)	429	5.6
4.	Kennecott	376	4.9
5.	Asarco	359	4.7
6.	Phelps Dodge	346	4.5
7.	Newmont	329	4.3
8.	Anaconda	193	2.5
9.	Anglo-American	168	2.2
10.	Inco	166	2.2
11.	RTB Bor (Yugoslavia)	155	2.0
12.	RTZ	152	2.0
	Subtotal	3,766	49.2
	Others	3,876	51.8
	Total (market economies)	7,642	100.0

Source: Copper Studies, Commodities Research Unit Metals Databank, December 15, 1978. Includes mines directly and indirectly owned and operated.

Reproduced from: Moran, T.H. and D.H. Maddox, Structure and Strategy in the International Copper Industry (mimeographed preliminary draft prepared for UNCTC, 1980), p. 79.

diffused than in the mining, smelting and refining stages. Table III.5 shows major companies with copper semi-fabricating capacity, although the data are somewhat old (1974). The identified largest 25 companies accounted for 55% of market economies' total capacity as at the end of 1974.

6. The question of industry concentration takes on a far more serious complexion when vertical integration through the stages of mining, smelting, refining and semi-fabricating is considered. This is evident in data shown in Tables III.1, III.2, III.3 and III.4. Many of the large companies owning refineries have their own mines and smelting facilities and some of them own semi-fabricating facilities as well. For example, the state mining companies in Zambia, Zaire, Chile and Peru have their own smelting and refining facilities. Most of the large US copper mining companies own their own smelting, refining and semi-fabricating facilities. ASARCO, whose mining capacity in the US is rather limited, has part ownership in a number of large mining operations overseas. In Canada, Noranda and INCO, the two largest copper mining companies are vertically integrated up to the refining stage. Large proportions of refined copper produced by American and Japanese smelting/refining companies are sold to their own semi-fabricating companies, although, the mining capacity of the Japanese companies are quite limited. On the whole, "independent" smaller producers at each stage of copper production tend to depend on the large integrated producers for either supplies of raw materials or marketing outlets, or both. Thus, "the presence of vertical concentration in the copper industry does militate against effective competition...." 1/

7. Market economies' supply of copper is thus dominated by large producers. But, it should also be noted that, compared with some other nonferrous metal industries, such as nickel and aluminum, the degree of concentration in the copper industry appears to be much less than in such industries. 2/ Indeed,

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1/ W. Gluschke, J. Shaw and B. Varon, Copper: The Next Fifteen Years, A United Nations Study, Boston and London, 1979, page 20.

2/ For a strong argument on this point, see Gluschke, Shaw and Varon (1979) pp. 13-14.

Table III.3: CONCENTRATION IN SMELTER AND REFINERY CAPACITY 1979

(Thousand metric tons, beginning of year)

		Smelter	Capacity (%)	Refinery	Capacity (%)
1.	**Codelco**	**765**	**8.7**	**486**	**5.3**
2.	**Gecamines**	**536**	**6.1**	**230**	**2.5**
3.	**Zimco**	**444**	**5.0**	**380**	**4.2**
4.	Kennecott	463	5.3	525	5.8
5.	Asarco	628	7.2	606	6.6
6.	Phelps Dodge	521	5.9	404	4.4
7.	Newmont	245	2.8	217	2.4
8.	Anaconda /a	258	2.9	261	2.9
9.	Anglo-American	155	1.8	115	1.3
10.	Inco	170	1.9	182	2.0
11.	RTB Bor	190	2.2	190	2.1
12.	RTZ	75	0.9	75	0.8
	Subtotal	4,450	50.7	3,671	40.2
	Others	4,321	49.3	5,453	59.8
	Total Industry (market economies)	8,771	100.0	9,124	100.0

/a In 1980, Anaconda decided to close its smelter.

Source: Copper Studies, Commodities Research Unit International Metals Databank, December 15, 1978.

Note: There are crossholdings between Anglo-American and RTZ.

Reproduced from: Moran, T.H., and D.H. Maddox, Structure and Strategy in the International Copper Industry (mimeographed preliminary draft prepared for UNCTC, 1980), p. 79.

