CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

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Preprint from the 1975

BUREAU OF MINES MINERALS YEARBOOK

Copper

UNITED STATES DEPARTMENT OF THE INTERIOR

The statistical data in this volume represents the most comprehensive, verified, domestic and international coverage for 1975, at the time the volume went to press. More recent information can be found in the monthly Copper Industry and the monthly Copper Production Mineral Industry Surveys obtainable from: Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213.

UNITED STATES DEPARTMENT OF THE INTERIOR • Cecil D. Andrus, Secretary

BUREAU OF MINES

This publication is a chapter from the current Bureau of Mines Minerals Yearbook, comprising *Volume I, Metals, Minerals, and Fuels; Volume II, Area Reports: Domestic; Volume III, Area Reports: International.* The separate volumes of the Yearbook are sold by the Superintendent of Documents, Washington, D.C. 20402.

Table 44.—Copper: World refinery production, by country [1]—Continued
(Short tons)

Country	1973	1974	1975 [p]
Africa:			
Rhodesia, Southern [e]	33,000	33,000	33,000
South Africa, Republic of	99,870	97,550	95,240
Zaire [5]	246,429	280,617	249,012
Zambia	703,835	746,103	698,518
Asia:			
China, People's Republic of [e]	130,000	[r] 165,000	165,000
India	[r] 13,241	12,976	18,016
Iran [e]	[r] 7,700	[r] 7,700	7,700
Japan	1,048,057	1,097,955	902,442
Korea, North [e]	14,000	14,000	14,000
Korea, Republic of [2]	10,192	13,668	23,069
Taiwan	7,329	10,868	9,413
Turkey	[r] 16,500	32,630	17,600
Oceania: Australia	[r] 160,160	179,082	182,257
Total	[r] 8,011,136	8,389,205	7,852,069

[e] Estimate. [p] Preliminary. [r] Revised.
[1] Unless otherwise noted, data presented for each country represent total primary refined copper (both fire refined and electrolytically refined), including refined from imported crude copper (blister and electrolytic anode).
[2] Includes secondary.
[3] Includes electrolytic output of Ventanas refinery.
[4] Data include leach cathodes from Zaire, secondary and alloy material.
[5] Excludes metal content of leach cathodes which are included in Belgium production.

Copper

By Harold J. Schroeder [1] and George J. Coakley [1]

World mine production of copper was 7.68 million tons, a decrease of 5% and a reversal from the preceding seven consecutive annual increases. The United States continued to lead the world in mine production, followed by Chile, the U.S.S.R., Canada, Zambia, Zaire, and Poland. Among these major producers, only Poland recorded a substantial increase, where an advance of 36% moved the country from a position of 10th to 7th largest. The lower world output was a reflection of the worldwide recession that severely reduced demand. Despite the curtailed production, stocks of refined copper were built-up to record high levels and prices were consequently depressed.

In the United States, consumption of refined copper and mine, smelter, and refinery outputs were all substantially smaller for the second consecutive year. Despite the curtailed output, the components of new supply exceeded consumption with a resultant buildup of industrial refined copper stocks and price cuts totaling 9 cents for a yearend quotation of 63 cents per pound for cathode copper. Foreign trade in unmanufactured copper was at a greatly reduced level in 1974, and net imports were a relatively small supply component. For refined copper, the largest trade category, exports exceeded imports.

[1] Physical scientist, Division of Nonferrous Metals.

Table 1.—Salient copper statistics

	1971	1972	1973	1974	1975
United States:					
Ore produced thousand short tons	242,656	266,831	289,998	293,443	263,003
Average yield of copper percent	0.55	0.55	0.53	0.49	0.47
Primary (new) copper produced—					
From domestic ores, as reported by—					
Mines short tons	1,522,183	1,664,840	1,717,940	1,597,002	1,413,366
Value thousands	$1,583,071	$1,704,796	$2,044,349	$2,468,964	$1,814,763
Smelters short tons	1,470,815	1,649,130	1,705,065	1,532,066	1,374,324
Percent of world total	22	22	22	19	18
Refineries short tons	1,410,523	1,680,412	1,698,337	1,420,905	1,286,189
From foreign ores, matte, etc., as reported by refineries do	181,259	192,821	170,151	233,753	157,189
Total new refined, domestic and foreign do	1,591,782	1,873,233	1,868,488	1,654,658	1,443,378
Secondary copper recovered from old scrap only do	445,157	458,194	486,214	483,432	369,173
Exports:					
Metallic copper do	262,838	241,600	292,504	246,205	304,712
Refined do	187,654	182,743	189,396	126,526	172,426
Imports, general:					
Unmanufactured do	359,479	415,611	420,513	608,602	324,126
Refined do	163,988	192,379	202,955	313,569	146,805

See footnotes at end of table.

Table 1.—Salient copper statistics—Continued

	1971	1972	1973	1974	1975
Stocks, Dec. 31: Producers:					
Refined ---------- short tons --	75,000	57,000	37,000	101,000	207,000
Blister and materials in solution ---------- do ----	303,000	281,000	265,000	324,000	312,000
Total ---------- do ----	378,000	338,000	302,000	425,000	519,000
Consumption:					
Refined copper -------- do ----	2,019,507	2,238,867	2,437,048	2,194,168	1,534,508
Apparent consumption, primary copper ----- do ----	1,623,000	1,901,000	1,902,000	1,778,000	1,312,000
Apparent consumption, primary and old copper (old scrap only) ---- do ----	2,068,000	2,359,000	2,388,000	2,261,000	1,681,000
Price: Weighted average, cents per pound ----------	52.0	51.2	59.5	77.3	64.2
World:					
Production:					
Mine ---------- short tons --	6,688,634	7,321,950	r 7,844,901	r 8,063,457	7,678,948
Smelter ---------- do ----	6,591,741	7,404,601	r 7,878,480	r 8,110,822	7,779,908
Price: London, average cents per pound ----------	48.49	48.53	80.86	93.13	56.08

r Revised.

Legislation and Government Programs.—The 1974 disposal of nearly 252,000 tons of refined copper reduced the inventory of refined copper in the national stockpile to 489 tons. The 7,067 tons of copper contained in beryllium-copper master alloys remained in inventory as a stockpile item.

The Office of Minerals Exploration is authorized to grant loans for up to 50% of approved costs on exploration for copper deposits. However, no loans involving copper have been awarded since 1969.

In November 1974, the U.S. Department of Commerce placed all copper raw materials, except scrap, under the Defense Priorities System. Prior to that date, only refined copper made from ores mined in the United States was subject to defense ratings. In January 1975, the Commerce Department rescinded the 5% set-aside applicable to domestic refined copper. In September 1975, the Commerce Department excluded all copper raw materials except intermediate shapes from priority ratings, thus making copper exempt from rated orders in a manner similar to that in effect prior to 1974. Defense-rated shipments of mill and foundry products were approximately 50,000 tons (copper content) in 1975.

Public Law 93-497, temporarily suspending the 0.8 cent per pound import duty on copper ores, concentrates, blister, and refined copper, expired on June 30, 1975. With the exception of July 1972–June 1973, the duty had been suspended since January 1966. A suspension of the duty on copper and copper-base scrap, however, has been continued through June 1978.

DOMESTIC PRODUCTION

Mine Production.—Domestic mine production of recoverable copper was 1.41 million tons, a 12% decline from that of 1974 and the smallest quantity since strike-disrupted 1968. Principal copper-producing States were Arizona, with 58% of the total, Utah (13%), New Mexico (10%), Montana (6%), Nevada (6%), and Michigan (5%). These States accounted for 98% of total production. Weak demand for copper and increased costs of production led to the permanent closure of several marginal underground operations, cutbacks, and temporary closures at other operating properties, and a slowdown of several new developments.

Open pit mines accounted for 80% of mine output and underground mines for 20%. The production of copper from dump and in-place leaching, mainly recovered by precipitation with iron, was 144,294 tons, or 10% of mine output. Total copper recovered by leaching methods was 231,760 tons, of which 194,495 tons was precipitated with iron and 37,265 tons was electrowon.

Table 43.—Copper: World smelter production, by country [1]—Continued
(Short tons)

Country	1973	1974	1975 p
Africa:			
Rhodesia, Southern e [8]	r 40,800	r 45,200	47,400
South Africa, Republic of	165,790	162,920	165,020
South-West Africa, Territory of [9]	39,737	51,381	40,135
Uganda	10,684	9,827	8,800
Zaire [10]	507,591	517,980	509,930
Zambia	759,024	781,828	726,453
Asia:			
China, People's Republic of e	110,000	110,000	110,000
India	12,070	12,100	12,100
Iran [11]	2,200	7,170	6,600
Japan	1,102,885	1,049,955	905,496
Korea, North e	14,000	14,000	14,000
Korea, Republic of	8,490	13,670	23,100
Taiwan [11]	3,970	4,400	4,400
Turkey	28,372	32,603	29,707
Oceania: Australia	r 179,200	215,853	198,327
Total	r 7,878,480	8,110,822	7,779,908

e Estimate. p Preliminary. r Revised.
[1] Unless otherwise noted, data presented for each country represent primary copper metal output, whether produced by thermal or electrowinning. To the extent possible, refined copper produced from imported blister or electrolytic anode copper has been excluded.
[2] Copper content of impure bars and electrolytic copper.
[3] Smelter output of domestic and foreign ores, exclusive of that from scrap. Production from domestic ores only was as follows in short tons: 1973—1,705,065; 1974—1,532,066; 1975—1,374,324.
[4] Figures presented are total blister and equivalent copper output including that blister subsequently refined in Chile and copper which is produced by electrowinning. Material produced for refining at Ventanas smelter is included.
[5] Belgium reports a large output of refined copper, but this is produced mainly from imported blister; domestic smelter production is reported output of blister copper from ores.
[6] Reported Norwegian copper output is derived in part from copper-nickel matte imported from Canada, and reported Canadian smelter production may also include this material. Norwegian smelter output from domestic ores was as follows (approximately) in short tons: 1973—7,500; 1974—6,500; 1975—7,500.
[7] Refined output.
[8] Year ending September 30 of that stated.
[9] Data from Tsumeb Corp., Ltd.
[10] Data include refined copper plus exported blister and leach cathodes.
[11] Includes secondary.

Table 44.—Copper: World refinery production, by country [1]
(Short tons)

Country	1973	1974	1975 p
North America:			
Canada [2]	548,489	616,329	583,350
Mexico	63,065	75,179	69,610
United States	1,868,488	1,654,658	1,443,378
South America:			
Argentina	90	90	90
Brazil [2]	r 32,740	41,120	31,750
Chile [3]	r 457,240	593,150	589,960
Peru	r 42,965	42,940	58,390
Europe:			
Albania e	7,690	8,540	8,540
Austria	25,215	29,446	29,686
Belgium [4]	r 416,673	437,253	393,548
Bulgaria e	52,900	52,900	52,900
Czechoslovakia [2]	r 19,665	22,981	19,800
Finland	47,297	42,193	39,423
France	e 23,800	24,866	21,491
Germany, East e	46,300	50,700	52,900
Germany, West [2]	448,263	466,896	465,397
Hungary e [2]	19,000	19,000	19,000
Norway	r 28,456	27,345	21,687
Poland	r 172,000	215,000	273,400
Portugal	2,551	2,777	e 2,800
Romania e	46,300	55,100	55,100
Spain	r 134,923	160,055	140,214
Sweden	52,760	52,335	e 49,600
U.S.S.R. e	733,000	777,000	800,000
United Kingdom	83,619	76,165	83,226
Yugoslavia	r 147,334	154,038	136,562

See footnotes at end of table.

Table 42.—Copper: World mine production, by country [1]—Continued
(Short tons)

Country	1973	1974	1975 p
Asia:			
Burma [10]	77	77	94
China, People's Republic of e	110,000	110,000	110,000
Cyprus [6]	r 15,672	10,830	10,882
India	r 18,916	30,953	42,990
Indonesia	r 41,780	71,210	68,450
Iran [11]	3,300	1,980	2,650
Israel	11,202	12,100	8,270
Japan [3 12]	r 123,994	90,538	93,011
Korea, North e	14,000	14,000	14,000
Korea, Republic of	2,558	3,080	2,944
Malaysia e	55	r 55	40
Philippines	243,825	248,554	249,894
Taiwan e	2,650	2,760	2,760
Turkey	r 33,290	42,765	40,319
Oceania:			
Australia	r 242,877	277,055	240,821
New Zealand	(13)	--	--
Papua New Guinea [3]	r 201,610	202,940	190,123
Total	r 7,844,901	8,063,457	7,678,948

e Estimate. p Preliminary. r Revised.
[1] Data shown represent copper content (recoverable where indicated) of ore mined wherever possible. If such data are not available, the nonduplicative total copper content of ores, concentrates, matte, metal and/or other copper-bearing products measured at the least stage of processing for which data are available has been used.
[2] Recoverable.
[3] Copper content of concentrate produced.
[4] Corporación Minera de Bolivia (COMIBOL) production plus exports by medium and small mines.
[5] Smelter production.
[6] Includes copper content of cupriferous pyrites.
[7] Excludes an unreported quantity of copper in iron pyrites which may not be recovered.
[8] Year ending September 30 of that stated.
[9] Data are compiled from operating company reports of Tsumeb Corp. Ltd., General Mining and Finance Corp. Ltd. for Klein Aub Koper Maatskappy Ltd.'s mine near Rehoboth, and Falconbridge Nickel Mines Ltd. for Oamites Mining Company (Pty.) Ltd., Oamites mine. Data for General Mining and Finance Corp. Ltd. are for fiscal years ending June 30 of that stated, while data from other companies are for calendar years.
[10] Copper content of matte produced.
[11] Year beginning March 21 of that stated.
[12] Copper content of run-of-mine production was as follows in short tons: 1973—r 103,874; 1974—90,985; 1975—93,952.
[13] Revised to zero.

Table 43.—Copper: World smelter production, by country [1]
(Short tons)

Country	1973	1974	1975 p
North America:			
Canada	545,641	591,990	551,152
Mexico [2]	80,506	86,322	84,188
United States [3]	1,743,963	1,569,816	1,447,128
South America:			
Argentina e	90	90	90
Brazil	4,630	2,756	e 2,700
Chile [4]	650,253	798,403	798,513
Peru	r 190,650	194,560	173,081
Europe:			
Albania e	r 7,690	r 8,540	8,540
Austria	330	2,870	e 2,870
Belgium [5]	17,600	17,600	16,500
Bulgaria e	58,000	r 53,000	62,000
Czechoslovakia	7,700	6,600	6,600
Finland	45,836	48,569	51,731
Germany, East e	1,650	--	--
Germany, West	r 175,501	191,834	185,326
Hungary e	1,300	1,300	1,300
Norway [6]	r 38,193	34,984	29,044
Poland [7]	r 172,000	215,000	273,400
Portugal	r 4,080	3,970	4,400
Romania e	46,300	55,100	55,100
Spain	r 104,482	142,443	157,410
Sweden	48,875	45,125	45,793
U.S.S.R. e	772,000	816,000	843,000
Yugoslavia	r 176,397	195,063	178,574

See footnotes at end of table.

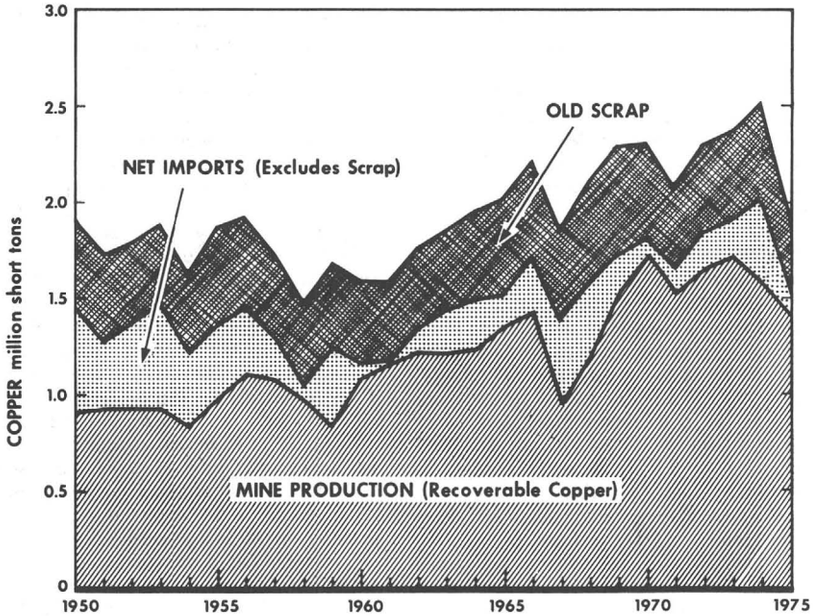

Figure 1.—Sources of copper supply for United States copper consumption.

Duval Corp., a subsidiary of Pennzoil Company, operated the Duval Sierrita open pit mine near Tucson, Ariz., milling a record 31.4 million tons of ore averaging 0.33% copper and 0.030% molybdenum. Reserves at yearend were estimated at 523 million tons grading 0.32% copper and 0.033% molybdenum. Duval also operated the Esperanza and Mineral Park copper-molybdenum open pit mines in Arizona and the Copper Canyon open pit copper mine in Nevada. These three operations milled 12.7 million tons of ore and also produced leach-precipitation copper from waste dumps. Total output from all operations was 127,721 tons of copper in concentrates and 11,170 tons of copper in precipitates.