Table III.4: COPPER REFINING CAPACITY IN THE MARKET ECONOMIES BY PRODUCING UNIT (END 1977)

Rank Order	Producing Unit	Country	Capacity ('000 tons)	Share of Total Capacity —(%)—
1.	**Roan Consolidated Mines, Ltd.**			
	Nchanga Consolidated Copper Mines	**Zambia***	**755**	**8.9**
2.	**Metallurgie**	**Belgium**	**780**	**9.1**
3.	**ASARCO**	**US**	**675**	**7.8**
4.	**Compania de Cobre, S.A. (CODELCO)**			
	Empresa Nacional de Mineria (ENAMI)	**Chile***	**637**	**7.4**
5.	Kennecott Copper Corporation	US	517	6.0
6.	Phelps Dodge Refining Company	US	487	5.7
7.	Canadian Copper Refiners	Canada	435	5.1
8.	Nippon Mining and Smelting Company, Ltd.	Japan	360	4.2
9.	Gecamines	Zaire*	250	2.9
10.	United States Metal Refining Co. (AMAX)	US	250	2.9
11.	Norddeutsche Affinerie	F.R. of Germany	240	2.8
12.	Onahama Smelting and Refining Co. Ltd.	Japan	234	2.7
13.	The Anaconda Company	US	228	2.7
14.	International Nickel Co. of Canada, Ltd.	Canada	191	2.2
15.	Magma Copper Company	US	181	2.1
16.	Sumitomo Metal Mining Company, Ltd.	Japan	180	2.1
17.	Mitsubishi Metal Mining Company, Ltd.	Japan	163	1.9
18.	Copper Refineries Pty., Ltd	Australia	155	1.8
19.	Rudarsko Topiomiarski Basen	Yugoslavia	150	1.7
20.	Palabora Mining Co. Ltd.	Rep. of S. Africa	142	1.7
21.	B.I.C.C. Metals Ltd.	UK	140	1.6
22.	Rio Tinto Patino, S.A.	Spain	105	1.2
23.	Hibi Kyodo Smelting Company	Japan	102	1.2
24.	White Pine Copper Company	US	90	1.0
25.	Mitsui Mining and Smelting Company, Ltd.	Japan	88	1.0
26.	Huttenwerke Kayser A.G.	F.R. of Germany	85	1.0
27.	IMI Refiners, Ltd.	UK	74	0.9
28.	Cobre de Mexico, S.A.	Mexico	72	0.8
29.	Southwire Company, Copper Division	US	65	0.8
30.	Inspiration Consolidated Copper	US	64	0.7
31.	Boliden Aktiebolag	Sweden	63	0.7
32.	Dowa Mining Company, Ltd.	Japan	58	0.7
33.	Electrolytic Refining and Smelting Co.	Australia	55	0.6
	TOTAL OF ABOVE 33		8,086	93.9
	Other		525	6.1
	GRAND TOTAL		8,611	100.0

*** All refining capacity is state owned.**

Source: American Bureau of Metal Statistics, Non-Ferrous Metals Data, 1977.

Table III.5: COPPER SEMI-FABRICATING CAPACITY IN THE MARKET ECONOMIES BY PRODUCING UNIT, AS AT THE END OF 1974

Rank Order	Producing Unit	Country	Capacity ('000 mt)	Share of total identified capacity (%)
1.	British Insulated Callender's Cables, Ltd.	United Kingdom	475	6.1
2.	Anaconda Company	USA	362	4.6
3.	Drawn Metal Tube Co.	USA	315	4.0
4.	Sumitomo Metal Mining	Japan	295	3.8
5	Pirelli International S.A.	Italy	250	3.2
6.	Furukawa Electric	Japan	240	3.1
7.	Delta Metal	United Kingdom	234	3.0
8.	MIM	United Kingdom	190	2.4
9.	Hitachi	Japan	187	2.4
10.	IMI	United Kingdom	180	2.3
11.	PUK	United Kingdom	164	2.1
12.	A.T. and T. (West. Elec. Co. Inc.)	USA	150	1.9
13.	Ste. Generale	Belgium	150	1.9
14.	Mitsui Mining and Smelting	Japan	142	1.8
15.	Mitsubishi Metal Mining	Japan	120	1.5
16.	Noranda	Canada	117	1.5
17.	Toshiba Denko	Japan	96	1.2
18.	Gutehoffnungshutte, AG	F.R. of Germany	80	1.0
19.	Metallgesellschaft, AG	F.R. of Germany	80	1.0
20.	Sta. Metallurgica Italiana	Italy	80	1.0
21.	Continental Copper and Steel Industries, Inc.	USA	80	1.0
22.	Direccion General de Fabricaciones Militares	Argentina	79	1.0
23.	Sdad. Espanola de Construcciones Electro-Mecanicas, S.A.	Spain	76	1.0
24.	Diehl Metal Works	F.R. of Germany	75	0.9
25.	UV Industries Inc.	USA	67	0.9
	Other		3,537	45.3
	Total Identified Semi-fabricating Capacity		7,821	100.0

Source: Metals Bulletin, special issue, 1974, as cited in Gluschke, Shaw & Varon, Copper: The Next Fifteen Years, p. 17.

there are "relatively broad and apparent vigorous arms-length markets among independent buyers at each stage in the production of finished copper (refined wirebars or cathodes)." 1/

C. Production and Trade Arrangements

8. In world copper market today, there are no effective market control arrangements in operation. Although the Intergovernmental Council of Copper Exporting Countries (CIPEC) was created in 1967, its direct influence on the market has been rather modest (see VI.B below). Efforts to establish a formal international copper agreement involving major producing and consuming countries have been continued since 1976 under the auspices of UNCTAD, but so far no concensus has been reached on creating such an agreement. The International Wrought Copper Council (IWCC), consisting of major copper producing, trading and fabricating companies, meets regularly to exchange information on market situation and discuss specifically demand and supply prospects. IWCC appears to have a modest stabilizing influence through reducing information gaps on market conditions and corporate plans for capacity additions.

D. Barriers to Trade

9. Trade barriers in world copper market are not a major issue. They seem to be generally rather insignificant, although there are some significant barriers relating to copper fabricates and semi-fabricates. Table III.6 shows the most recent information available on the import duties of the United States, European Communities and Japan. Japan is the only country with significant MFN duties on blister and refined copper, but she offers a duty-free access under GSP.

1/ Moran and Maddox (1980), p. 80.

Table III.6: IMPORT DUTIES ON COPPER IN U.S., EC AND JAPAN

(% ad valorem)

	United States		EC		Japan	
	MFN	GSP	MFN	GSP	MFN	GSP
Ore, concentrates and matte	0.0	0.0	0.0	0.0	0.0	0.0
Black copper, blister and anode	1.0-1.3	0.0	0.0	0.0	8.5 /a	0.0
Refined copper	1.0	0.0	0.0	0.0	8.5 /a	0.0

/a A variable duty schedule would be applicable for imports at below a certain price level.

Source: U.S. - Bureau of Mines, Mineral Commodity Summaries 1981.
EC - European Communities, Official Journal, L 342, vol. 22, December 31, 1979.
Japan- Japan Tariff Association, Customs Tariff Schedules of Japan 1979.

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IV. ECONOMIC PARAMETERS FOR MARKET ANALYSIS OF THE COPPER INDUSTRY

A. Price Elasticity of Demand

1. Available estimates of the price elasticity of demand for copper are varied. Copper's own-price elasticity of demand and its cross-price elasticity with respect to aluminum price as estimated by the models prepared by (a) Arthur D. Little, Inc. (ADL), (b) Fisher, Cootner and Bailey (FCB), (c) Charles River Associates (CRA), and (d) David McNichol, are summarized in Table IV.1.

2. As expected, in all of the cases shown in Table IV.1, the estimated values of short-run price elasticities of demand for copper, i.e., both own-price elasticities and cross-price elasticities with respect to aluminum, are smaller than the corresponding long-run elasticities. However, the differences between the short-run and long-run elasticities vary depending on the cases reported. Especially, it is noteworthy that the CRA estimate of the long-run, own-price elasticity of demand is extremely high. But, except for the CRA estimate, other estimates of the long-run, own-price elasticity of demand are less than unity; this means that, even in the long-run, demand for copper is price-inelastic.