The Anaconda Company produced 6,500 tons of copper from underground operations at Butte, Mont., compared with 17,450 tons in 1974, and reflected the phasing out of underground vein mining. Output at the Berkeley pit was 75,030 tons of copper compared with 98,890 tons in 1974. The Continental-East pit produced 12,680 tons of copper before closure in October due to depletion of ore reserves. Production of copper from the Yerington mine at Weed Heights, Nev., and the newly opened Victoria mine near Ely, Nev., totaled 41,190 tons compared with 37,970 tons in 1974. A major underground copper mine, the Carr Fork project in the Bingham District of Utah, was under development with completion scheduled for 1979. The initial rate of production was planned to be 48,000 tons per year with an increase to 56,000 tons 3 years later.

Anamax Mining Co., a joint venture of The Anaconda Company and AMAX Inc., operated the Twin Buttes, Ariz., open pit mine and produced 28,300 tons of copper compared with 40,140 tons in 1974. The 40,000-ton-per-day sulfide mill was shutdown in March to permit an intensified overburden-removal program. Startup of the 10,000-ton-per-day oxide ore leach-electrowinning plant began in August and approximately 6,700 tons of refined electrowon cathodes were produced.

Kennecott Copper Corp. operated mines in Arizona, Nevada, New Mexico, and Utah; these mines produced a combined total of 288,100 tons of copper, compared with 402,200 tons in 1974. The reduced output reflected shutdowns of from 2- to 12-week duration at the operating units

because of the weak copper market. The Utah Copper Div. accounted for 171,500 tons of the total followed by Chino Mines Div. (New Mexico) with 53,200 tons, the Ray Mines Div. (Arizona) with 42,000 tons, and the Nevada Mines Div. with 21,400 tons. Development work on a potential copper deposit beneath the perimeter of the Utah Copper Division's Bingham Canyon open pit mine continued during 1975. Sinking a large shaft, underground core drilling, test mining to determine ground conditions, and metallurgical testing is scheduled for completion by 1981. Design engineering continued for development of a copper mine near Ladysmith, Wis. If undue delays are not encountered in obtaining mining and other permits, operation at an annual estimated production of 11,000 tons of copper in concentrates could be achieved by 1978.

ASARCO Incorporated operated three copper mines in the vicinity of Tucson, Ariz. The Mission and Silver Bell units operated on a reduced 5-day-per-week schedule through June, then following a 3-week vacation shutdown in July, operated on a 4-day-per-week schedule. Outputs at the two units were 26,900 tons and 18,300 tons of copper in concentrates and precipitates compared with 40,300 tons and 23,500 tons, respectively, in 1974. Production at the San Xavier mine and leach plant in the first full year of operation was 9,700 tons of copper in precipitates. The Sacaton mine and mill near Casa Grande, Ariz., also in its first full year of operation, produced 21,900 tons of copper in concentrates. Production was from an open pit but development work was underway for the mining of a deeper ore body by underground block-caving methods beginning in 1980.

Mines of the Phelps Dodge Corp. produced 249,686 tons of copper compared with 281,338 tons in 1974. The decrease reflected closure of the Lavender pit near Bisbee, Ariz., in December 1974, and the Bisbee underground mines on June 13, 1975, and reduced work schedules. These factors more than offset production from the Metcalf mine near Morenci, Ariz., which became operational in January and produced 29,195 tons of copper in concentrates, well below its 60,000-ton capacity. Output at Morenci, Ariz.; Ajo, Ariz.; and Tyron, N. Mex., was 100,775 tons, 33,025 tons, and 75,386 tons, respectively. The Bisbee operation contributed 5,600 tons and miscellaneous sources, mostly tailings retreatment, contributed 5,707 tons of copper. Underground development work continued at Safford, Ariz., toward eventual mining of a deep ore body containing an estimated 400 million tons of ore with an average grade of 0.72% copper. However, no decision was made on when to bring this property into production.

Cities Service Co., through its North American Chemicals and Metals Group, operated mines in Arizona and Tennessee that produced 46,900 tons of copper compared with 30,600 tons in 1974. The increased output reflected the first full year of operation of the Pinto Valley open pit mine and mill facilities near Miami, Ariz., at about 90% of design capacity of 40,000 tons of ore per day. Minable ore reserves of the Copper Cities and Diamond H mines near Miami were depleted but in situ leaching operations at declining rates were to continue for several years. A solvent extraction-electrowinning plant to replace the leach-precipitation plant was under construction with completion scheduled for mid-1976. Startup of the underground Miami-East mine, originally scheduled for 1976, was postponed because of escalated costs and adverse market conditions.

The White Pine, Mich., operations of White Pine Copper Co., milled a record high 9.0 million tons of copper ore averaging 1.01% copper with an 85.6% recovery of copper in concentrate. At year-end, extractable ore reserves to the present operating depth of 2,200 feet were estimated to be 94 million tons averaging 1.2% copper, assuming that 43% of the ore would be left in pillars and allowing a 9% grade dilution. Using similar assumptions, there is a probable extractable ore reserve of 128 million tons of ore averaging 1.06% copper at depths between 2,200 and 3,500 feet.

Magma Copper Co. operated two underground copper mines in Arizona with a combined output of 133,000 tons of copper in concentrate compared with 149,600 tons in 1974. Production at the San Manuel mine was reduced 23% as an adjustment to the weak copper market. At the smaller Superior mine, production was increased by 33% to achieve the best possible unit operating costs.

The Inspiration Consolidated Copper Co. operated the Thornton, Live Oak, Red

Table 41.—U.S. imports for consumption of copper (copper content) by class

Year	Ore and concentrates		Matte		Blister	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1973	19,582	$16,029	139	$106	128,166	$159,922
1974	r 84,728	r 121,422	2,426	12,033	200,607	383,491
1975	29,301	35,649	5,675	20,560	78,969	90,846

Year	Refined		Scrap		Total value (thousands)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
1973	207,739	$264,967	19,018	$23,540	$464,564
1974	313,349	551,442	31,109	r 50,641	r 1,119,029
1975	142,945	166,159	14,399	14,459	327,678

r Revised.

Table 42.—Copper: World mine production, by country [1]
(Short tons)

Country	1973	1974	1975 p
North and Central America:			
Canada [2]	r 908,241	905,416	798,132
Cuba e	r 2,300	r 6,600	5,500
Dominican Republic	e 500	e 500	--
Mexico	88,737	91,128	86,196
Nicaragua [3]	1,703	1,957	711
United States [2]	1,717,940	1,597,002	1,413,366
South America:			
Argentina	313	347	202
Bolivia [4]	9,432	8,940	7,045
Brazil	3,761	3,390	e 3,300
Chile	810,639	994,394	913,043
Colombia e	80	80	80
Ecuador	335	197	263
Peru	r 223,423	233,241	[2] 197,340
Europe:			
Albania e [5]	7,690	8,540	8,540
Austria	r 3,023	2,962	2,186
Bulgaria	r 52,911	55,160	52,900
Czechoslovakia	r 4,960	e 5,000	e 5,000
Finland	41,192	39,850	42,770
France	456	432	441
Germany, East e	1,700	--	--
Germany, West [2 6]	1,583	1,911	2,162
Greece	1,587	e 3,300	e 3,300
Hungary e	1,300	1,300	1,300
Ireland [3]	r 14,338	14,000	10,800
Italy [6]	946	915	1,011
Norway [6]	r 24,521	22,417	30,260
Poland	170,900	218,300	297,600
Portugal [6]	6,409	6,226	5,577
Romania e [2]	46,300	55,100	55,100
Spain [6 7]	42,420	37,807	23,545
Sweden	49,404	44,795	44,823
U.S.S.R. e [2 5]	772,000	816,000	843,000
United Kingdom	506	478	e 440
Yugoslavia	r 123,235	123,587	126,722
Africa:			
Algeria	389	e 410	e 440
Botswana	e 1,500	2,623	7,154
Congo (Brazzaville) [3]	1,022	1,025	1,010
Ethiopia e	440	440	440
Kenya e	r 80	r 80	80
Mauritania	23,454	22,133	17,861
Morocco [3]	4,762	5,952	5,291
Mozambique [3]	441	689	e 850
Rhodesia, Southern [8]	46,100	43,315	e 43,000
South Africa, Republic of	193,783	197,436	197,233
South-West Africa, Territory of [3 9]	37,664	35,801	43,028
Uganda	17,259	13,496	9,370
Zaire	r 538,552	550,524	547,111
Zambia	778,864	769,364	746,177

See footnotes at end of table.

Table 40.—U.S. imports[1] of unmanufactured copper (copper content), by class and country—Continued

Year and country	Ore, concentrates		Matte		Blister		Refined		Scrap		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975—Continued												
Peru	6,077	$6,746	--	--	30,951	$32,423	6,864	$7,011	--	--	43,892	$46,180
Philippines	12,601	14,199	--	--	--	--	--	--	--	--	12,601	14,199
Poland	117	40	--	--	--	--	--	--	--	--	117	40
South Africa, Republic of	--	--	3,153	14,451	2,470	2,679	--	--	--	--	5,623	17,130
South West Africa	--	--	--	--	20,414	23,154	--	--	--	--	20,414	23,154
United Kingdom	--	--	1	10	--	--	771	1,157	46	54	818	1,221
Yugoslavia	--	--	--	--	--	--	21,494	21,347	--	--	21,494	21,347
Other	(2)	(2)	328	858	--	--	212	842	2,180	2,526	2,720	3,726
Total	64,879	71,821	9,092	35,781	88,951	96,879	146,805	170,086	14,399	14,459	324,126	389,026

[1] Data are general imports, that is, they include copper imported for immediate consumption plus material entering the country under bond.
[2] Less than ½ unit.

Hill, and Joe Bush open pit copper mines in the vicinity of Inspiration, Ariz.; 19.6 million tons of waste and 6.3 million tons of ore were mined for a combined 25.9 million tons of material handled. Approximately 5.4 million tons of the ore was treated in the concentrator, with about 77% of the concentrator feed first processed in leaching tanks to recover acid-soluble copper. The combined production from in-plant processed ore in the form of concentrates, precipitates, and electrowon cathodes was 34,263 tons of copper. Waste dump leaching of mined material too low in copper content for in-plant treatment yielded an additional 10,633 tons of copper. At the Ox Hide mine, 2.3 million tons of ore was mined for heap-leaching dumps and 5,053 tons of copper was recovered in the form of precipitates. At the Christmas open pit mine, southeast of Miami, Ariz., output was 5,865 tons from processing 1.4 million tons of ore and removal of 4.8 million tons of waste. Total mine production from all operating mines was 55,815 tons of copper compared with 61,238 tons in 1974.

The Cyprus Pima Mining Co. operated the open pit Pima mine near Tucson, Ariz., milling 19.6 million tons of ore averaging 0.48% copper. Delivery of 15 new 170-ton-capacity trucks to replace smaller vehicles and a third 20-cubic-yard shovel for 1976 delivery was expected to improve mine efficiency. Cyprus Bagdad Copper Co. at its Bagdad, Ariz., property mined 2.1 million tons of sulfide ore averaging 0.70% copper. In addition, 7,500 tons of cathode copper produced by a leach-electrowinning process was sold. Progress on a major mine-mill expansion program, designed to handle 40,000 tons of ore per day and planned to be completed by late 1977, included site preparation of the primary crusher and concentrator, and acquisition of 11 of 20 new 170-ton trucks and 1 of 4 20-cubic-yard shovels planned for the operation. Ore reserves at yearend were 300 million tons of proven ore averaging 0.49% copper, with additional tonnages indicated. The Cyprus Bruce Copper and Zinc Co. operated its underground copper-zinc mine near Bagdad, Ariz., and mined 94,600 tons of ore grading 3.7% copper and 12.5% zinc. The Cyprus Johnson Copper Co. completed development of an oxide-copper ore deposit near Johnson, Ariz., and production began in March. The leach-electrowinning process was expected to achieve the rated capacity of 5,000 tons of copper annually as cathodes during 1976. Reserves consist of nearly 13 million tons of oxide ore with 0.50% acid-soluble copper, which assures a life for the operation of about 9 years. An additional 10 million tons of mixed oxide and sulfide ore underlie the oxide deposit.

Ranchers Exploration & Development Corp. produced a record 7,605 tons of copper cathodes by a leaching-solvent extraction-electrowinning process at its Bluebird mine near Miami, Ariz. Lower copper prices and the unfavorable economic climate prompted the company to postpone its planned 50% expansion program. The in situ leaching operation at the Old Reliable deposit near San Manuel, Ariz., and the leaching operation at the Big Mike mine near Winnemucca, Nev., were placed on standby to await higher prices. The curtailed outputs for the year were 735 tons of copper in precipitates at the Old Reliable and 214 tons of copper in precipitates at the Big Mike.

Hecla Mining Co. in a joint venture with El Paso Natural Gas Co. continued mine development and plant construction at the Lakeshore copper mine south of Casa Grande, Ariz. The $195 million project was 95% complete and production was scheduled for early 1976, with output to gradually buildup to 65,000 tons of copper per year. Sulfide ore will be milled in a 11,000-ton-per-day concentrator with the concentrate treated by roasting, leaching, and electrowinning to produce 30,000 tons per year of cathode copper. The roasting operation will produce 200 tons per day of sulfuric acid for use in a 6,000-ton-per-day vat-leaching plant to process oxide ore. The leaching-plant output will be 35,000 tons of copper in the form of precipitate copper.

Operations at the UV Industries, Inc., Continental mine near Bayard, N. Mex., was curtailed by a 3-month strike. Output was 17,614 tons of copper in concentrate from milling 1,644,000 tons of ore averaging 1.17% copper. Reserves at yearend were 18 million tons averaging 0.86% copper suitable for open pit mining and 19 million tons averaging 1.97% copper suitable for underground mining.

Smelter Production.—Output of copper at primary smelters in the United States

was 1.50 million tons, a 9% decrease from that of 1974 and the smallest quantity since 1968. The reduced production reflects curtailment of operations as an adjustment to the reduced demand for copper.

ASARCO completed water-control and dust-collection facilities to meet primary water-quality standards and to improve in-plant working conditions at its Tacoma, Wash., smelter. An air monitoring and meteorological measurement system for air quality control was placed in operation at the Hayden, Ariz., smelter. At the El Paso, Tex. smelter, design work began on a second acid plant to collect sulfur emissions from both the copper smelter and the sinter machine of the lead smelter. An agreement was reached with the State of Texas to improve fugitive emissions at ground level by enclosing completely and ventilating the building housing the converter furnaces.

Anaconda completed construction of a fluid-bed roaster and 37,000-kilowatt electric furnace complex in October. The new facility will permit greater recovery of sulfur gases and particulates and replace some of the reverberatory furnace capacity.

In August, Kennecott began operating a supplementary control system for regulating sulfur dioxide emissions at its Hurley, N. Mex., smelter. During the last 5 months of the year, curtailment of smelter operation to meet ambient air quality standards resulted in an average loss of 2 days of operation per month. The McGill, Nev., smelter was shutdown for 8 weeks during the third quarter. One week after resumption of operation, a furnace failure caused an additional 5-week curtailment. At the Garfield, Utah smelter, work continued on an extensive construction project for improved environmental controls to be completed in 1977. Included in the project will be the replacement of existing reverberatory furnaces and converters with a continuous smelting-converting unit developed by Noranda Mines Ltd. and also construction of an additional sulfuric acid plant.

Phelps Dodge essentially completed construction of a new copper smelter in Hidalgo County, N. Mex. Cost of the smelter project, including a townsite and a 36-mile industrial railroad, was estimated at $240 million. It will be the first smelter in the United States to utilize the flash smelting process. Initially, the facility will have the capacity to treat about 1,400 tons of concentrates per day, equivalent to about 100,000 tons of anode copper annually. Agreement was reached to smelt concentrates from the Cyprus Mines Corp. expanded Bagdad, Ariz., mine beginning in 1978, which requires additional construction, including a second acid plant to increase the smelter capacity.

Magma Copper Co. installed equipment and storage facilities at the San Manuel smelter to permit greater use of oil as smelter fuel during periods of natural gas scarcity. However, the increased cost of oil prompted an engineering study and search for an adequate source of coal as an alternative.

Inspiration Consolidated Copper Co. experienced several equipment failures during the first full year of operation of its new electric furnace and acid plant completed in 1974. The most serious problem was failure of the furnace wall in December. However, prior to this failure, both plants demonstrated performances at rated capacities. New copper-bearing material treated at the smelter rose from 248,000 tons in 1974 to 299,000 tons in 1975. The portion supplied from other producers' mines increased from 45% to 64%.

Refined Production.—Production of refined copper from primary materials decreased 13% to 1.44 million tons. Refined copper produced from scrap was 344,500 tons compared with 496,900 tons in 1974. Total production of refined copper in the United States was 1.79 million tons, derived 81% from primary and 19% from scrap sources.

ASARCO completed construction on a new refinery of 420,000 tons of annual copper capacity at Amarillo, Tex., and by yearend was operating at about 50% capacity. Together with the necessary infrastructure and related facilities, the project was estimated to cost on the order of $190 million and will employ 700 people. ASARCO's Baltimore refinery, replaced by the Amarillo refinery, was closed in December as planned.

An expansion project by Anaconda to increase capacity at its Great Falls, Mont., refinery by 38% to 42 million pounds per month was completed during the year. Renovation of the silver slime and solution purification circuits was in progress. General economic conditions and a lack of feed

Table 40.—U.S. imports[1] of unmanufactured copper (copper content), by class and country

Year and country	Ore, concentrates		Matte		Blister		Refined		Scrap		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1973	43,335	$54,707	746	$542	154,104	$198,790	202,955	$262,129	19,373	$23,979	420,513	$540,147
1974:												
Australia	2,379	3,219	--	--	--	--	83	140	198	310	2,660	3,669
Belgium-Luxembourg	--	--	--	--	--	--	8,024	15,915	826	1,400	8,850	17,315
Botswana	--	--	625	3,018	--	--	--	--	--	--	625	3,018
Canada	19,907	26,876	155	81	3	4	118,429	190,373	12,828	22,355	151,322	239,689
Chile	--	--	7	14	65,093	126,897	66,549	119,837	242	479	131,891	247,227
France	--	--	--	--	--	--	664	1,343	290	638	954	1,981
Germany, West	--	--	--	--	--	--	7,177	13,290	1,427	2,691	8,604	15,981
Honduras	4,595	1,695	--	--	--	--	--	--	42	62	4,637	1,757
Hong Kong	--	--	--	--	--	--	22	34	1,137	1,325	1,159	1,359
Japan	--	--	--	--	94	231	73,055	136,988	4,259	8,245	77,408	145,464
Kenya	--	--	--	--	3,081	5,461	--	--	85	126	3,166	5,587
Mexico	2,069	1,288	--	--	7,644	17,396	873	1,396	6,188	7,407	16,774	27,487
Netherlands	--	--	--	--	17	5	3,253	5,651	484	884	3,754	6,540
Nicaragua	2,771	1,034	--	--	--	--	--	--	361	556	3,132	1,590
Norway	--	--	--	--	--	--	294	666	39	72	333	738
Peru	7,284	14,918	--	--	94,686	171,612	6,913	12,495	22	32	108,905	199,057
Philippines	14,244	27,206	--	--	--	--	--	--	34	55	14,278	27,261
Poland	--	--	--	--	--	--	2,192	4,162	--	--	2,192	4,162
South Africa, Republic of	--	--	1,754	9,080	37,211	71,946	110	143	--	--	39,075	81,169
U.S.S.R	--	--	--	--	--	--	1,102	1,762	--	--	1,102	1,762
United Kingdom	166	265	--	--	1	1	6,643	13,044	214	442	7,024	13,752
Yugoslavia	--	--	--	--	--	--	14,844	28,357	222	100	15,066	28,457
Zambia	--	--	--	--	--	--	2,825	5,160	--	--	2,825	5,160
Other	6	3	83	100	--	--	517	970	2,260	3,538	2,866	4,611
Total	53,421	76,504	2,624	12,293	207,830	393,553	313,569	551,726	31,158	50,717	608,602	1,084,793
1975:												
Australia	2,134	1,723	--	--	7	13	1,273	1,409	77	84	3,491	3,229
Belgium-Luxembourg	--	--	--	--	(2)	1	7,405	8,204	59	96	7,464	8,301
Botswana	5,489	--	20,374	--	--	--	--	--	--	--	5,489	20,374
Canada	38,958	46,922	75	29	4	4	70,747	88,484	7,679	7,663	117,463	143,102
Chile	18	(2)	19	35	26,283	27,007	28,626	30,378	24	25	54,970	57,445
Honduras	2,094	706	--	--	--	--	--	--	65	53	2,159	759
Japan	9	10	27	24	8,822	11,598	8,259	10,469	37	86	8,332	10,589
Mexico	2,461	1,054	--	--	--	--	912	993	4,202	3,844	16,397	17,489
Nicaragua	410	421	--	--	--	--	--	--	30	28	440	449
Norway	--	--	--	--	--	--	242	292	--	--	242	292

See footnotes at end of table.

Table 39.—U.S. imports for consumption of copper scrap, by country

Country	Unalloyed copper scrap (copper content)			
	1974		1975	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Australia	198	$310	77	$84
Bahamas	21	16	11	8
Belgium-Luxembourg	826	1,400	59	96
Canada	12,779	22,279	7,679	7,663
Chile	242	479	24	25
Dominican Republic	386	535	329	286
France	290	638	226	533
Germany, West	1,427	2,691	87	107
Guatemala	52	131	65	37
Honduras	42	62	65	53
Hong Kong	1,137	1,325	76	84
Jamaica	113	145	125	77
Japan	4,259	8,245	37	86
Mexico	6,188	7,407	4,202	3,844
Netherlands	484	884	129	233
Netherlands Antilles	217	279	272	265
Nicaragua	361	556	30	28
Panama	275	365	231	220
Switzerland	327	577	--	--
Trinidad and Tobago	19	28	36	29
United Kingdom	214	442	46	54
Other	1,252	r 1,847	593	647
Total	31,109	r 50,641	14,399	14,459

Country	Copper alloy scrap					
	1974			1975		
	Gross weight (short tons)	Content weight (short tons)	Value (thousands)	Gross weight (short tons)	Content weight (short tons)	Value (thousands)
Australia	40	38	$50	16	10	$24
Bahamas	183	119	108	170	106	101
Belgium-Luxembourg	82	58	89	242	130	194
Canada	11,507	7,565	16,443	6,820	4,461	5,828
Dominican Republic	166	123	161	132	94	81
Germany, West	236	143	301	60	31	49
Guatemala	61	46	43	9	6	4
Haiti	29	22	34	18	13	13
Hong Kong	1,057	721	1,531	320	206	481
Israel	59	52	71	--	--	--
Jamaica	30	20	26	2	1	1
Japan	564	320	578	--	--	--
Mexico	754	510	721	723	474	449
Netherlands	181	135	268	--	--	--
Netherlands Antilles	172	96	132	14	10	9
Nicaragua	55	38	53	4	3	3
Panama	78	59	88	177	115	149
Poland	--	--	--	221	115	186
Sudan	87	61	130	--	--	--
Switzerland	295	183	365	--	--	--
Trinidad and Tobago	83	67	98	24	17	10
United Kingdom	21	13	30	--	--	--
Other	150	108	181	59	39	57
Total	15,890	10,497	21,501	9,011	5,831	7,639

r Revised.

material dictated closure of the company's Perth Amboy, N.J., copper refinery, which for 40 years had been the principal processor of blister and anode copper from Anaconda's Chilean operations.

In the first full year of operation, AMAX produced 5,000 tons of refined copper at its nickel-copper-cobalt refinery at Braithwaite, La. The facility was designed to process nickel-copper matte produced by Bamangwato Concessions, Ltd. (BCL) in Botswana, as well as feed material from other sources. Capacity operation of 23,500 tons of copper per year was scheduled to be attained early in 1977.

Copper Sulfate.—Copper sulfate was produced from primary and/or secondary metal by companies with plants located as follows:

Company	Plant location
The Anaconda Company	Great Falls, Mont.
Chevron Chemical Co	Richmond, Calif.
Cities Service Co	Copperhill, Tenn.
Phelps Dodge Refining Corp	Laurel Hill, N.Y.
	El Paso, Tex.
Van Waters & Rogers Inc	Wallace, Idaho.

Copper sulfate production decreased 15% to 35,614 tons, the smallest quantity since 1971. Production exceeded shipments plus consumption by producing companies by 3,792 tons, and ending stocks of 6,866 tons were the highest yearend level since 1970. Of the total 31,822 tons shipped, producers' reports indicated that 16,187 tons was for agricultural uses, 15,119 tons was for industrial uses, and 516 tons was for other uses.

Byproduct Sulfuric Acid.—Sulfuric acid was produced at 12 copper smelters from the sulfur contained in offgases, and output increased for the eighth consecutive year, from 1,277,400 tons to a record 1,784,700 tons, on a 100%-acid basis. A sulfuric acid plant was under construction at the new Hidalgo County, N. Mex., smelter. Work was suspended on construction of an acid plant at the McGill, Nev., smelter pending resolution of a disagreement between the company and the Environmental Protection Agency over interpretation of applicable clean air standards.

SECONDARY COPPER AND BRASS

Domestic recovery of copper in all forms from all classes of purchased scrap totaled 971,965 tons in 1975, a 28% decrease from the 1974 total. Recovery from copper-base scrap declined from 1.32 million tons to 946,176 tons. Brass mills accounted for 43% of the recovered copper, primary producers for 29%, and secondary smelters for 23%. The remaining 5% was reclaimed at chemical plants, foundries, and manufacturers.

Consumption of purchased copper-base scrap in 1975 was 1.25 million tons consisting of 61% new scrap and 39% old scrap. Of the major categories of copper and copper-alloy products derived from scrap, the output of unalloyed copper, brass mill products, and brass and bronze ingots were 355,500 tons, 510,400 tons, and 188,200 tons, respectively.

CONSUMPTION

Consumption of refined copper dropped 30% to 1.53 million tons, a decrease for the second consecutive year and the smallest quantity since 1961. The reduced level of consumption was a reflection of the slump in construction, automobile production, and other areas of the economy which consume copper. Wire mills accounted for 69% of refined copper consumption, brass mills for 29%, and all other categories for the remaining 2%.

Apparent withdrawals of primary refined copper on domestic account was 1.31 million tons compared with 1.78 million tons in 1974, the latter figure excluding the supply component of approximately 252,000 tons released from the Government stockpiles in 1974.

STOCKS

Stocks of refined copper at primary producers increased from 101,000 tons at the start of the year to 225,000 tons by the end of June and were 207,000 tons at yearend. This was the largest yearend stock level since 1934. At wire rod mills, brass mills, other refined copper consumers, and secondary smelters there was a small increase in refined copper stocks from 150,900 to 156,100 tons during 1975. Refined copper stocks reported by the New York Commodity Exchange (COMEX) rose from 43,200 to 100,000 tons.

PRICES

The domestic price for refined cathode copper was established at 68 cents per pound on January 2, following an initiating reduction from 72 cents by one producer on December 27, 1974. A 5-cent price cut to 63 cents was effective February 1 for all producers. Between mid-June and late July, two producers decreased their quotes to 60 cents per pound but then returned to the 63 cents maintained by the others throughout the remainder of the year. Electrolytic wire bar quotations were 0.625 cent to 2 cents above quotations for cathode copper. Average quoted prices for electrolytic wire bar copper was 64.2 cents per pound for 1975 compared with 77.3 cents for 1974.

Prices on the London Metal Exchange (LME) increased from a monthly average of 54.9 cents per pound for January to 60.9 cents for March then declined to 52.2 cents for December. The average for the year was 56.1 cents compared with the record high 93.1 cents for 1974.

FOREIGN TRADE

Net imports of copper were a relatively small supply component in 1975 as imports of unmanufactured copper, excluding alloyed copper scrap, were 324,100 tons compared with 608,600 tons in 1974 while exports increased from 191,200 to 233,900 tons. Refined copper, the largest trade category, showed a net export quantity as imports dropped from 313,600 to 146,800 tons while exports advanced from 126,500 to 172,400 tons. Imports of blister copper were 89,000 tons compared with 207,800 tons in 1974. The other import categories of ore, concentrates, matte, and unalloyed copper scrap totaled 88,400 tons; the other export categories of ore, concentrates, matte, blister, unalloyed scrap, and ash and residues totaled 61,500 tons.

Exports of alloyed copper scrap, in gross weight, were 99,200 tons compared with 118,200 tons in 1974. Imports of alloyed copper scrap were 9,000 tons, gross weight, or 5,800 tons, copper content.

WORLD REVIEW

World mine production of copper dropped to 7.68 million tons in 1975, a decrease of 5%. The recession generated drop in demand, low prices and high operating costs led to production decreases of up to 15% in several of the major individual copper-producing countries. A notable exception of this trend was Poland, where a copper mine output increase of 36% moved Poland from 10th to 7th largest producer in the world. The United States continued to lead the world in mine production with 18% of the total, followed by Chile 12%, the U.S.S.R. 11%, Canada 10%, Zambia 10%, Zaire 7%, Poland 4%, the Philippines 3%, Australia 3%, Peru 2.6%, and the Republic of South Africa 2.6%.

World stocks of refined copper, as reported by the World Bureau of Metal Statistics, accumulated dramatically from 953,000 tons at the beginning of the year to 1,719,000 tons to yearend representing an increase of 80% over 1974 and 151% over 1973. The stocks included producer, consumer, and merchant inventories of 511,000 tons (including 100,000 tons in COMEX warehouses) of refined copper in the United States, 329,000 tons in Japan, 205,000 tons combined between West Germany, France, and the United King-

Table 38.—U.S. exports of copper scrap, by country

Country	Unalloyed copper scrap				Copper alloy scrap			
	1974		1975		1974		1975	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	409	$920	453	$538	409	$577	2,035	$2,101
Belgium-Luxembourg	7,998	7,664	3,998	3,105	9,617	10,815	5,289	3,628
Brazil	658	1,157	15	62	3,253	4,789	310	280
Canada	8,652	10,563	4,755	5,575	9,120	10,118	6,838	6,307
Denmark	11	6	--	--	47	47	199	159
France	42	41	101	90	502	534	2,016	1,382
Germany, East	21	34	83	56	128	189	190	130
Germany, West	3,193	4,601	4,184	3,825	12,113	15,227	9,804	9,929
Hong Kong	207	290	644	668	626	739	821	706
India	--	--	46	46	--	--	1,543	1,396
Italy	837	909	702	587	18,285	19,641	11,862	9,371
Japan	2,157	2,763	7,118	7,220	24,779	29,077	23,038	20,045
Korea, Republic of	7,667	9,612	9,945	9,560	12,422	13,510	10,905	9,446
Mexico	1,185	1,527	1,104	845	311	290	303	236
Netherlands	773	679	558	519	3,609	4,177	2,705	2,455
Norway	328	394	115	119	60	81	167	160
Pakistan	--	--	803	871	62	67	1,829	1,650
Spain	2,042	1,529	3,882	2,715	4,120	4,023	5,823	5,203
Sweden	349	384	303	385	1,809	1,477	3,042	1,917
Switzerland	143	192	627	615	766	818	1,604	1,410
Taiwan	2,914	1,100	4,325	2,265	9,850	3,233	2,981	2,750
Thailand	--	--	136	139	--	--	2,586	515
United Kingdom	741	1,055	295	272	5,192	6,713	2,421	2,428
Venezuela	852	736	360	198	615	138	429	121
Other	168	257	450	518	503	471	473	428
Total	41,342	46,413	45,002	40,793	118,198	126,751	99,213	84,153

Table 34.—U.S. exports of copper, by class

	Ore, concentrate and matte (copper content)		Blister		Refined copper and semimanufactures	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1973	23,508	$30,147	7,362	$8,069	242,856	$386,993
1974	r 12,488	r 17,387	2,660	3,568	202,203	448,584
1975	8,307	6,917	1,545	1,270	258,165	465,553

	Other copper manufactures [1]		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1973	7,431	$12,160	281,157	$437,369
1974	8,332	17,583	r 225,683	487,122
1975	9,518	14,158	277,535	487,898

r Revised.
[1] Does not include wire cloth; 1973, 2,017,365 square feet ($458,740); 1974, 1,954,750 square feet ($869,778); 1975, 2,268,914 square feet ($1,064,516).

Table 35.—U.S. exports of copper-base alloy (including brass and bronze), by class

Class	1974		1975	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Ingots	705	$1,972	304	$1,195
Scrap and waste	118,198	126,751	99,213	84,153
Bars, rods, shapes	15,227	31,189	7,754	13,197
Plates, sheets, strips	7,249	29,437	3,187	12,375
Pipes and tubing	8,026	23,907	6,609	19,193
Pipe fittings	9,827	31,409	6,953	23,146
Plumbers' brass goods	2,104	7,818	1,277	4,484
Welding rods and wire	4,190	13,987	2,477	7,939
Castings and forgings	987	2,409	997	3,181
Powder and flakes	2,722	7,243	1,266	2,901
Foil	286	1,453	217	796
Articles of copper and copper-base alloys, n.e.c.	(1)	7,264	(1)	7,278
Total	169,521	284,839	130,254	179,838

[1] Quantity not reported.

Table 36.—U.S. exports of unfabricated copper-base alloy [1] ingots, bars, rods, shapes, plates, sheets, and strip

Year	Quantity (short tons)	Value (thousands)
1973	15,253	$34,446
1974	23,181	62,598
1975	11,245	26,767

[1] Includes brass and bronze.

Table 37.—U.S. exports of copper sulfate (blue vitriol)

Year	Quantity (short tons)	Value (thousands)
1973	1,716	$2,043
1974	1,815	2,138
1975	1,248	2,067

3

dom, plus 548,000 tons held in LME warehouses. The LME stocks, valued at over $600 million, have served as a key market indicator, increasing over fourteenfold from the 1973 prerecession level of 38 tons. The total world stock level represented the equivalent of a 3.5-month demand based on the average monthly western-world consumption of refined copper of 490,000 tons in 1974 or a 2.7-month demand based on the 1973 peak consumption level of 638,000 tons monthly.

In response to market conditions, the conference of Ministers of the Conseil Intergouvernemental des Pays Exportateurs de Cuivre (CIPEC), comprised of Chile, Peru, Zaire, and Zambia, met in an extraordinary seventh session in Paris, April 9–11, 1975. The decision was made to reduce copper production by 15% from April 15, 1975, and to increase export cutbacks from 10% to 15% at the same date. At the eighth annual conference of CIPEC ministers held in Lima, Peru, November 18–20, 1975, it was decided to continue the cutbacks until June 30, 1976. During the meeting, Indonesia was formally admitted as a new full member and Australia and Papua New Guinea were admitted as nonvoting associate members. As a result, CIPEC claimed to control 38% of mine production, and over 72% of internationally traded copper. Major policy decisions announced at the conclusion of the conference included a CIPEC proposal to initiate a dialogue between producing and consuming countries with a view toward negotiating a copper price stabilization agreement.

Argentina.—Cía. Minera Aguilar S.A., the Argentina subsidiary of St. Joe Minerals Corp., continued engineering and feasibility studies on the Pachon porphyry copper deposit and increased the size of reported ore reserves to 790 million tons of 0.59% copper and 0.016% molybdenum. Potential production in 1981 is dependent on the arrangement of financing.

Australia.—The Australian copper industry, hard hit by high wage and cost inflation and low copper prices, dropped mine output 13% to 241,000 tons; refined copper production increased 2% to 182,300 tons in 1975. The industry had appealed to the Government through the Industries Assistance Commission to provide assistance that would allow unprofitable producers to remain in operation until copper prices recovered. Delayed by the December elections and the resulting change in government, no action had been taken by yearend.