3. The estimates of the cross-price elasticities of demand for copper with respect to aluminum price tend to indicate that, while the short-run effects of changes in the relative price of copper vis-a-vis aluminum might have been rather modest in the past, (with cross elasticity ranging from 0.20 to 0.66) the long-run effects of changes in the relative price of copper vis-a-vis aluminum seem to have been rather significant degrees of substitution between the two materials.

B. Activity Elasticity of Copper Demand

4. The activity elasticity of demand for copper indicates the percent change in consumption of copper "induced" by a percent change in the level of a macroeconomic activity variable relevant to copper demand. In the cases shown in Table IV.1, the indexes of durable manufacturers, industrial production and construction materials in the United States were used in estimating such elasticities. The results reported tend to show that although the short-run activity

Table IV.1: ESTIMATES OF DEMAND ELASTICITIES FOR COPPER

Nature of Elasticity	Source	Short-run	Long-run
Own-Price Elasticity of Demand	Arthur D. Little /a	-0.47	-0.64
	Fisher-Cootner-Baily (A) /b	-0.21	-0.90
	Fisher-Cootner-Baily (B) /b	-0.17	-0.82
	Charles River Assts. /c	-0.21	-2.88
	D. McNichol (A) /d	-0.33	-0.77
	D. McNichol (B) /d	-0.12	-0.39
Cross-Price Elasticity of Demand (with aluminum)	Arthur D. Little /a	0.61	0.84
	Fisher-Cootner-Baily (A) /b	0.24	1.01
	Fisher-Cootner-Baily (B) /b	0.20	0.98
	Charles River Assts. /c	0.46	6.30
	D. McNichol (A) /d	0.66	1.57
	D. McNichol (B) /d	0.35	1.13
Activity Elasticity of Demand, with respect to:			
FRB durable manufacturers	Arthur D. Little /a	1.30	1.78
FRB industrial production	Fisher-Cootner-Baily (A) /b	0.33	1.40
US construction materials	Fisher-Cootner-Baily (B) /b	0.15	0.73
FRB durable manufacturers	Charles River Assts. /c	0.26	3.56
FRB durable manufacturers	D. McNichol (A) /d	0.44	1.06
FRB durable manufacturers	D. McNichol (B) /d	0.32	1.05

/a Refer to Arthur D. Little, Inc., Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry, Technical Appendix to Economic Impact of Environmental Regulations on the U.S. Copper Industry, draft report submitted to U.S. Environmental Protection Agency under Contract No. 68-01-2842 (October 1976).

/b F. Fisher, P. Cootner, M. Baily, "An Economic Analysis of the World Cooper Industry," The Bell Journal of Economics and Management Science, vol. 3, no. 2 (Autumn 1972) pp. 568-609.

/c Charles River Associates, Inc. (CRA), Economic Analysis of the Copper Industry (March 1970) pp. 278-315.

/d D. McNicol, "The Two Price Systems in the Copper In the Copper Industry," unpublished Ph.D. dissertation, Massachusetts Institute of Technology (February 1973), pp. 68-69. The results given here reflect the use of the domestic producers' price and the domestic price of scrap.

Source: Taken from Raymond F. Mikesell, The World Copper Industry. (Baltimore, 1979), p. 155.

elasticity of demand for copper is low (0.15 - 0.44) 1/, the long-run activity elasticity is rather high (0.73 - 1.78). 2/

5. Since the activity indexes chosen tend to fluctuate more than real GNP, the income elasticity of copper consumption demand should be somewhat less than is indicated by the results shown in Table IV.1. 3/

C. Price Elasticity of Supply

6. In econometric studies of copper markets, which are usually based on time series analysis, estimation of supply functions in notoriously problematical. As a result, the estimates of price elasticity of supply derived by such studies tend to show widely different results. Table IV.2 shows the estimates made by Jirapol Pobukadee. While these estimates are very interesting as indicative of the estimates of the parameters relevant to the estimation period (1963-1975, in the case of the Pobukadee study), extreme caution is necessary in applying the estimates to problems relating to any period outside the estimation period (especially a future period). 4/

D. Price Determination Mechanisms

7. The most important price of refined copper is the cash price for wirebars at the London Metal Exchange (LME), which is a twice-daily auction market. A "settlement price" is announced by the LME authorities for each

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1/ Excluding the ADL results.

2/ Excluding the CRA results.

3/ The rule of thumb relationship between industrial production and real GNP in the industrialized countries taken as a whole seems to be that when real GNP increases by 1%, industrial production increases by 1.2% (meaning an "elasticity" of 1.2).

4/ As for the reasons why quantitative analysis of supply is difficult and the criticisms of some econometric estimates of price-supply relationships in copper, see Chapter 6 of R.F. Mikesell, The World Copper Industry (1979).

Table IV.2: PRICE ELASTICITY OF COPPER SUPPLY

COUNTRY	SHORT-RUN	LONG-RUN
U.S.	.151	.052
Canada	.342	3.80
Chile	.007	.083
Oceania	.153	very high
Peru	.069	.087
Philippines	.075	2.344
Zaire	.131	very high
Zombia	.088	.2701
Rest of World	.028	.667
OME SCRAP	.242	.634

Source: Pobukadee, Jirapol, "An Econometric Analysis of the World Copper Market," prepared for the WEFA-AID Project, Wharton Econometric Forecasting Associates, Inc., May 1979, p. 12.

day, and this price is almost universally used as the basis for determining the prices for most of copper traded internationally (see also V below).

8. Stock changes influence LME prices. Econometric estimates confirm the importance of stocks as a determinant of short term price changes. Thiebach and Helterline 1/, for example, have explained LME prices using an equation that relates copper prices in a given period, to lagged refined copper production, lagged copper prices and stocks (as a ratio of consumption) in the same period:

$$\ln P/_{III_t} = 9.01914 - .0001863\ Q_{t-1} + .000119\ P/_{III_{t-1}} - 3.18441\ S/_{C_t}$$

$$(-6.02) \qquad (2.25) \qquad (7.16)$$

$R^2 = .908$ S.E.E. = .106 D.W. = 2.0

Where:

P = Copper price (LME spot price of wire bars), annual average in US$/MT (adjusted for 1964-66)

Q = World production of refined copper ('000 metric tons)

C = World consumption of refined copper ('000 metric tons)

S = World stocks of refined copper ('000 metric tons)

III = Index of international inflation, 1977 = 100, World Bank, EPD/IE

1/ Thiebach, Gerhard and Ray Helterline, "Copper: Current Situation and Short-Term Outlook," World Bank Commodity Note No. 3, May 1978, mimeographed, pp. 17-18.

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V. MARKET PRICES

1. There are two major categories of pricing systems for refined copper. First, there are the "free market" prices quoted on the two major exchanges, the London Metal Exchange (LME) and the New York Commodity Exchange (Comex), where standard grades and shapes of refined copper are traded daily. Second, there are the domestic producers' prices charged by copper refineries to local semi-fabricators and fabricators; these prices are changed by the sellers less frequently than the prices at the exchanges. There are also prices quoted by dealers (merchants), such as the New York dealer price, which usually fluctuates at a small premium above the prices on the exchanges. 1/

2. The most important prices are those quoted on the LME, especially the spot price for wirebars. The LME cash price for wirebars is used as the basis for the transaction price in a variety of contracts including those between mining companies selling ores/concentrates and smelters and refineries; those between refineries and fabricators; and those between merchants and fabricators. Prices used for domestic transactions in various major consuming countries outside North America follow the LME price fairly closely.

3. In the United States, there has been the tradition of selling primary refined copper to domestic buyers at the U.S. producers' price which has not always followed the LME price. Some of Canadian producers' prices also have tended to follow U.S. producers' price(s). However, since spring 1978, some major producers in the U.S. have shifted to the Comex-related price quotations and some others in the U.S. and Canada also shifted to quoting prices which move very closely with the LME price. Thus, currently, the IME wirebar price is the representative world copper price, although the volume of copper transactions on the LME is only a fraction of the total turnover of copper in the world market.