Mount Isa Mines Ltd., operated its copper-lead-zinc-silver mine at Mount Isa and a copper smelter at Townsville to produce a record 175,000 tons of blister copper for the fiscal year ended June 30, 1975. This output exceeded the rated productive capacity of 170,000 tons, which was the result of the expansion program completed in 1973.

The Mount Lyell Mining & Railway Co., Ltd., a subsidiary of Consolidated Gold Fields Ltd., for the year ended June 30, 1975, increased production 2% to 27,350 tons of copper in concentrate from 2.32 million tons of ore grading 1.24% copper, mined and milled at its Queenstown, Tasmania, operation. Ore production came 90% from underground operations. Reserves in all ore zones were estimated at 31.7 million tons of proven ore grading 1.5% copper and 11.4 million tons of probable ore grading 1.42% copper.

Gunpowder Copper Ltd., owned 48% by Consolidated Gold Fields and located 80 miles north of Mt. Isa, increased production 4% to 8,046 tons of contained copper. A development program was underway to double capacity to 600,000 tons of ore annually by late 1978. Reserves at Gunpowder's Mammoth mine were 8.8 million tons grading 3% copper.

Cobar Mines Pty., Ltd., owned by BH South Ltd., treated 666,300 tons of ore averaging 1.9% copper producing 10,700 tons of copper contained in 42,800 tons of concentrates. The severe economic conditions led to an announcement to cut the rate of production from 800,00 to 500,000 tons per year and to suspend all development work. Drilling prior to this decision, however, increased ore reserve estimates at the CSA, Chesney, and Gladstone ore bodies to 44 million tons. Previous estimates reported average reserve grades of 1.0% copper and 4.4% zinc.

Kanmantoo Mines Ltd., in Kanmantoo, South Australia, also held by BH South Ltd., decreased production for the fiscal year ended June 30, 1975, 16% to 6,626 tons of copper contained in 32,700 tons of concentrates recovered from 967,000 tons of copper ore milled. Due to increasing losses, BH South announced that the Kanmantoo mine would be closed in mid-1976.

Peko-Wallsend Ltd., operated the

copper-gold mine at Mount Morgan, Queensland, and the Tennant Creek copper-gold-bismuth mines in the Northern Territory. At the Tennant Creek operations, the suspension of all copper mining and smelting activities continued throughout the year. The smelter was to be kept on a care and maintenance basis through 1976. Copper production for the fiscal year ended July 8, 1975, decreased 40% to 9,800 tons. The production figures represent a full rate of production for July-December 1974, and production of by-product copper only from the mining of gold shoots within the Juno, Peko, and Warrego mines for January–June 1975. During the 1974–75 fiscal year, Mount Morgan produced 9,100 tons of contained copper in 1.4 million tons of ore treated. Remaining reserves were estimated at 2.2 million tons grading 0.62% copper. The smelter handled 82,700 tons of concentrate feed yielding an output of 9,530 tons of blister copper. Decreasing ore grades and a major slide in the open pit in November led to a yearend decision to close down one of the two mills at Mount Morgan.

Botswana.—Bamangwato Concessions, Ltd. (BCL), operated the Pikwe open pit and underground nickel-copper mine and flash smelter and continued development work on the Selebi underground ore body. Production at Selebi must be phased in to offset the depletion of the open pit during 1979. Modifications and improvements to the plant process control areas, designed to remove production bottlenecks, were scheduled for completion by late 1976. Ownership of BCL is 15% by the Government of Botswana and 85% by Botswana Roan Selection Trust, Ltd. (BRST), which in turn is owned 40% by the public and about 30% each by AMAX and the Anglo American Corp./Charter Consolidated, Ltd. Group.

During the year, ore milled increased 41% to 1,267,500 tons grading 1.15% nickel and 0.94% copper compared with 901,300 tons grading 1.18% nickel and 1.01% copper in 1974. Production of a 75% to 80% copper-nickel matte improved from 7,345 tons to 18,200 during the year, but was still below the 50,000-ton planned capacity. The matte product was shipped to AMAX's Port Nickel, La., plant for refining. The 16,553 tons of matte processed yielded 5,000 tons of nickel and 6,582 tons of copper.

Canada.—Mine production decreased 12% in 1975 to 798,132 tons of recoverable copper. Smelter output decreased 7% to 551,150 tons, and refinery production decreased 5% to 583,350 tons of copper. Mine production decreased in nearly all Provinces in 1975 except for New Brunswick and Newfoundland. Ontario moved ahead as the leading copper-producing Province with 37% of the total, followed by British Columbia 33%, Quebec 16%, Manitoba 9%, and the remaining Provinces 5%.

In 1975, the double burden of Federal and provincial mining tax and royalty levies were an important added factor in delaying new copper expansion and mine development programs in Canada. Changes announced or being discussed in the second half of the year indicated the mining industry could expect some easing of restrictive taxes in 1976. In particular, the Federal Government introduced a new "Resource Allowance" deduction amounting to 25% of resource production profits after the deduction of operating and capital costs. The Resource Allowance recognizes and allows for a limited deduction of provincial resource taxes and increases the tax value of incentive write-offs, such as exploration and development costs. In British Columbia, the election of a new Social Credit Government in December was expected to bring changes in the mining tax and royalty legislation, which left most mines with little or no profits in 1974 and 1975. In Manitoba and Saskatchewan, legislation passed during the year gave the provincial Governments authority to participate directly in exploration and development projects. The Yukon and the Northwest Territories, with no restrictive mining tax legislation, saw increased exploration activity relative to the other Provinces. There was also a trend, particularly in Ontario and Quebec, to provide incentives to attract an increased degree of mineral processing, smelting, and refining within the Provinces.

In British Columbia, Afton Mines Ltd., controlled 54% by Teck Corp. Ltd., announced plans in October for the only new major copper development in the Province in 1975. The $80 million mine, mill, and smelter complex will have a capacity of 25,000 tons per year of copper with construction scheduled for completion in late 1977. The smelter will be the first

	Pipes and tubing		Plates and sheets		Wire and cable, bare		Wire and cable, insulated		Other copper manufactures [2]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1974	6,738	$18,376	793	$2,176	5,632	$11,438	62,514	$188,890	8,332	$17,583
1975:										
Africa	152	525	12	52	130	803	11,614	19,226	283	534
Argentina	--	--	2	7	(1)	6	45	273	98	257
Belgium-Luxembourg	1	4	--	--	23	94	254	1,458	139	236
Brazil	36	165	--	--	95	313	332	1,175	130	177
Canada	1,244	2,453	66	185	1,376	1,871	25,809	80,859	1,262	1,901
Denmark	--	--	--	--	(1)	1	152	898	84	94
Finland	1	2	--	--	4	7	14	153	44	82
France	79	289	2	10	4	21	221	1,874	220	416
Germany, West	18	39	4	8	30	121	167	1,720	2	8
India	(1)	2	--	--	--	--	65	440	(1)	1
Israel	32	79	1	2	36	237	427	2,318	11	33
Italy	(1)	1	7	29	31	110	143	1,694	26	168
Japan	64	736	12	38	11	54	202	1,502	120	199
Korea, Republic of	--	--	1	7	40	146	44	251	--	--
Mexico	48	129	11	45	559	1,676	8,732	17,564	61	93
Netherlands	(1)	1	7	37	20	49	469	2,318	64	76
Oceania	5	17	--	--	32	103	426	1,725	24	49
Pakistan	2	6	1	5	--	--	11	109	288	581
Philippines	12	28	6	32	6	31	1,105	2,550	79	108
Spain	(1)	1	--	--	60	282	199	1,273	317	362
Sweden	3	8	--	--	13	69	44	617	65	89
Switzerland	--	--	--	--	5	21	66	311	110	172
Taiwan	20	101	--	--	14	66	1,168	4,002	752	1,026
Thailand	1	2	--	--	1	8	92	351	8	15
United Kingdom	40	100	29	90	112	304	645	5,739	1,298	1,557
Venezuela	37	630	1	9	4	17	172	905	2,120	2,704
Other	407	962	24	90	1,115	3,456	27,012	72,638	1,913	3,220
Total	2,202	6,280	186	646	3,721	9,266	79,630	223,943	9,518	14,158

r Revised.
1 Less than ½ unit.
2 Does not include wire cloth: 1974, 1,954,750 square feet ($869,778); 1975, 2,268,914 square feet ($1,064,516).

Table 33.—U.S. exports of copper, by class and country

Year and country	Ore, concentrates, and matte (copper content)		Ash and residues (copper content)		Refined		Scrap		Blister	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1974	r 12,488	$17,387	8,233	$7,864	126,526	$227,704	41,342	$46,413	2,660	$3,568
1975:										
Africa	--	--	--	--	626	758	61	86	1	1
Argentina	--	--	--	--	55	68	453	538	--	--
Belgium-Luxembourg	297	121	2,322	2,385	13,154	17,118	3,998	3,105	887	542
Brazil	--	--	--	--	24,740	32,261	15	62	--	--
Canada	2,292	2,033	1,636	1,860	6,709	8,487	4,755	5,575	--	--
Denmark	--	--	--	--	772	864	--	--	--	--
Finland	--	--	--	--	926	1,101	--	--	--	--
France	--	--	--	--	22,753	31,860	101	90	--	--
Germany, West	--	--	455	536	34,117	40,636	4,184	3,825	--	--
India	--	--	--	--	119	125	46	46	--	--
Israel	--	--	--	--	10	19	--	--	--	--
Italy	--	--	82	69	22,156	31,487	702	587	(1)	1
Japan	4,741	3,943	163	283	2,999	3,823	7,118	7,220	52	70
Korea, Republic of	933	733	198	192	1,263	1,484	9,945	9,560	--	--
Mexico	--	--	--	--	31	73	1,104	845	2	2
Netherlands	--	--	676	416	14,906	19,575	558	519	--	--
Oceania	--	--	--	--	7	10	--	--	--	--
Pakistan	--	--	--	--	97	139	803	871	--	--
Philippines	--	--	--	--	1,740	2,467	--	--	--	--
Spain	--	--	58	22	133	137	3,832	2,715	54	103
Sweden	--	--	--	--	978	1,281	303	385	--	--
Switzerland	--	--	22	18	581	664	627	615	--	--
Taiwan	13	12	--	--	3,974	4,869	4,325	2,265	--	--
Thailand	--	--	--	--	649	806	136	139	--	--
United Kingdom	10	16	657	405	15,055	20,193	295	272	546	546
Venezuela	--	--	--	--	3,246	4,146	360	198	(1)	1
Other	21	59	330	81	630	967	1,231	1,275	3	4
Total	8,307	6,917	6,599	6,267	172,426	225,418	45,002	40,793	1,545	1,270

copper smelter to employ the new top-blown rotary-converter (TBRC) process developed by International Nickel Co. of Canada, Ltd. (INCO) and Dravo Corp. The Afton property is located only 8 miles west of Kamloops, British Columbia, on the route of the Trans Canada Highway and electric power and pipelines, which must be moved to develop the mine. The complex syenite porphyry deposit contains 34 million tons of open pit ore grading 1% copper. The heavily oxidized portion of the ore body above 500 feet is rich in native copper, which is expected to concentrate to a low-sulfur-bearing, high-grade 60%-copper product. Under an incentive program to encourage the construction of copper smelters in the Province, the British Columbia Government will provide Afton with payment of 2 cents per pound of copper produced from the smelter during its first 4 years of operation. The Province also has an option to purchase, at cost, a 5% joint-venture interest in the smelter unit, exercisable for a period of 1 year after completion of the project.

Bethlehem Copper Corp., Ltd. milled 6.5 million tons of ore grading 0.47% copper from open pit mines in the Highland Valley, and produced concentrates containing 27,300 tons of copper compared with 28,500 tons in 1974. Reserves at the operating Huestis, Iona, and Jersey mines total 56 million tons of 0.46% copper. Negotiations were underway regarding the feasibility of bringing into production the 900-million-ton 0.48%-copper ore body of Valley Copper Co., in which Bethlehem has a 20% interest. Development of the Maggie ore zone, north of Highland Valley, with indicated reserves of 200 million tons of 0.40% copper equivalent, was also delayed.

The Granduc mine of Granduc Operating Co., north of Stewart, British Columbia, operating at 60% of capacity, produced 18,700 tons of copper in concentrate from 1.6 million tons of ore grading 1.20% copper. Granduc deferred underground development work needed to make more ore available for mining after 1977. Reserves at yearend were 19.6 million tons of 1.69% copper. Engineering studies were being made to determine the feasibility of mining an estimated 11 million tons of 1.50% copper below the 2,100-foot level.

Lornex Mining Corp. Ltd., controlled by the Rio Tinto-Zinc Corp. Ltd., operated an open pit copper-molybdenum mine in the Highland Valley and produced 53,569 tons of copper and 1,542 tons of molybdenum in concentrate from 12.9 million tons of ore.

The Bell Copper Div. of Noranda Mines Ltd., in Granisle, British Columbia, mined 4.8 million tons of ore grading 0.46% copper in 1975. Concentrate output of 69,760 tons contained 18,150 tons of copper. Reserves decreased to 29.6 million tons of 0.49% copper and 0.012 ounce of gold per ton.

Brenda Mines Ltd. (50.9% Noranda), located in Peachland, British Columbia, operating one of the lowest grade porphyry copper-molybdenum mines in the world, produced a record 10 million tons of ore averaging 0.188% copper and 0.052% molybdenum yielding 16,600 tons of copper in concentrates. The initial 5-year contract with Japanese smelters was not renewed, and since mid-1975 copper concentrate was sold to North American smelters. Yearend reserves were 126 million tons of 0.176% copper and 0.047% molybdenum.

Placer Development Ltd. (33% Noranda) operated the Craigmont mine in Merritt, British Columbia, and the Gibralter mine in McLeese Lake, British Columbia, during the year. At the Gibralter mine 11.5 million tons of ore grading 0.43% copper were milled. Production of copper in concentrates was reduced 7% to 41,780 tons in response to smelter requests and the harder ore coming from the Granite Lake pit. Reserves decreased to 308 million tons, with an average grade of 0.35% copper. At Craigmont 1.97 million tons of ore grading 1.42% copper was milled. The 91,100 tons of concentrates produced contained 26,813 tons of copper, an increase of 23% over strike-affected 1974. Ore reserves of 7 million tons of 1.83% copper were sufficient to maintain operations at the 1975 level for 3 to 4 years.

Similkameen Mining Co. Ltd., a subsidiary of Newmont Mining Corp., operated its open pit mine near Princeton, British Columbia. Seriously affected by equipment problems and a 9-week strike, output for the year decreased 23% to 16,300 tons of copper in concentrate from milling 4.1 million tons of 0.46% copper

ore. Expansion of the concentrator, from 15,000 to 22,000 tons of ore per day, was completed in September 1975 to permit milling an additional 7,000 tons per day of material grading about 0.25% copper. Ore reserves at yearend were estimated at 58.2 million tons averaging 0.53% copper.

Utah International Inc., rebounding from the 1974 strike, shipped approximately 58,000 tons of copper and 62,000 ounces of gold in concentrate from its Island Copper mine on the northern end of Vancouver Island in British Columbia. The mill treated 13.7 million tons of ore in 1975.

In Manitoba, Hudson Bay Mining & Smelting Co. Ltd., operated nine mines and one smelter in the Flin Flon-Snow Lake area. Approximately 1.47 million tons of ore with an average grade of 2.4% copper and 3.0% zinc were mined and milled to produce 198,308 tons of a 16.48% concentrate containing 32,680 tons of copper, a decrease of 5%. The copper smelter produced 65,445 tons of anode copper from feed supplied 48% from Hudson Bay mines and 52% from purchased concentrates. Development work continued on the new Centennial and Westarm mines with both shafts down to over 1,400 feet at yearend. High costs shutdown the Dickstone mine in August, while depletion of developed ore reserves was expected to shutdown the Schist Lake and White Lakes mines in 1976. Total ore reserves at yearend were about 17.5 million tons grading 2.77% copper, 2.8% zinc, 0.033 ounce of gold per ton, and 0.52 ounce of silver per ton.

Sheritt Gordon Mines, Ltd. operated the Fox, Lynn Lake, and Ruttan Lake mines in Manitoba with a combined output of 43,400 tons of copper in concentrates compared with 50,800 tons in 1974. Copper production was down 11% to 27,470 tons at the Ruttan open pit mine, in which 3.34 million tons of ore averaging 0.96% copper and 1.90% zinc were milled. The lower Ruttan output was attributed to high pit equipment downtime and pit slope instability problems. At the Fox underground mine, 1.0 million tons of ore averaging 1.74% copper and 1.81% zinc were milled with production of copper in concentrates decreasing 20% to 15,747 tons. Output at the Lynn Lake nickel-copper mine continued below expectations, with copper in concentrates decreasing 20% to 2,366 tons. At yearend, production plans called for reducing output by 25% at both the Fox and Ruttan mines.

The Ontario-based Falconbridge Nickel Mines Ltd. delivered 59,260 tons of copper from nine nickel-copper mines in Sudbury, Ontario, and Manibridge, Manitoba, and from five copper-zinc, copper, and iron-copper mines in Lake Dufault and Opemiska, Quebec, Sturgeon Lake, Ontario, and Tasu Harbor, British Columbia. Concentrates from the nickel-copper operations were processed at the company smelter in Sudbury and from the other copper-zinc operations at the Noranda Mines Ltd. smelter at Noranda. Due to a 10-week labor strike at Sudbury that ended on November 2, deliveries of copper from the integrated nickel operations decreased 25% to 20,357 tons. Following the strike, production was resumed at 70% of the prestrike level, as three mines, one mill, and one of two blast furnaces were shutdown and placed on standby status. Ore reserves at yearend at Sudbury and Manibridge were 89.1 million tons averaging 1.43% nickel and 0.68% copper.