4. Table V.1 shows the LME price and the US producers' price in 1955-1980, while Figure V.1 shows them graphically.

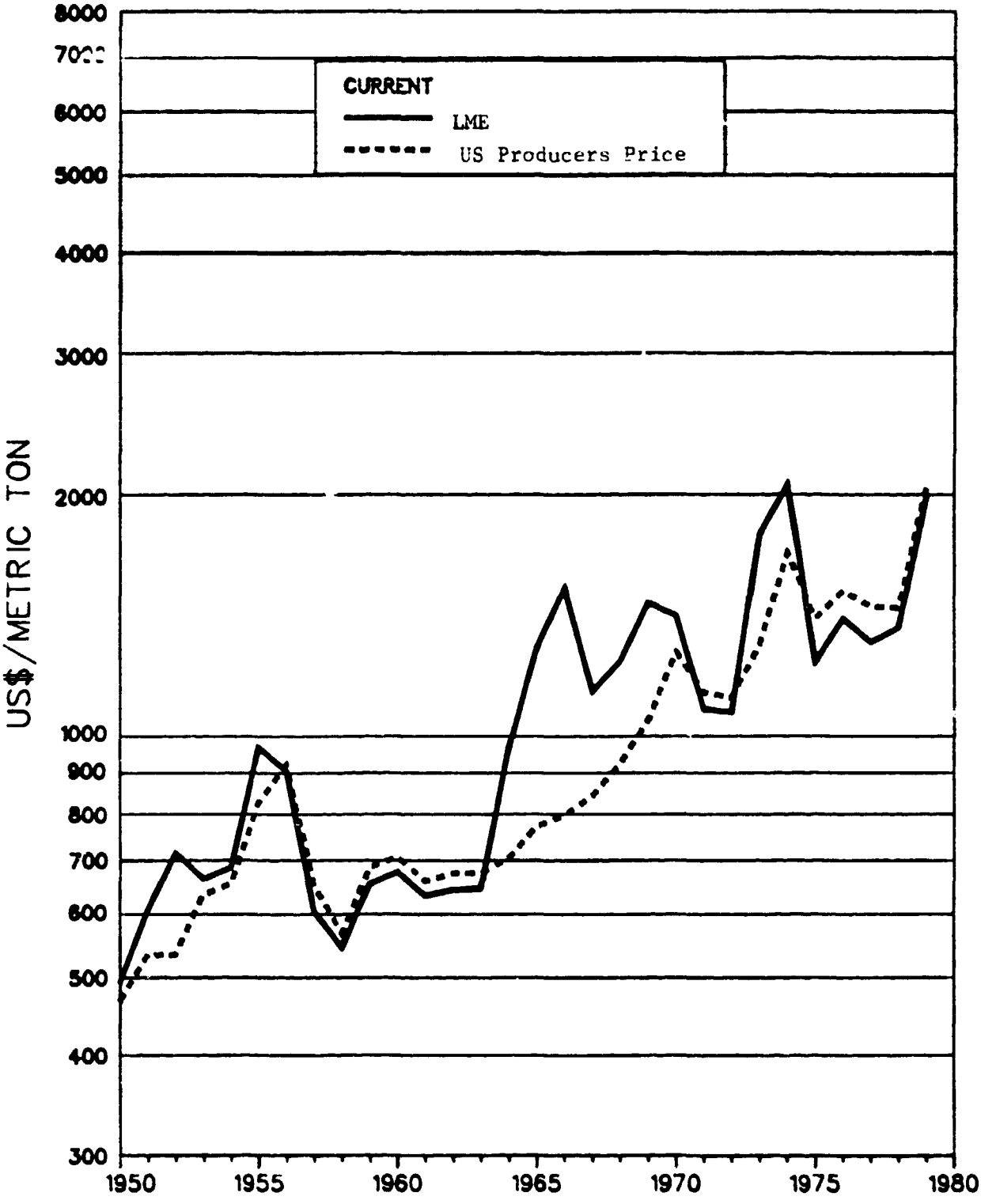
1/ Mikesell, R.F., The World Copper Industry, p. 81.