Deliveries of copper from Falconbridge Copper Ltd. increased 32% to 38,900 tons as the new Sturgeon Lake Mines Ltd. began full production on February 1. The $20 million Sturgeon Lake project, with a rated capacity of 1,200 tons per day of ore, produced 7,960 tons of copper for the year. Ore reserves at yearend were calculated at 1.8 million tons grading 2.85% copper, 10.28% zinc, 1.36% lead, 5.66 ounces of silver per ton, and 0.022 ounce of gold per ton.

INCO mined 21.2 million tons of ore with an average grade of 1.40% nickel and 0.92% copper from 16 mines in Ontario and Manitoba in 1975, compared with 22 million tons of ore with an average grade of 1.39% nickel and 0.97% copper in 1974. Deliveries of copper metal from the Copper Cliff refinery decreased 9% to 167,275 tons. At yearend, INCO estimated that proven ore reserves in Canada were 415 million tons, containing 1.61% nickel and 1.04% copper. In December, production at the Victoria mine was suspended to allow the undertaking of a year-long redevelopment program. The small Kirkwood ore body was nearly mined out and expected to close in early 1976. Development work on the new Levack East mine at Sudbury began during the year with startup scheduled for 1984.

Table 30.—Dealers' monthly average buying price for copper scrap and consumers' alloy-ingot prices at New York in 1975
(Cents per pound)

Grade	Jan.	Feb.	Mar.	Apr.	May	June
No. 2 copper scrap	31.86	30.50	33.93	33.82	31.07	29.50
No. 1 composition scrap	29.32	28.50	32.79	34.50	34.07	32.31
No. 1 composition ingot	67.61	65.00	66.21	68.00	67.48	65.50

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
No. 2 copper scrap	32.50	36.69	38.07	37.33	36.20	35.86	33.94
No. 1 composition scrap	31.91	34.69	34.93	32.94	32.20	31.50	32.47
No. 1 composition ingot	65.50	66.28	67.00	65.59	63.30	63.30	65.87

Source: Metal Statistics, 1976.

Table 31.—Average monthly quoted prices of electrolytic copper for domestic delivered, in the United States and for spot copper at London
(Cents per pound)

Month	1974			1975		
	Domestic delivered		London spot [1] Metals Week	Domestic delivered		London spot [1] Metals Week
	American Metal Market	Metals Week		American Metal Market	Metals Week	
January	68.70	68.75	92.12	68.86	69.03	54.91
February	68.70	68.58	103.80	64.32	64.18	57.44
March	68.70	68.58	124.44	64.32	64.18	60.85
April	68.70	68.58	137.50	64.32	64.18	60.28
May	81.19	81.46	130.35	64.32	63.78	56.81
June	86.09	86.24	110.60	63.67	63.14	54.04
July	86.31	86.60	87.03	63.02	62.48	55.43
August	86.31	86.60	81.74	64.31	63.79	57.91
September	83.01	83.66	66.20	64.31	63.79	54.86
October	78.23	78.43	63.40	64.31	63.79	53.46
November	75.79	76.25	64.13	64.31	63.79	53.44
December	73.03	73.57	58.43	64.31	63.79	52.18
Average	77.06	77.27	93.13	64.53	64.16	56.08

[1] Based on average monthly rates of exchange.

Table 32.—Average weighted prices of copper delivered
(Cents per pound)

Year	Domestic copper	Foreign copper
1971	52.0	49.3
1972	51.2	48.6
1973	59.5	80.8
1974	77.3	93.5
1975	64.2	56.0

Source: Metals Week.

Table 27.—Primary refined copper supply and withdrawals on domestic account
(Short tons)

	1971	1972	1973	1974	1975
Production from domestic and foreign ores, etc	1,591,782	1,873,233	1,868,488	1,654,658	1,443,378
Imports [1]	163,988	192,379	202,955	313,569	146,805
Stocks Jan. 1 [1]	130,000	75,000	57,000	37,000	101,000
Total available supply	1,885,770	2,140,612	2,128,443	2,005,227	1,691,183
Copper exports [1]	187,654	182,743	189,396	126,526	172,426
Stocks Dec. 31 [1]	75,000	57,000	37,000	101,000	207,000
Total	262,654	239,743	226,396	227,526	379,426
Apparent withdrawals on domestic account [2]	1,623,000	1,901,000	1,902,000	1,778,000	1,312,000

[1] May include some copper refined from scrap.
[2] Excludes copper, if any, delivered to industry from national stockpile sales.

Table 28.—Refined copper consumed by class of consumer
(Short tons)

Year and class of consumer	Cathodes	Wire bars	Ingots and ingot bars	Cakes and slabs	Billets	Other	Total
1974:							
Wire mills	365,111	1,101,675	W	--	--	7,554	1,474,340
Brass mills	205,803	32,023	117,791	177,663	136,878	--	670,158
Chemical plants	--	--	W	--	--	715	715
Secondary smelters	5,142	W	3,097	W	W	945	9,184
Foundries	1,725	1,508	15,494	W	W	631	19,358
Miscellaneous [1]	1,873	1,521	6,721	346	1,713	8,239	20,413
Total	579,654	1,136,727	143,103	178,009	138,591	18,084	2,194,168
1975:							
Wire mills	312,066	745,102	W	--	--	4,087	1,061,255
Brass mills	171,812	21,571	72,452	97,236	75,899	--	438,970
Chemical plants	--	--	--	--	--	467	467
Secondary smelters	2,542	W	1,931	--	W	10	4,483
Foundries	1,176	897	11,661	W	W	264	13,998
Miscellaneous [1]	2,742	217	5,421	214	178	6,563	15,335
Total	490,338	767,787	91,465	97,450	76,077	11,391	1,584,508

W Withheld to avoid disclosing individual company confidential data; included in "Other."
[1] Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and miscellaneous manufacturers.

Table 29.—Stocks of copper in the United States, Dec. 31
(Short tons)

Year	Blister and materials in process of refining [1]	Refined copper				
		Primary producers	Wire rod mills	Brass mills	Other [2]	New York Commodity Exchange
1971	303,000	75,000	93,000	40,000	6,000	20,300
1972	281,000	57,000	50,000	28,000	5,400	57,800
1973	265,000	37,000	42,000	30,000	5,600	5,900
1974	324,000	101,000	108,000	36,000	6,900	43,200
1975	312,000	207,000	119,000	31,000	6,100	100,000

[1] Includes copper in transit from smelters in the United States to refineries therein.
[2] Includes secondary smelters, chemical plants, foundries, and miscellaneous plants.

At Mattagami Lake Mines Ltd. Mattabi mine in northwestern Ontario, the concentrator treated 1.08 million tons of ore grading 0.97% copper yielding 8,700 tons of contained copper in concentrate. Ore reserves were 9.9 million tons of 6.70% zinc, 0.74% copper, 0.70% lead, 2.62 ounces of silver per ton, and 0.007 ounce of gold per ton. Development work on Mattagami's new underground mine at Lyon Lake, in the Sturgeon Lake area, continued with initial production of 1,000 tons per day of ore scheduled to begin in 1978. Reserves at the Lyon Lake deposit were increased to 4.03 million tons of 6.66% zinc, 1.15% copper, 0.63% lead, 3.39 ounces of silver per ton, and 0.010 ounce of gold per ton.

The Geco Division of Noranda Mines Ltd., at Manitouwadge, Ontario, produced 1.6 million tons of ore grading 1.84% copper, 3.54% zinc, and 1.44 ounces of silver per ton. Concentrates produced contained 27,400 tons of copper, a decrease of 6%. Reserves at yearend were 28.1 million tons grading 1.87% copper, 3.62% zinc, and 1.52 ounces of silver per ton.

Texasgulf Canada Ltd. operated the Kidd Creek mine near Timmins, Ontario, and mined 3.63 million tons of ore in 1975, down 2% from 1974. Production was about 63% from the open pit and 37% from underground. The mine yielded 228,800 tons of a 25%-copper concentrate and 9,600 tons of a copper-silver concentrate during the year, representing only a 1% drop in production for the year. At the end of 1975, measured and indicated reserves above the 2,800-foot level were estimated at 86 million tons containing 2.70% copper, 5.92% zinc, 2.31 ounces of silver per ton, and 0.217% lead. An additional 6 million tons was classified as inferred ore. Texasgulf was proceeding with a $100 million project to increase the mine production rate from 3.6 to 5.0 million tons per year by adding a fourth 3,500-ton-per-day circuit to the concentrator and by constructing a mile-deep shaft to develop the lower portion of the ore body. An agreement was signed in mid-1975 with the Mitsubishi Metal Corp. of Japan for the process license and basic design of a continuous copper smelter and mechanized copper refinery. This system was reported to be the most environmentally sound and lowest cost pyrometallurgical copper-smelting process in existence. At an estimated cost of over $250 million, the facility was scheduled for a late 1978 startup with an initial 100,000-ton-per-year capacity, later expanding to 130,000 tons per year. A gold, silver, and selenium slimes-processing refinery was also to be built.

Union Minière Canada Ltd., continued development of its Thierry copper deposit in the Pickle Lake, Ontario region with planned production for the second half of 1976 at an annual rate of 1.4 million tons of ore milled. Initial output will be from two small open pits, to be followed by underground mining. Proven reserves amounted to 15 million tons averaging 1.63% copper and exploration work in progress indicated further potential.

In the Northwest Territories, Texasgulf reported the discovery of an important base-metal sulfide deposit at Izok Lake, 225 miles north of Yellowknife. Drilling at the central of three zones showed 7 million tons of indicated ore containing 3.15% copper and 14.8% zinc.

In Quebec, Campbell Chibougamau Mines Ltd. failed to negotiate a new labor contract and suspended operations on May 5, 1975, accounting for the 48% decrease in copper production to 6,160 tons. Reserves remaining in the Chibougamau area mines total 10.3 million tons grading 1.72% copper and 0.045 ounce of gold per ton.

The Lake Dufault Division of Falconbridge Copper Ltd., in 1975, produced 13,084 tons of copper in concentrate. The 7% increase in production over that of 1974 was attributed to a higher grade of ore treated. Reserves at yearend were 1.86 million tons of ore grading 3.56% copper and 4.62% zinc. The Opemiska Division milled 952,000 tons of 2.02% copper in 1975 to produce 18,383 tons of copper in concentrate. Remaining reserves consist of 5.69 million tons of 2.39% copper. Shaft sinking at the Cooke mine was completed and development was in progress.

Madeleine Mines, near Ste. Anne des Monts, Quebec, milled 908,000 tons of copper yielding 9,677 tons of copper. Approximately a 4-year supply of reserves remained.

Noranda Mines Ltd. had an interest in the treatment of 49.5 million tons of ore containing 216,300 tons of contained copper from 19 copper and zinc-copper mines in Quebec, British Columbia, Ontario, and New Brunswick. Shortages of skilled miners continued to hamper a number of No-

randa's operations during the year. The company's two copper smelters at Noranda, Quebec, and Gaspé Copper in Murdochville, Quebec, treated 879,700 tons of concentrates from Noranda operations and 839,500 tons of custom material from other Canadian copper mines and from overseas. The 1.7 million tons of total material treated yielded 304,200 tons of copper contained in anodes for a decrease of 10% from that of 1974. The Noranda smelter accounted for 76% and Gaspé 24% of anode production. Canadian Copper Refineries, Ltd. (CCR) in Montreal East, Quebec, operated by Noranda, is one of the world's largest copper refineries, with a rated annual capacity of 480,000 tons. In 1975, refinery production decreased 7% to 395,000 tons of copper. CCR processed the output of the Noranda smelters, the Flin Flon smelter of Hudson Bay Mining & Smelting Co. Ltd., and imported and secondary material.

Noranda's Horne Division in Noranda, Quebec, produced 344,300 tons of ore averaging 2.15% copper and 0.135 ounce of gold per ton. Reserves of 231,000 tons of 1.05% copper at the Horne mine were expected to be depleted by 1976.

Gaspé Copper Mines Ltd. (Noranda) milled 1.25 million tons of 1.19% copper ore from the Needle Mountain mine and 9.75 million tons of 0.44% copper ore from Copper Mountain mine yielding 48,000 tons of copper contained in concentrates. Reserves at the two mines were, respectively, 21.6 million tons of 1.33% copper and 201 million tons of 0.38% sulfide copper plus 33 million tons of 0.45% oxide copper.

Mattagami Lake Mines Ltd. (43% Noranda) treated, at the Mattagami Lake mine, 1.29 million tons of ore averaging 7.3% zinc, 0.62% copper, 0.86 ounce of silver, and 0.014 ounce of gold per ton, which yielded 6,000 tons of copper in concentrate. Remaining ore reserves totaled 10.8 million tons grading 8.4% zinc, 0.65% copper, 0.95 ounce of silver per ton, and 0.015 ounce of gold per ton.

Patino Mines (Quebec) Ltd., a subsidiary of the Dutch company Patino, N.V., operated or had an interest in five copper-gold mines in Quebec. Affected by a strike for the first 3½ months of 1975 and by the temporary shutdown of the Copper Cliff, Jaculet, and Portage mines, total mill production of 440,000 tons of 1.67% copper was down from the 1974 input of 859,000 tons of 1.56% copper. Metal production derived solely from the Copper Rand mine amounted to 6,900 tons of copper in concentrate, down 45% from 1974. Ore reserves at yearend were 6.2 million tons of 1.74% copper and 0.055 ounce of gold per ton. The associated company, Lemoine Mines Ltd., nearly completed its $8.6 million, 400-ton-per-day mine and mill complex, 37 miles southeast of Chibougamau, with startup scheduled for March 1976. The high-grade volcanogenic massive sulfide deposit contains reserves of 625,000 tons of 4.5% copper, 10.8% zinc, 2.7 ounces of silver per ton, and 0.138 ounce of gold per ton.

In the Yukon Territory, Whitehorse Copper Mines Ltd., owned in part by Hudson Bay and Anglo-American Corp. of Canada Ltd., mined and milled 739,000 tons of 1.51% copper ore and produced 27,700 tons of a 36% concentrate containing 9,972 tons of copper. Development work below the 1,750-foot level continued.

Chile.—Mine production for the year decreased 8% to 913,000 tons of copper as Chile continued as the world's second largest copper producer behind the United States. Production from the large mines was as follows: Chuquicamata, 335,800 tons compared with 393,200 tons in 1974; El Teniente, 257,900 tons compared with 248,500 tons; El Salvador, 89,600 tons compared with 88,200 tons; and Andina, 68,800 tons compared with 75,400 tons. Approximately 30,000 to 35,000 tons of the production decrease was accounted for by the closure of the high-cost Exótica mine for the year.

In the medium and small mine production area, Mantos Blancos decreased output 9% to 32,200 tons, Empresa Nacional de Minera (ENAMI) increased output 9% to 85,500 tons, and Disputada raised production 26% to 35,900 tons of copper.

Minera Sagasca, S.A. controlled 59% by Continental Copper & Steel Industries Inc., operated at 30% of capacity for the year and produced 6,000 tons of copper. Sagasca, due to poor oxide leach recovery rates and difficulties in meeting long term debt schedules, applied to the Chilean Government to suspend operations at yearend.

Production of blister copper at Chile's six smelters remained at 798,000 tons, the same as in 1974. Electrolytic and fire-

Table 26.—Foundry consumption of brass ingot by type, refined copper, and copper scrap, in the United States in 1975, by geographic division and State

(Short tons)

Geographic division and State	Tin bronzes	Leaded red brass and semi-red brass	Yellow brass	Manganese bronze	Hardeners and master alloys	Nickel silver	Aluminum bronze	Total brass ingot	Refined copper consumed	Copper scrap consumed
New England:										
Connecticut	701	1,704	1,067	43	6	166	228	3,750	623	319
Massachusetts	866	3,708	614	235	13		58	5,659	700	25
Maine, New Hampshire, Rhode Island, Vermont	131	1,752	204	188	4	115	46	2,440		--
Total	1,698	7,164	1,885	466	23	281	332	11,849	1,323	344
Middle Atlantic:										
New Jersey	611	896	240	155	120	34	43	2,099	1,325	2,038
New York	1,330	5,869	844	293	64	194	116	9,210	1,433	1,356
Pennsylvania	6,296	6,869	1,690	583	1,162	319	1,397	18,306	4,957	4,529
Total	8,737	13,634	2,774	1,031	1,336	547	1,556	29,615	7,720	7,923
East North Central:										
Illinois	2,042	10,502	715	654	91	7	700	14,711	806	2,337
Indiana	2,606	5,565	838	359	1,151	282	43	10,844	993	7,075
Michigan	8,177	3,724	42,752	607	167	6	403	55,836	4,973	2,105
Ohio	8,177	8,929	4,173	1,245	299	19	447	23,289	3,347	5,969
Wisconsin	1,432	5,153	2,661	118	1,143	298	129	10,934	5,313	886
Total	22,434	33,873	51,139	2,983	2,851	612	1,722	115,614	15,432	18,372
West North Central:										
Iowa, Kansas, Minnesota	820	2,883	123	472	60	5	139	4,500	1,099	868
Missouri, Nebraska, South Dakota	126	753	826	194			17	1,918		711
Total	946	3,636	949	666	60	5	156	6,418	1,099	1,579
South Atlantic:										
Delaware, District of Columbia, Florida, Georgia, Maryland	431	364	103	100	3	784	69	1,852	142	679
North Carolina, South Carolina, Virginia, West Virginia	495	5,522	442	210			260	6,931	202	7,615
Total	926	5,886	545	310	3	784	329	8,783	344	8,294
East South Central:										
Alabama, Kentucky, Mississippi, Tennessee	2,215	7,674	3,166	523	56	74	102	13,810	1,389	7,528
West South Central:										
Arkansas, Louisiana, Oklahoma, Texas	2,371	2,092	3,758	347	3	76	865	9,512	1,293	898
Mountain:										
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah	263	389	57	36	4	--	8	757	298	468
Pacific:										
California	1,236	10,388	1,515	395	84	57	135	13,810	8	9,743
Oregon and Washington	156	103	11	86	--	1	82	439	427	2,344
Total	1,392	10,491	1,526	481	84	58	217	14,249	435	12,087
Grand total	40,982	84,839	65,799	6,843	4,420	2,437	5,287	210,607	29,333	57,493

Table 24.—Consumption of copper and brass materials in the United States by principal consuming groups
(Short tons)

Year and item	Primary producers	Brass mills	Wire mills	Foundries, chemical plants, and miscellaneous users	Secondary smelters	Total
1974:						
Copper scrap	602,832	710,889	--	79,481	384,327	1,777,529
Refined copper [1]	--	670,158	1,474,340	40,486	9,184	2,194,168
Brass ingot	--	23,902	--	[2] 260,828	--	284,730
Slab zinc	--	170,669	--	3,631	7,263	181,563
Miscellaneous	--	--	--	200	13,167	13,367
1975:						
Copper scrap	372,505	518,364	--	60,098	301,601	1,252,568
Refined copper [1]	--	438,970	1,061,255	29,800	4,483	1,534,508
Brass ingot	--	5,645	--	[2] 188,669	--	194,314
Slab zinc	--	106,942	--	2,084	6,300	115,326
Miscellaneous	--	--	--	150	12,717	12,867

[1] Detailed information on consumption of refined copper will be found in table 28.
[2] Shipments to foundries by smelters plus decrease in stocks at foundries.