Table V.1: REFINED COPPER PRICES - NEW YORK AND LONDON, 1955-1980

	US Producers Price Current $		London Metal Exchange, Cash, Wirebars Current $		1977 Constant $	
	($/ton)	(¢/lb.)	($/ton)	(¢/lb)	($/ton)	(¢/lb)
1955	827	37.5	968	43.9	2,719	123.3
1956	922	41.8	906	41.1	2,455	111.4
1957	652	29.6	605	27.4	1,588	80.0
1958	568	25.8	545	24.7	1,423	64.5
1959	687	31.2	655	29.7	1,710	75.9
1960	707	32.1	677	30.8	1,727	78.6
1961	660	29.9	633	28.7	1,603	72.7
1962	675	30.1	644	29.2	1,647	74.7
1963	675	30.6	646	29.3	1,648	74.7
1964	705	32.0	968	43.9	2,426	110.0
1965	772	35.0	1,290	58.5	3,139	142.3
1966	797	36.1	1,530	69.4	3,696	167.6
1967	843	38.2	1,138	51.6	2,710	122.9
1968	923	41.9	1,241	56.3	3,158	143.3
1969	1,048	47.5	1,466	66.5	3,693	167.5
1970	1,272	57.7	1,413	64.1	3,211	145.7
1971	1,134	51.4	1,080	49.0	2,269	102.9
1972	1,116	50.6	1,071	48.6	2,032	92.2
1973	1,298	58.9	1,786	80.9	2,817	127.6
1974	1,690	76.6	2,059	93.4	2,606	118.2
1975	1,401	63.5	1,237	56.1	1,358	61.6
1976	1,517	68.8	1,401	63.5	1,511	68.5
1977	1,451	65.8	1,310	59.4	1,310	59.4
1978	1,444	65.5	1,367	62.0	1,179	53.5
1979	2,034	92.3	1,985	90.0	1,513	68.6
1980	1,929	87.5	2,183	99.0	1,432	65.0

Source: Engineering and Mining Journal, various issues.

Figure V.1: COPPER (YEARLY AVERAGE)



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VI. SPECIAL ISSUES

A. Stocks

1. Stocks in the analysis of copper market require special attention for, at least, three reasons: (a) deficiencies in basic data; (b) the behavior of "invisible" stocks; and (c) goverument stockpiles.

2. Table VI.1 shows reported stocks of refined copper as at the end of each year for the 1960-1979 period for the market economies as a whole. In performing any global copper market analysis based on time series data, it is important to bear in mind that data on copper stocks before and after 1973 are not comparable because of change in coverage as noted in the notes for the table.

3. Another problem related to copper stocks in a broader sense is the existence of "invisible" stocks, which seem to fluctuate rather significantly. This problem was addressed to by Marian Radetzki. 1/ The level of consumption of copper can be expected to move in parallel with overall industrial production as copper is used as an industrial raw material. However, reported consumption of refined copper in industrialized countries varies somewhat erratically and often more sharply than total industrial output over the business cycle. The

refined copper and overall industrial production is that the former reflects not only actual refined copper consumption, but also changes in copper-containing products as well as changes in unreported inventories (stocks) of unfabricated copper.

4. The issue here is not so much the problem of changes in unreported refined copper stocks at refineries, as (a) the problem of changes in the

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1/ Marian Radetzki, "Fluctuations in Invisible Stocks: A Problem for Copper Market Forecasting," World Bank Commodity Paper No. 27, October 1977.

Table VI.1: REFINED COPPER STOCKS IN MARKET ECONOMIES, 1960-1980

('000 tons)

Year	Reported Producers' Stocks /a Level at End of Period (1)	Change During Period (2)	LME Stocks (3)	US Govt. Stockpile (4)	Japan Private Stockpile (5)	Total =(1)+(4)+(5) (6)	Producers' Stocks as Percent of Refined Production (7)	Total Stocks as Percent of Refined Production (8)
1960	311	109	15	1,040	-	1,351	7.4	32.2
1961	284	-27	17	1,036	-	1,320	6.6	30.0
1962	335	51	13	1,029	-	1,364	7.7	31.2
1963	321	-14	14	1,018	-	1,339	7.2	30.1
1964	293	-28	5	993	-	1,286	6.2	27.1
1965	309	16	8	814	-	1,123	6.1	22.3
1966	326	17	14	410	-	736	6.3	14.2
1967	297	-29	12	250	-	547	6.2	11.5
1968	338	41	19	237	-	575	6.3	10.7
1969	255	-83	19	230	-	485	4.3	8.3
1970	435	180	72	230	-	665	7.1	10.9
1971	431	-4	140	229	-	660	7.5	11..
1972	515	84	183	229	-	744	8.1	11.2
1973	361	-217	35	229	-	590	5.4	8.8
1974	713	352	133	32	-	745	10.2	10.2
1975	1,357	512	504	24	-	1,381	21.6	22.0
1976	1,443	86	603	38	50	1,531	21.7	23.1
1977	1,517	74	641	21	65	1,603	22.1	23.3
1978	1,188	-329	374	29	72	1,289	17.2	18.6
1979	723	-456	127	29	37	789	10.3	11.2
1980								