Table 25.—Foundry consumption of brass ingot, by type, in the United States
(Short tons)

	1971 r	1972 r	1973 r	1974 r	1975
Tin bronzes	36,755	40,526	47,963	53,702	40,982
Leaded red brass and semired brass	132,419	145,617	136,012	117,038	84,839
Yellow brass	34,681	36,865	34,820	58,922	65,799
Manganese bronze	8,257	9,933	10,868	9,773	6,843
Hardeners and master alloys	5,366	5,291	6,633	6,053	4,420
Nickel silver	3,466	2,838	2,908	3,104	2,437
Aluminum bronze	6,739	6,222	6,882	7,743	5,287
Total	227,683	247,292	246,086	256,335	210,607

r Revised.

refined copper output remained essentially constant at 590,000 tons. In 1975, Chile exported 776,000 tons of copper contained in all classes valued at US$854 million. Corporación del Cobre de Chile (Codelco) invested approximately $115 million to maintain installed capacity and to lower production costs, which during the year dropped from 51 cents to 48 cents per pound of copper. The expenditures included the expansion of the secondary grinding plant and a new molybdenum recovery plant at Chuquicamata, and an addition of the third reverberatory furnace, and expansion of the Rancagua foundry at El Teniente.

At Codelco's Andina mine, Cerro Corp. was engineering an $18 million project to expand mill capacity to produce 86,000 tons of contained copper by 1978.

Sociedad Minera Pudahuel CPA, owned by private Chilean interests, hired the U.S. firm, Holmes and Narver, as engineer and construction manager for the $40 million Lo Aguirre project near Santiago. The mine, mill, solvent extraction, and electrowinning plant complex is scheduled to start production in 1978 at an annual capacity of 22,000 tons of cathode copper. The Lo Aguirre deposit contained reported reserves of 10.4 million tons of 2.12% copper.

Of the four large ore bodies being made available for foreign exploitation under the Foreign Investment Law (DL-600) of July 1974, Noranda Mines Ltd. signed a letter of intent on Andacolla, located in Coquimbo Province, with reserves of 193 million tons of 0.75% copper and 0.15% molybdenum. Leon Tempelsman & Sons signed one for El Abra, with a minimum 770 million tons grading 0.9% copper, while the other two, Quebrada Blanca and Los Pelambres, were still in an earlier phase of negotiations.

Codelco published *El Cobre Chileno–1975,* a comprehensive 500-page book that gave a detailed property-by-property account of all aspects of the Chilean copper industry. The book reported the magnitude of Chile's copper resources at 10.2 billion tons of 1.02% copper, demonstrated and inferred reserves, plus an additional 7.3 billion tons of identified subeconomic resources averaging 0.32% copper.

Finland.—Copper output increased 7% to 42,770 tons. Principal producing mines, operated by Outokumpu Oy, were the Keretti with 14,000 tons, the Vuonos with 8,260 tons, the Pyhasalmi with 4,970 tons, the Hammaslahti with 4,420 tons, and the Vihanti with 3,620 tons.

France.—The French Government committed over $55 million during the year to establish a raw materials stockpile chiefly to purchase copper and nickel to minimize the impact of price fluctuations on domestic industries. The copper stockpile, managed by the Groupement d'Importation et de Repartition des Metaux S.A. (GIRM), is reportedly maintained at a level sufficient to cover a 2-month consumption. In 1975, refined-copper consumption in France averaged 34,000 tons per month.

Indonesia.—Freeport Indonesia, Inc., a subsidiary of Freeport Minerals Co., and operator of the 11,500-foot-high Gunung Bijih (formerly Ertsberg) copper mine in Irian Jaya, produced 68,500 tons of copper contained in 219,600 tons of concentrates, a decrease of 4% from that of 1974.

Freeport Indonesia Inc. was continuing to study the feasibility of maximizing recovery of ore by open pit mining and to appraise possibilities for underground operations. Present estimates project depletion of the mine's remaining open pit reserves between 1981 and 1983. In late 1975, the Government accepted, in principle, a plan to acquire an 8.5% interest in Freeport Indonesia, reducing Freeport's equity in Freeport Indonesia to slightly over 80%.

Iran.—Sar Cheshmeh Copper Mining Co., an Iranian Government-owned company, continued development of the copper mine and metallurgical complex in southern Iran. Design capacity of the $500 million complex is approximately 160,000 tons of copper per year with initial production scheduled for mid-1977. Anaconda, which is developing and operating the project under a technical assistance contract, reported reserves, at a 0.40% cutoff and to a depth of 500 feet, at nearly 500 million tons of ore averaging 1.13% copper and 0.03% molybdenum.

Israel.—Timna Copper Mines Ltd., operating one of the world's highest cost copper mines with a capacity of around 14,000 tons per year, ceased operations at yearend.

Japan.—Mine production of copper from the Kuroko deposits of Japan, increased 3% to 93,000 tons. Mine output contributed only 10% of the consumption of

refined copper since Japan was dependent on imports for about 90% of its copper requirements. The continued recession and high cost of petroleum imports were reflected in the 14% decrease in blister copper production to 905,500 tons and the 18% decrease in refined copper output to 902,400 tons. Based on sales of refined copper, Mitsubishi Metal Corp. was the leading copper company providing 25% of the copper supply, followed by Nippon Mining Co. Ltd. (22%), Mitsui Mining & Smelting Co. Ltd. (15%), Sumitomo Metal Mining Co. Ltd. (15%), The Dowa Mining Co. Ltd. (14%), Furukawa Mining Co. Ltd. (8%), and Toho Zinc Co. Ltd. (1%).

Japan, the world's third largest consumer of refined copper, following the United States and the U.S.S.R., consumed 888,700 tons of copper, a decrease of 3% from 1974 and 33% from the 1973 record.

Restricted by the Ministry of International Trade and Industry (MITI) ban on exporting copper, in effect the full year, producers built-up stock levels at yearend to 207,000 tons, up 76% over 1974 and over 250% above 1973 levels. An additional 122,000 tons of stockpiled copper was held by Japanese merchants and consumers. At yearend, the Japanese cabinet approved approximately $100 million to fund a nonferrous stockpiling program beginning in April 1976. The Government was considering an industry request to establish the copper stockpile at a 90,000-ton level, but the limited funds made this level unlikely.

Mitsubishi, incorporating a significant breakthrough in smelter technology, brought its new Naoshima smelter into full commercial operation in 1975. The new plant, with a design capacity of 4,400 tons of copper per month, is the first commercial plant to use the Mitsubishi continuous copper smelting and converting process.

Malaysia.—The Mamut Mines Development Co., under the management of Overseas Mineral Resources Development Sabah Bhd., a consortium of seven Japanese firms, in a joint venture with the Sabah Government and other Malaysian interests, completed development of the $94 million mine-mill project near Mamut, Sabah. By yearend, technical beneficiation problems were delaying shipments of concentrates from the mill, which is rated at a capacity of 30,000 tons per year of contained copper. The dioritic porphyry and contact serpentinite ore body, discovered by the United Nations in 1965, contains reserves of 196 million tons of ore grading 0.576% copper, chiefly in the form of chalcopyrite.

Mauritania.—The Mauritania Government, which applied for membership in CIPEC, completed arrangements in April with Charter Consolidated Ltd. for the takeover of the Société Minière de Mauritania (SOMIMA) copper mine at Akjoujt. Charter will continue to operate the mine under contract to the Government agency, Société Nationale Industrielle et Minière (SNIM). Production for 1975 was estimated at around 60% of the current capacity of 24,000 tons of copper in concentrate. SNIM announced preliminary plans to build a 33,000-ton-per-year smelter at Akjoujt. Reserves were estimated at 23 million tons of 2% copper.

Mexico.—The Mexican Government passed a new mining law effective February 20, 1975, which among other items increased the compulsory percentage of Mexican capital in mining companies from 51% to 60% when their purpose is to exploit ordinary substances, and from 66% to 75% when their purpose is to exploit substances forming part of the national mining reserve. Mexican copper production decreased slightly in all areas during the year. Mine production dropped 5% to 86,200 tons, smelter output was down 2% to 84,200 tons, and refined copper was down 7% to 69,000 tons.

Industrial Minera Mexico S.A., in which ASARCO has a 34% interest, decreased the output of blister copper 7% to 35,100 tons. Exploration work continued on the large El Arco porphyry copper deposit in the Baja, California peninsula, with reserves now estimated at 770 million tons of about 0.5% copper. Development plans called for the treatment of El Arco concentrates at the proposed new La Caridad refinery complex at Guaymas.

Compañía Cuprifera La Verde, S.A., delayed construction of a $100 million, 27,500-ton-per-year copper project at the La Verde deposit at Gabriel Zamora, Michoacan, 200 miles west of Mexico City. Legal and financing problems postponed the original mid-1975 construction startup. Lytton Minerals Ltd., a Hudson Bay subsidiary, held a 48% interest in the

Table 23.—Stocks and consumption of purchased copper scrap in the United States in 1975
(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks Dec. 31
SECONDARY SMELTERS						
No. 1 wire and heavy copper	2,717	24,745	2,449	22,829	25,278	2,184
No. 2 wire, mixed heavy and light copper	2,535	62,763	17,791	42,386	60,177	5,121
Composition or red brass	4,179	50,367	11,205	38,071	49,276	5,270
Railroad-car boxes	229	1,178	--	1,083	1,083	324
Yellow brass	5,193	38,577	4,818	33,850	38,668	5,102
Cartridge cases and brass	72	35	--	75	75	32
Auto radiators (unsweated)	3,565	46,169	--	45,659	45,659	4,075
Bronze	1,421	19,913	2,789	16,853	19,642	1,692
Nickel silver and cupronickel	831	2,743	329	2,456	2,785	789
Low brass	542	2,400	1,711	618	2,329	613
Aluminum bronze	94	436	225	114	339	191
Low-grade scrap and residues	14,032	55,463	45,521	10,769	56,290	13,205
Total	35,410	304,789	86,838	214,763	301,601	38,598
PRIMARY PRODUCERS						
No. 1 wire and heavy copper	2,544	100,286	47,516	50,271	97,787	5,043
No. 2 wire, mixed heavy and light copper	4,336	128,393	76,815	52,386	129,201	3,528
Refinery brass	20,132	2,472	2,267	962	3,229	9,619
Low-grade scrap and residues		132,532	47,043	95,245	142,288	
Total	27,012	363,683	173,641	198,864	372,505	18,190
BRASS MILLS [1]						
No. 1 wire and heavy copper	10,938	137,580	112,736	24,844	137,580	11,246
No. 2 wire, mixed heavy and light copper	4,316	43,061	41,851	1,210	43,061	4,415
Yellow brass	22,321	209,959	209,959	--	209,959	23,886
Cartridge cases and brass	8,543	55,987	55,471	516	55,987	8,090
Bronze	1,272	3,803	3,803	--	3,803	995
Nickel silver and cupronickel	7,110	39,233	39,233	--	39,233	7,228
Low brass	4,946	28,347	28,347	--	28,347	4,334
Aluminum bronze	29	394	394	--	394	34
Total [1]	59,475	518,364	491,794	26,570	518,364	60,228
FOUNDRIES, CHEMICAL PLANTS, AND OTHER MANUFACTURERS						
No. 1 wire and heavy copper	4,033	23,493	7,555	17,747	25,302	2,224
No. 2 wire, mixed heavy and light copper	1,222	9,587	2,284	7,791	10,075	734
Composition or red brass	879	4,320	1,522	3,170	4,692	507
Railroad-car boxes	278	4,904	--	4,585	4,585	597
Yellow brass	745	5,920	2,102	4,040	6,142	523
Auto radiators (unsweated)	1,136	7,737	--	7,662	7,662	1,211
Bronze	78	675	122	547	669	84
Nickel silver and cupronickel	--	10	--	10	10	--
Low brass	56	621	323	318	641	36
Aluminum bronze	59	269	45	224	269	59
Low-grade scrap and residues	373	[2] - 229	51	--	51	93
Total	8,859	57,307	[3] 14,004	[3] 46,094	[3] 60,098	6,068
GRAND TOTAL						
No. 1 wire and heavy copper	20,232	286,104	170,256	115,691	285,947	20,697
No. 2 wire, mixed heavy and light copper	12,409	243,804	138,741	103,773	242,514	13,798
Composition or red brass	5,058	54,687	12,727	41,241	53,968	5,777
Railroad-car boxes	507	6,082	--	5,668	5,668	921
Yellow brass	28,259	254,456	216,879	37,890	254,769	29,511
Cartridge cases and brass	8,615	56,022	55,471	591	56,062	8,122
Auto radiators (unsweated)	4,701	53,906	--	53,321	53,321	5,286
Bronze	2,771	24,391	6,714	17,400	24,114	2,771
Nickel silver and cupronickel	7,941	41,986	39,562	2,466	42,028	8,017
Low brass	5,544	31,368	30,381	936	31,317	4,983
Aluminum bronze	182	1,099	664	338	1,002	284
Low-grade scrap and residues [4]	34,537	190,238	94,882	106,976	201,858	22,917
Total	130,756	1,244,143	766,277	486,291	1,252,568	123,084

[1] Brass-mill stocks include home scrap; purchased scrap consumption assumed equal to receipts, so lines in brass-mill and grand total sections do not balance.
[2] Negative receipts indicate shipments greater than receipts.
[3] Of the totals shown, chemical plants reported the following: Unalloyed copper scrap, 1,214 tons new and 1,391 old.
[4] Includes refinery brass.

Table 21.—Production of secondary copper and copper-alloy products in the United States
(Short tons)

Item produced from scrap	1974	1975
UNALLOYED COPPER PRODUCTS		
Refined copper by primary producers	412,519	270,880
Refined copper by secondary smelters	84,389	73,606
Copper powder	16,329	10,957
Copper castings	71	69
Total	513,308	355,512
ALLOYED COPPER PRODUCTS		
Brass and bronze ingots:		
Tin bronzes	40,210	33,474
Leaded red brass and semired brass	128,250	89,799
High-leaded tin bronze	33,192	23,304
Yellow brass	15,328	9,824
Manganese bronze	11,664	9,110
Aluminum bronze	8,359	6,743
Nickel silver	3,907	2,636
Silicon bronze and brass	4,445	2,584
Copper-base hardeners and master alloys	16,198	10,765
Total	261,553	188,239
Brass-mill products	702,688	510,384
Brass and bronze castings	40,162	31,759
Brass powder	812	571
Copper in chemical products	2,649	2,723
Grand total	1,521,172	1,089,188

Table 22.—Composition of secondary copper-alloy production
(Short tons)

	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze production: [1]							
1974	201,911	12,541	18,137	28,227	665	72	261,553
1975	144,209	9,297	13,419	20,848	422	44	188,239
Secondary metal content of brass-mill products:							
1974	562,196	455	3,255	132,554	4,168	60	702,688
1975	408,959	341	2,305	94,652	4,083	44	510,384
Secondary metal content of brass and bronze castings:							
1974	32,835	1,088	2,634	3,536	8	61	40,162
1975	25,860	857	1,963	3,045	1	33	31,759

[1] About 93% from scrap and 7% from other than scrap.

company with the balance shared equally between the Government, Comision de Fomento Minero, and the privately held Mexican company Sociedad de Fomento Industrial, S.A. de C.V.

Compañía Minera de Cananea, S.A., operated the Cananea mine and smelter to produce 44,100 tons of copper compared with 44,400 tons in 1974. Production was hampered by labor problems and some mechanical breakdowns. An expansion program designed to achieve a capacity of 77,000 tons of copper was expected to be completed in 1976.

Cobre de Sonora, S.A. de C.V. was 70% owned by the Mexican Government and Mexican nationals, with the Government intending to acquire the remaining interests, 26.25% held by Anaconda and 3.75% by Phelps Dodge. The company has committed $128 million to develop the Santa Rosa and Pilares copper deposits in the Nacozari region of the State of Sonora with annual planned capacity of 37,000 tons of copper in concentrates.

Mexicana de Cobre S.A., 44% owned by the Mexican Government, continued development of the La Caridad porphyry copper open pit mine in Sonora. The 66,000-ton-per-day mill will be followed by a smelter and refinery complex at the port of Guaymas with a planned capacity of 175,000 tons of copper per year by late 1977. Investment costs increased from $480 to $600 million. Ore reserves were reported at 760 million tons of 0.76% copper and 0.16% molybdenum.

Panama.—The Government of Panama, in a shift in policy, broke off negotiations with Canadian Javelin Ltd. and announced that the Cerro Colorado deposit with reserves estimated at up to 2 billion tons of 0.6% copper would be developed by the Government. On August 27, 1975, the Government signed an agreement to pay Canadian Javelin $5 million in cash plus $18.6 million worth of 8% tax-free, 20-year, Republic of Panama bonds in compensation for exploration and development work already carried out on the property. In July, following open bidding, Panama selected Texasgulf Inc., in an agreement in principle to establish a joint private-Government project to exploit Cerro Colorado at a cost of about $800 million. Texasgulf would receive a 15% to 20% equity interest in the project and be responsible for the evaluation, construction, and operation of the mine.

In the Cerro Petaquilla area of Central Panama, a second major copper deposit reportedly containing an estimated 300 million tons of 0.6% copper was discovered by Cobre Panama, S.A., a consortium of Japanese mining companies.

Papua New Guinea.—On September 16, 1975, Papua New Guinea (PNG) became an independent country. As one of the new CIPEC member countries, PNG with one mine, was the world's 12th largest copper producer in 1975. Copper was expected to play an increasingly important economic role for PNG as the Ok Tedi deposit with reserves of 275 million tons of 0.85% copper and 0.02 ounce of gold per ton, and the Freida River deposit with 400 million tons of 0.45% copper were considered for development. Including a number of additional known copper prospects, this island nation possesses around the 10th largest copper resource base in the world.

Bougainville Copper Ltd., controlled 53.6% by Conzinc Riotinto of Australia Ltd. (CRA), 20% by the PNG Government, and 26.4% by the public, milled 34.3 million tons of a lower grade ore containing 0.64% copper and 0.025 troy ounce of gold per ton. Copper production decreased 6% from that of 1974, owing to the lower head grade with 657,000 tons of a 28.94% copper concentrate or 190,120 tons of contained copper. Estimated ore reserves in the Panguna ore body at the end of 1975 were 915 million tons of ore averaging 0.46% copper and 0.017 troy ounce of gold per ton. Moves for the secession of Bougainville Island from PNG were unresolved at yearend.

Peru.—Affected by the CIPEC agreement to cut production 15% and by large strike-related losses, Peruvian copper mine and smelter production decreased 15% and 11% to 197,340 and 173,081 tons, respectively. Copper exports dropped 30% to 138,900 tons of copper contained in concentrate, blister, and refined products. Refinery production, in contrast, increased 36% to 58,390 tons of electrolytic copper as Empresa Minera del Perú's (Minero Perú) new, $60 million, 165,000-ton-per-year refinery at Ilo came onstream in July, reaching full design capacity in October 1975.

Southern Peru Copper Corp. (SPCC),

Peru's largest copper operation, lost 69 days of production at the Toquepala mine and 26 days at the Ilo smelter due to strikes in 1975. Only 12.2 million tons of 1.06% copper ore were milled compared with 13.5 million tons of 1.24% copper in 1974. Blister copper output decreased to 119,600 tons from 134,400 tons in 1974. On July 1, 1975, SPCC entered into a commercialization agreement with the Government agency Minero Perú Comercial (MINPECO), under which MINPECO will take title to, and market all Toquepala production. Toquepala reserves were estimated at 238 million tons averaging 0.88% copper.

Northern Peru Mining Corp., an ASARCO subsidiary, operated the Quiruvilca mine and produced 6,200 tons of copper in concentrates compared with 7,400 tons in 1974.

Compañía Madrigal, a subsidiary of Homestake Mining Co., processed 235,700 tons of ore, up 20% from 1974, at its Madrigal copper-lead-zinc mine in southern Peru and produced approximately 11,100 tons of copper concentrates, up 4%. Ore grade averaged 1.7% copper, 2.4% lead, and 5.0% zinc. Plans are underway to increase the mill capacity from 770 to 1,100 tons of ore per day.

Most of the approximately 65,000 tons of remaining mine production came from Empresa Minera del Centro del Perú (Centromin), the State-owned mining agency, which operates one open pit and six underground copper mines, including the former Cerro Corp. holdings nationalized in 1974. Centromin is currently undertaking a $46 million expansion of the Cobriza mine and mill to increase capacity to 7,200 tons of ore per day.

Peru has embarked on a major development program to increase copper mine capacity from 245,000 tons to approximately 1,050,000 tons per year. Twelve new copper deposits with combined reserves of over 4 billion tons of ore containing over 27 million tons of copper were in various stages of construction, planning, and feasibility studies. These 12 projects were planned to establish 800,000 tons of new copper capacity at an estimated cost of over $4 billion. From 300,000 to 500,000 tons of this new capacity was expected onstream by 1980 with the remainder dependent on market conditions and financing. In addition, Minero Perú was scheduled to complete the doubling of the capacity of the Ilo refinery to 330,000 tons of electrolytic copper per year by 1977 at a cost of $85 million. Centromin was planning a $52 million project to expand La Oroya refinery capacity from 52,000 tons to 80,000 tons of electrolytic copper.

The major projects included Cuajone (SPCC and Billiton, B.V.), Toro Mocho (Centromin), and Minero Perú's Santa Rosa/Cerro Verde, Michiquillay, and Quellaveco deposits. Construction of the $656 million Cuajone mine, mill, and smelter project was on schedule with start-up planned for mid-1976 at an annual capacity of 170,000 tons of blister copper. Cuajone ore reserves were estimated at 470 million tons of 1% copper. Centromin awarded a consortium of Fluor Utah Inc., Furukawa Mining Co. Ltd., Furakawa Electric Co. Ltd., and Mitsui & Co. Ltd., a contract to carry out a feasibility study on the Toro Mocho mine-smelter project, with a design capacity of 90,000 tons per year of blister copper. Located 90 miles east of Lima, Toro Mocho was planned for a 1982 startup at an estimated cost of $730 million. Reserves at Toro Mocho were estimated at 330 million tons of 0.77% copper.

The superjacent Cerro Verde/Santa Rosa deposits contain Peru's largest copper reserves. Cerro Verde, which contains 94 million tons of 0.70% copper, approximately half of which is oxide ore, overlies the giant Santa Rosa sulfide ore body with reserves of 1.3 billion tons of ore averaging 0.55% copper. Engineering work was underway on the $100 million, first-stage development of the oxide property, a copper mine with an annual capacity of 36,000 tons, scheduled for completion in 1977. The second-stage development of Santa Rosa was to add 182,000 tons of annual copper capacity and include a smelter-refinery complex to be built at Matarani. The project, scheduled for completion in 1980, would cost Minero Perú an estimated $1.3 billion.

Michiquillay, with ore reserves of 650 million tons averaging 0.72% copper, was expected to require $800 million to develop an annual concentrate capacity of 88,000 tons of contained copper by 1980. At Quellaveco, tentative plans called for a $600 million project to produce 80,000 tons of blister copper by about 1980. Re-

Table 17.—Byproduct sulfuric acid[1] (100% basis) produced in the United States
(Short tons)

Year	Copper plants[2]	Lead plants	Zinc plants[3]	Total
1971	803,284	971,946		1,775,230
1972	1,010,614	859,103		1,869,717
1973	1,088,322	146,591	819,537	2,054,450
1974	1,277,440	132,594	830,969	2,241,003
1975	1,784,744	129,756	711,769	2,626,269

[1] Includes acid from foreign materials.
[2] Excludes acid made from pyrites concentrates.
[3] Excludes acid made from native sulfur.

Table 18.—Secondary copper produced in the United States
(Short tons)

	1971	1972	1973	1974	1975
Copper recovered as unalloyed copper	429,095	447,409	484,623	513,308	355,512
Copper recovered in alloys[1]	771,025	853,564	892,534	831,012	616,453
Total secondary copper	1,200,120	1,300,973	1,377,157	1,344,320	971,965
Source:					
New scrap	754,963	842,779	890,943	860,888	602,792
Old scrap	445,157	458,194	486,214	483,432	369,173
Percentage equivalent of domestic mine output	79	78	80	84	69

[1] Includes copper in chemicals, as follows: 1971—3,206; 1972—3,038; 1973—3,704; 1974—2,649; and 1975—2,480.

Table 19.—Copper recovered from scrap processed in the United States by kind of scrap and form of recovery
(Short tons)

Kind of scrap	1974	1975	Form of recovery	1974	1975
New scrap:			As unalloyed copper:		
Copper-base	846,917	585,426	At primary plants	412,519	270,880
Aluminum-base	13,433	17,103	At other plants	100,789	84,632
Nickel-base	524	248	Total	513,308	355,512
Zinc-base	14	15			
Total	860,888	602,792	In brass and bronze	787,118	571,991
			In alloy iron and steel	2,601	1,927
Old scrap:			In aluminum alloys	38,293	39,583
Copper-base	476,331	358,496	In other alloys	351	472
Aluminum-base	6,387	10,226	In chemical compounds	2,649	2,480
Nickel-base	642	349	Total	831,012	616,453
Tin-base	8	7			
Zinc-base	64	95	Grand total	1,344,320	971,965
Total	483,432	369,173			
Grand total	1,344,320	971,965			

Table 20.—Copper recovered as refined copper, in alloys and in other forms from copper-base scrap processed in the United States
(Short tons)

Recovered by—	From new scrap		From old scrap		Total	
	1974	1975	1974	1975	1974	1975
Secondary smelters	63,904	53,606	212,541	162,508	276,445	216,114
Primary copper producers	r 229,328	139,230	r 183,191	131,650	r 412,519	270,880
Brass mills	523,102	381,744	36,319	26,140	559,421	407,884
Foundries and manufacturers	20,663	11,426	44,702	37,383	65,365	48,809
Chemical plants	1,071	1,159	1,890	1,330	2,961	2,489
Total	r 838,068	587,165	r 478,643	359,011	r 1,316,711	946,176

r Revised.

Table 14.—Primary and secondary copper produced by primary refineries in the United States
(Short tons)

	1971	1972	1973	1974	1975
PRIMARY					
From domestic ores, etc.: [1]					
Electrolytic	1,274,084	1,520,943	1,536,819	1,298,712	1,171,726
Lake	57,218	70,025	78,179	66,624	70,549
Casting	79,221	89,444	83,339	55,569	43,914
Total	1,410,523	1,680,412	1,698,337	1,420,905	1,286,189
From foreign ores, etc.: [1]					
Electrolytic	167,213	160,781	159,786	202,127	154,558
Casting and best select	14,046	32,040	10,365	31,626	2,631
Total refinery production of primary copper	1,591,782	1,873,233	1,868,488	1,654,658	1,443,378
SECONDARY					
Electrolytic [2]	323,913	341,581	377,523	398,976	265,413
Casting	18,599	16,667	14,290	13,543	5,467
Total secondary	342,512	358,248	391,813	412,519	270,880
Grand total	1,934,294	2,231,481	2,260,301	2,067,177	1,714,258

[1] The separation of refined copper into metal of domestic and foreign origin is only approximate, as accurate separation is not possible at this stage of processing.
[2] Includes copper reported from foreign scrap.

Table 15.—Copper cast in forms at primary refineries in the United States

	1974		1975	
	Thousand short tons	Percent	Thousand short tons	Percent
Billets	101	5	61	3
Cakes	132	6	67	4
Cathodes	661	32	765	45
Ingots and ingot bars	172	8	132	8
Wire bars	988	48	676	39
Other forms	13	1	13	1
Total	2,067	100	1,714	100

Table 16.—Production, shipments, and stocks of copper sulfate
(Short tons)

Year	Production		Shipments	Stocks Dec. 31 [1]
	Quantity	Copper content		
1971	34,648	8,662	36,852	5,936
1972	38,052	9,513	37,964	5,828
1973	43,360	10,840	44,092	4,580
1974	42,092	10,523	43,598	3,074
1975	35,614	9,204	31,822	6,866

[1] Some small quantities are purchased and used by producing companies, so that the figures given do not balance exactly.

serves were estimated at 440 million tons of ore grading 0.80% copper.

Among the smaller projects, Minero Perú planned to develop the 56-million-ton, 2.0% copper Tintaya deposit. A $100 million mine-mill facility to produce 33,000 tons of copper in concentrates was planned for 1980 or later. Minero Perú, in association with Geomin of Romania, was planning to bring the 91-million-ton, 1.45% Antamina deposit into production in 1978 at a rate of 44,000 tons of copper per year at an estimated cost of $100 million. In the private sector, Mitsubishi Metal Corp. and Compañía Minera De Los Cerros Negros, a Homestake Mining Co. subsidiary, announced discovery of a deposit in the Bronce area near Pashap containing 50 million tons of ore grading 0.8% copper and 0.05% molybdenum. The companies started a feasibility study for a 20,000 to 30,000-ton-per-year operation.

Philippines.—The Philippines maintained eighth rank among world copper producers with 11 mining companies producing 249,900 tons of copper contained in concentrates and direct-shipping-grade ore. Total identified reserves of copper were estimated at 3.85 billion tons of ore with an average grade of 0.48% containing 18.5 million tons of copper. Approximately 60% of the total contained copper is located in developed deposits and 40% is awaiting development. Studies continued on the part of both industry and government on establishing smelter facilities in the country, but no firm decisions had been made by yearend. To assist the depressed industry, the Government removed the 30% premium export duties on byproduct gold and silver on January 1 and the remaining 2% export duty on copper on March 21. To decrease dependence on Japanese smelters, the Philippines began opening new markets for copper in 1975, primarily in the People's Republic of China and Eastern Europe.

Atlas Consolidated Mining & Development Corp., one of the largest copper producers in Asia, milled 25.7 million tons of 0.52% copper ore. It produced 379,100 tons of concentrates, which contained 112,540 tons of copper, up 17% from that of 1974. The company operated the Frank, Lutopan, and Biga mines on Cebu Island, Central Philippines. Atlas announced plans to develop, at a cost of $100 million, the new Carmen open pit located between the Frank and Biga pits and an associated 35,000-ton-per-day mill by early 1977. The Carmen ore body contained reserves of 352 million tons grading 0.43% copper. These reserves were in addition to the 769 million tons of 0.47% copper contained in the two operating properties. Atlas also initiated plans to construct, pending Government approval, a new $200 million smelter, refinery, and acid plant complex by 1978. The smelter will be built to handle 525,000 tons of concentrates annually. In 1975, average concentrate grade was 29.7% copper. Capacity of the refinery was planned at 144,000 tons.

Marcopper Mining Corp., a subsidiary of Placer Development, Ltd., milled 7.2 million tons of 0.58% copper ore. The copper contained in the concentrates was 38,300 tons, off 26% from 1974. Minable reserves at yearend were 95 million tons at a 0.40% cutoff and a 0.58% average grade of copper. A $43 million expansion program to increase mill capacity from 18,000 to 27,000 tons per day was largely completed by yearend.

Marinduque Mining & Industrial Corp. operated the Sipalay open pit in Negros Oriental and the Bagacay pit in Samar. At Sipalay, despite a drop in head grade from 0.66% to 0.57%, copper production for the year totaled 26,753 tons of contained copper, about the same as in 1974. Plans to increase the Sipalay mill capacity from 20,000 to 55,000 tons per day of ore were suspended until more favorable economic conditions prevail. Production at Bagacay amounted to 7,018 tons of copper contained in 28,300 tons of concentrates and, in addition, 23,700 tons of direct-shipping-grade ore. Grade of the direct-shipping ore based on reserves was 12.72% copper. Approximately 3 years of reserves remain at Bagacay. In 1975, Marinduque, Lepanto Consolidated Mining Co., and two other Philippine mining companies formed the Copper Smelter Corp. of the Philippines (CSCP). CSCP completed process and design engineering studies for a $250 million flash smelter and refinery complex to be established in Negros Occidental with a capacity of 93,000 tons of cathode copper per year plus byproduct gold and silver. Plans for the project have been submitted to the President's Copper Smelter Advisory Committee for approval and possible Government assistance.

Philex Mining Corp. increased production 3% in 1975 to 29,880 tons of copper contained in concentrates. The company operated the Santo Tomas II underground mine near Benguet, northern Luzon, with reserves of 177 million tons of ore grading 0.45% copper and 0.031 ounce of gold per ton. Mill capacity was increased from 15,400 to 26,500 tons of ore per day by July 1975.

Lepanto Consolidated Mining Co. operated the Lepanto underground mine in Mt. Province, northern Luzon, with production of 14,670 tons of copper contained in concentrates representing only 50% of the 1968–73 average output. The mill treated 899,000 tons of ore yielding 53,800 tons of concentrates. ASARCO, which normally handles the bulk of Lepanto high arsenic-antimony concentrates, reduced smelting of Lepanto feed for the last 3 months of 1975 due to the affect of U.S. arsenic air pollution regulations on its Tacoma, Wash., smelter. With a stockpile in hand of 64,000 tons of concentrates, greater than the year's production of 48,300 tons, the decision was made to suspend Lepanto operations on December 10, 1975. Reserves at the Lepanto mine were reduced at yearend to 8.3 million tons of 2.62% copper and 0.137 ounce of gold per ton. Legal claim problems delayed engineering feasibility studies on Lepanto's Hinobaan deposit in Negros Occidental. Reported reserves at Hinobaan by yearend were increased to 155 million tons of 0.5% copper.