/a Includes LME stocks (Column 3) and Comex stocks (not shown here) but excludes US Government Stockpile (Column 4) and Japanese private stockpile (Column 5). American Bureau of Metal Statistics coverage represents about 80% of the free world.

/b ABMS data before and after 1973 not comparable because of change in coverage. Reports are not received covering data of Finland, Norway, Spain, Sweden, Yugoslavia and some other small producing countries or companies.

Source: American Bureau of Metal Statistics (Columns 1 and 2); World Bureau of Metal Statistics (Columns 3 and 5); US Bureau of Mines (Column 4); and Metallgesellschaft and World Bureau of Metal Statistics (Column 7).

(dealers) and (b) the problem of "copper stocks" in the form of fabricates and copper-containing products in the further downstream production stages. These "copper stocks" in the form of inventories of fabricated products and even more processed products do change rather significantly over the phases of a business cycle. This problem, however, is not unique to copper, but is common to other metals as well.

5. The third important point that may be noteworthy in connection with copper stocks is the existence of government stockpiles. As of the end of 1960, U.S. government stockpiles of refined copper was as high as 1,040,000 tons, or equivalent to 25% of annual production of refined copper in the market economies at that time (Table VI.1). As a result of intermittent releases (sales) in the subsequent years, the U.S. stockpile of copper was reduced to 32,000 tons by 1974. Recently, the U.S. stockpile objective was raised from zero to 907,000 tons, although there does not seem to be any immediate plans to increase the level of stocks to the target level (from the current level of less than 30,000 tons).

6. Japan also has a government sponsored stockpile program for copper among other metals. Furthermore, the question of government stockpiles may become more important for copper as, reportedly, the governments of France and the United Kingdom are considering some form of stockpiling metals and minerals which may include cooper.

B. CIPEC

7. CIPEC is one of the most talked about producers' associations next to OPEC. So-called CIPEC (the Intergovernmental Council of Copper Exporting Countries) was created in 1967, by the four major copper exporting developing countries, i.e., Zambia, Zaire, Peru and Chile. The headquarters has been in Paris.

8. According to Stephen Zorn: "CIPEC has never been concerned exclusively with price issues. From the outset, the organization has been concerned

with questions of control and information as much as with price." 1/ Zorn classifies the objectives of producers' associations into four broad categories: (a) information, (b) defensive measures, (c) stabilization and (d) raising the real level of prices on earnings.

9. First, CIPEC has achieved a great deal in terms of improvement in information gathering and dissemination. This is important because producer countries cannot bargain effectively with multinational corporations without a good understanding of industry and market structure. Second, CIPEC has taken defensive measures from time to time. In fact, the first significant policy action taken by CIPEC was a defensive measure -- a show of solidarity in reaction to company attempts to block the sale of copper from the newly nationalized Chilean mines in 1974.

10. In the areas of market stabilization and raising of the levels of prices or earnings, the effects of CIPEC's efforts have been rather modest. As the original four members of CIPEC realized that the share of the four in world supply of copper was not large enough to influence the market. Other significant producers of copper have thus been invited to join the organization. Today, in addition to the original four, Indonesia is a full member and Australia, Papua New Guinea and Yugoslavia are associate members.

11. Since the changeover of government in Chile in 1974, there has been a basic difference in thinking among some members of CIPEC. This apparently has affected the "solidarity" of the organization and the effectiveness in taking decisive actions.

1/ Stephen A. Zorn, "Producers' Associations and Commodity Markets: The Case of CIPEC."

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