Western Minolco, in the first full year of operation at its Boneng and Lobo ore bodies at Benguet, northern Luzon, produced 38,075 tons of concentrates from 4.3 million tons of ore milled in 1975 containing 9,350 tons of copper. An expansion program was started to increase the initial mill capacity of 16,500 tons of ore per day to 33,000 tons of ore per day, equivalent to about 50,000 tons of contained copper annually by 1976. Combined ore reserves at Boneng-Lobo were estimated at 108 million tons of 0.48% copper.

Poland.—In 1975, ore mined totaled 18.7 million tons yielding 297,600 tons of copper, an increase of 36% over 1974. Copper mine production came mainly from three underground mines, Lubin, Polkowice, and Rudna, all located in the sedimentary Kupferschiefer beds of the Legnica-Glogow copper region. A new smelter was planned for this region as copper production was planned to increase 20% annually. Poland's copper development program was based on reserves which increased fourteenfold since 1954, and including one deposit being exploited in the Lubin area, described as one of the world's largest copper deposits.

Rhodesia, Southern.—M.T.D. (Mangula) Ltd., a Messina Transvaal subsidiary, during the year ending September 30, 1975, produced 14,900 tons of copper in concentrates and precipitates from the Mangula mine about 80 miles northwest of Salisbury. Concentrates containing 14,900 tons of copper were produced from milling 1.4 million tons of sulfide ore. Precipitates containing 2,200 tons of copper were produced from treating 377,000 tons of an oxidized ore in the leach plant. Leach plant operations were closed at yearend due to the exhaustion of oxide reserves. Proven sulfide ore reserves were 16.5 million tons averaging 1.24% copper. The Norah and Silverside mines produced an additional 3,040 tons and 1,820 tons, respectively, of copper in concentrates. Proven ore reserves were 3.26 million tons of 1.21% copper at the Norah mine and 515,000 tons of 1.67% copper at the Silverside mine.

Lomagundi Smelting and Mining Ltd., also a Messina Transvaal subsidiary, produced 1,930 tons of copper in concentrate from mining and milling 282,200 tons of 0.95% copper ore from the Alaska mine. The Shackleton mine yielded 11,440 tons of copper in concentrate from 691,000 tons of 1.75% copper ore. Proved reserves at yearend were 500,000 tons of 1.18% copper at the Alaska mine and 1.7 million tons of 1.94% copper at the Shackleton mine. The Gwai River mine produced 536 tons of copper in concentrate from mining and milling 75,000 tons of 0.78% copper ore. The mine was placed on a care and maintenance basis in March 1975. Only 207,000 tons of 1.00% proven copper reserves remained.

South Africa, Republic of.—O'okiep Copper Co., Ltd., a subsidiary of Newmont Mining Corp., mined and milled 2.6 million tons of ore with an average grade of 1.38% copper, which yielded 33,800 tons of blister copper compared with 35,800 tons in 1974. Ore reserves at O'okiep mines at the end of 1975 were estimated at 29.5 million tons averaging 1.62% copper. Adverse market conditions forced

Table 10.—Copper ore shipped directly to smelters [1] in the United States, by State in 1975, with content in terms of recoverable copper

State	Ore shipped to smelters		
	Short tons	Recoverable copper content	
		Pounds	Percent
Arizona	258,877	12,796,668	2.47
Colorado	1,598	52,349	1.64
Montana	524	10,195	.97
New Mexico	35,209	43,755	.06
Utah	60,556	286,613	.24
Other States	339	12,181	1.80
Total	357,103	13,201,761	1.85

[1] Primarily smelter fluxing material.

Table 11.—Copper precipitates (from dump or in-place leaching) shipped directly to smelters and copper ore and tailings leached (heap, vat, or tank) in the United States, by State in 1975, with content in terms of recoverable copper

State	Precipitates shipped (short tons)	Recoverable copper content (pounds)	Ore leached (short tons)	Recoverable copper content (pounds)	Percent
Arizona	85,170	111,696,353	[1]17,229,313	[2]147,000,303	0.43
California	1	595	--	--	--
Montana	24,211	35,799,798	--	--	--
Nevada	12,412	16,715,334	5,802,219	27,931,898	.24
New Mexico	32,957	50,028,236	--	--	--
Utah	45,997	74,347,077	--	--	--
Total	200,748	288,587,393	23,031,532	174,932,201	.38

[1] Includes 9,934,979 short tons of ore leached for electrowinning, and excludes newly generated tailings.
[2] Includes 74,529,804 pounds of electrowon copper.

Table 12.—Copper ore smelted and copper ore concentrated in the United States, and average yield in copper, gold, and silver

Year	Smelting ore		Concentrating ore		Total				
	Thousand short tons	Yield in copper (percent)	Thousand short tons [1 2]	Yield in copper (percent)	Thousand short tons [1]	Yield in copper (percent)	Yield per ton in gold (ounce)	Yield per ton in silver (ounce)	Value per ton in gold and silver
1971	453	1.76	222,121	0.56	242,656	0.55	0.0022	0.059	$0.18
1972	484	1.68	248,663	.55	266,831	.55	.0019	.059	.21
1973	337	1.40	272,688	.53	289,998	.53	.0018	.058	.32
1974	305	1.26	269,016	.50	293,443	.49	.0014	.048	.45
1975	357	1.85	239,614	.48	263,003	.47	.0014	.051	.44

[1] Includes some ore classed as copper-zinc and minor amount of tailings (1971 excludes tailings).
[2] Excludes tank or vat and heap leaching. (See tables 7 and 11.)

Table 13.—Copper produced by primary smelters in the United States
(Short tons)

Year	Domestic	Foreign	Secondary	Total
1971	1,470,815	29,181	66,333	1,566,329
1972	1,649,130	41,263	69,017	1,759,410
1973	1,705,065	38,898	77,815	1,821,778
1974	1,532,066	37,750	79,543	1,649,359
1975	1,374,324	72,804	49,357	1,496,485

Table 7.—Mine production of recoverable copper in 1975, by method of treatment

Method of treatment	Ore treated (thousand short tons)	Recoverable copper		Remarks
		Thousand pounds	Percent yield	
Copper ore:				
By concentration	239,614	2,295,390	0.48	See table 9.
By smelting	357	13,202	1.85	See table 10.
By leaching	23,032	[1]174,932	.38	See table 11.
Total	263,003	2,483,524	.47	
Dump and in-place leaching	--	288,587	--	See table 11.
Miscellaneous from cleanup, tailings, and noncopper ores	--	54,622	--	
Total	XX	2,826,733	XX	

XX Not applicable.
[1] Includes 74,529,804 pounds of electrowon copper.

Table 8.—Copper ore shipped directly to smelters or concentrated in the United States, by State in 1975, with copper, gold, and silver content in terms of recoverable metal

State	Ore shipped or concentrated (thousand short tons)	Recoverable metal content				Value of gold and silver per ton of ore
		Copper		Gold (troy ounces)	Silver (troy ounces)	
		Thousand pounds	Percent			
Arizona	151,427	1,360,839	0.45	82,385	6,155,669	$0.27
Colorado	4	81	1.01	223	37,851	55.10
Idaho	123	1,294	.53	36	37,377	1.39
Michigan	9,033	147,380	.82	--	632,336	.31
Montana	19,262	140,057	.36	13,317	2,151,969	.61
Nevada	11,674	117,102	.50	33,288	701,940	.73
New Mexico	19,401	241,481	.62	12,634	660,505	.26
Tennessee [1]	1,635	20,083	.61	W	52,197	.15
Utah	27,380	279,381	.51	W	W	W
Other States	33	894	1.31	[2]183,737	[2]1,702,801	[2]1.36
Total [3]	239,971	2,308,592	.48	325,620	12,132,645	.44

W Withheld to avoid disclosing individual company confidential data; included in "Other States."
[1] Copper-zinc ore.
[2] Includes data for Utah.
[3] Data may not add to totals shown because of independent rounding.

Table 9.—Copper ore concentrated [1] in the United States, by State in 1975, with content in terms of recoverable copper

State	Ore concentrated (thousand short tons)	Recoverable copper content	
		Thousand pounds	Percent
Arizona	151,168	1,348,042	0.89
Colorado	2	29	.69
Idaho	123	1,294	.53
Michigan	9,033	147,380	.82
Montana	19,261	140,047	.36
Nevada	11,674	117,102	.50
New Mexico	19,366	241,437	.62
Tennessee [2]	1,635	20,083	.61
Utah	27,319	279,095	.51
Other States	33	881	1.33
Total	239,614	2,295,390	.48

[1] Includes following methods of concentration: "Dual process" (leaching followed by concentration); "LPF" (leach-precipitation-flotation); and froth flotation.
[2] Copper-zinc ore.

the shutdown of two mines and one of three mills by the company. O'okiep and the Tsumeb Corp. Ltd. (South-West Africa) continued to defer construction of a new 130,000-ton-per-year electrolytic copper refinery in the Capetown area to refine the smelter output of the two companies.

Palabora Mining Co. Ltd., assisted by good demand for copper in South Africa, produced 101,200 tons of copper, a 1% increase over that of 1974. The ore milled, 21 million tons of 0.56% copper, was equal to the 1974 level. A major, $100 million expansion of the open pit mining and ore processing facilities was underway with completion expected early in 1977. Milling capacity was to be increased from an average 58,000 tons to 82,000 tons of ore per day, equivalent to 138,000 tons of copper annually. The capacity of the electrolytic refinery will be increased to handle the entire copper output, allowing Palabora to retain its position as one of the lowest cost copper producers in the world.

Messina (Transvaal) Development Co. mined and milled 1.13 million tons of 0.94% copper ore from its Messina mine, which yielded 10,450 tons of copper in concentrate. The tonnage of proved ore reserves at yearend was estimated at 5.4 million tons averaging 1.40% copper.

South-West Africa, Territory of.—The Tsumeb Corp. Ltd. mined 467,000 tons of ore from the Tsumeb mine averaging 4.27% copper, 9.73% lead, and 2.47% zinc. At the Kombat mine 337,200 tons of ore grading 1.31% copper and 2.17% lead was milled. The Matchless mine, near Windhoek, produced 112,600 tons of higher grade ore averaging 2.72% copper. Smelter production at Tsumeb was 40,100 tons of blister compared with 51,400 tons in 1974. Approximately 35% of this total was from smelting of toll and custom concentrates. The smelter was expanded during the year to handle an additional 140,000 tons per year of toll and custom concentrates from other mines in South-West Africa. Combined ore reserves at the end of 1975 were estimated at 8.9 million tons averaging 4.24% copper, 5.76% lead, and 1.30% zinc for the Tsumeb, Kombat, and Matchless mines and the Asis Ost and West ore bodies, recently discovered adjacent to Kombat.

Oamites Mining Co. (Proprietary) Ltd. (75% Falconbridge) milled 626,100 tons of ore grading 1.31% copper. Metal recovery in 21,000 tons of concentrate was 93.40% yielding 7,553 tons of copper, an increase of 8% over 1974. The increase, offsetting the lower tonnage mined, was attributed to improved grade and mining control and higher metallurgical recovery.

Spain.—Rio Tinto Patiño S.A. (RTP), operated the Cerro Colorado open pit mines and a custom smelter-refinery complex in the southern province of Huelva in 1975 and the Santiago open pit mine in northwest Spain, which started up in June 1975. The Santiago mine, with an annual design capacity of 7,900 tons, in its first 6 months of operation, treated 787,000 tons of ore yielding 4,850 tons of copper. At Cerro Colorado, despite a 7% increase in ore treated to 3.26 million tons, total copper production decreased 10% to 21,600 tons. Ore reserves remaining include 70 million tons of 0.64% copper at Cerro Colorado and 20 million tons of 0.68% copper at Santiago. A major expansion program was completed during the year at Huelva with the opening of a new flash smelter and a second acid plant in September, increasing anode copper capacity to 93,000 tons annually.

The RTP smelter produced 61,000 tons of anode copper from primary feed and 57,900 tons from secondary sources. The expanded electrolytic refinery, with a capacity of 116,000 tons, produced 88,600 tons of refined copper compared with 80,800 tons in 1974.

Andaluzia de Piritas, S.A., began initial production from the Aznacolla mine in southern Spain in mid-1975. The $170 million mine-mill development will have a capacity of 14,000 tons of contained copper annually. Reserves in the complex pyritic and cupriferous shale ore deposit were estimated at 86 million tons of about 0.44% copper.

Sweden.—Boliden Aktiebolag, which produces essentially all of Sweden's blister and refined copper, announced plans to expand the capacity of the Ronnskar smelter-refinery complex to 94,000 tons per year by 1978 and to 110,000 tons per year at a later date, at a total estimated cost of $200 million.

U.S.S.R.—In 1975, the Soviet Union produced an estimated 1,019,000 tons of copper, including 843,000 tons of primary and 176,000 tons of secondary copper. An

estimated 227,000 tons of this output was exported in 1975. The Kazakstan copper industrial region continued to be the main center of copper production having increased refined metal production 50% during the 1971–75 period with an additional 25% increase called for under the 1976–80 5-year plan. While a shortage of ore was experienced at the Balkhash and Dzhezhazgan complexes within Kazakstan, the small Sayak-III porphyry copper open pit mine at Balkhash was completed, and development work at the No. 65 mine, within the large, sedimentary 1.6% to 1.9% copper-sandstone deposits of Dzhezhazgan, was begun during the year. Scheduled for completion by 1980 in Kazakstan are the new Akchu-Spassk, Dzheladinsk, Kargalinsk, Orlovsk, and the polymetallic Irtysh mines, and the expansion of the Tishinenk and Annensk mines.

In the Urals, the second largest copper-producing region, a prolonged lag in exploration and mine development created an imbalance between mine and smelter production. The Urals mines can supply only two-thirds of the concentrate feed for the Krasnouralsk, Kirovograd, and Karabash smelters, with the remaining feed requirements transported in at higher costs. Mine expansion and development programs were near completion or underway at Gaysk, Orenburg Oblast, and Bashkir.

In Uzbekstan, development of the Sarycheku copper mine, in the Almalyk porphyry copper mine and flash smelter complex, was completed in 1975. At the Norilsk copper-nickel complex in Siberia, three Finnish firms were constructing an Outokumpu-design flash smelter capable of treating 600,000 tons of copper concentrate annually. The Soviet Government is currently soliciting bids from western firms for a 110-ton-per-day pilot plant to test the Udokan sedimentary copper deposit in eastern Siberia. The deposit was reportedly one of the largest copper reserves in the world with reserves estimated at over 1.3 billion tons of ore containing an average copper content of about 2%, approximately 20% in the oxide form. Rio-Tinto Zinc has submitted bids on the pilot plant and Earth Resources Co. (ERC), was negotiating with the Soviet Union on the licensing of a patented flotation developed by ERC for improving the recovery of copper from similar sedimentary oxide ores at the Nacimiento, N. Mex., mine. The Udokan deposit has the potential for producing up to 440,000 tons of refined copper per year. Development of another major mining complex was also underway on the porphyry copper-molybdenum deposit at Erdenet, Mongolia.

Yugoslavia.—Estimated primary production of copper by Rudarsko Topionicarski Bazen (RTB), Bor, Serbia, included 126,700 tons of copper in concentrates, 178,600 tons of blister copper, and 136,600 tons of refined copper. RTB operated a mine, flotation plant, and smelter at Bor, and a mine and flotation plant at Majdanpek. Expansion of the Majdanpek mill to handle 12 million tons of ore annually was completed during the year. Development work continued on the large 660-million ton, 0.5% copper deposit at Krivelj with plans for an annual capacity of 66,000 tons of copper, to be reached by 1981. Work also continued on the development of the second major copper-producing facility in Yugoslavia at Bucim, near Radoviste, Macedonia. Work on a mine and beneficiation plant at the Bucim copper deposit continued during the year and was scheduled to reach an annual capacity of 23,000 tons of copper in concentrates by 1977.

Zaire.—Mining the highest grade copper ore in the world with an average reserve content in producing mines of 3.83% copper, Zaire produced 547,100 tons of copper, less than 1% below that of 1974. Disruptions caused by the closure of the Benguela railroad from Shaba Province to the Angolan port of Lobito, as a result of the Angolan Civil War, had a strong impact on the economy and copper industry of Zaire in the latter part of 1975. According to CIPEC statistics, Zaire was able to export only 68% of 1975 copper production. With the loss of the Benguela railroad, which normally handles 38% of Shaba's imports and 61% of its exports, primarily mineral, alternative overland trade routes were established. Zairian copper was redirected through Zambia to the Mozambique port of Beira and via the newly opened Tanzania-Zambia Railway (Tazara), to the port of Dar es Salaam.

The Government mining agency, La Générale des Carrières et Mines du Zaire (Gécamines), which operated 10 mines, 5 mills, 1 copper smelter at Lubumbashi, and 2 copper-cobalt refineries at Shituru

Table 5.—Mine production of recoverable copper in the United States, by State
(Short tons)

State	1971	1972	1973	1974	1975
Arizona	820,171	908,612	927,271	858,783	813,211
California	515	598	369	194	344
Colorado	3,938	3,944	3,123	3,012	3,560
Idaho	3,776	2,942	3,625	2,841	3,192
Maine	2,510	1,220	1,107	1,522	2,024
Michigan	56,005	67,260	72,221	67,012	73,690
Missouri	8,445	11,509	10,273	12,665	14,258
Montana	88,581	123,110	132,466	131,131	87,959
Nevada	96,928	101,119	93,702	84,101	81,210
New Mexico	157,419	168,034	204,742	196,585	146,263
Pennsylvania	3,349	2,611	1,845	--	--
Tennessee	13,916	11,310	8,500	6,304	10,041
Utah	263,451	259,507	256,589	230,593	177,155
Other States [1]	3,179	3,064	2,107	2,259	459
Total	1,522,183	1,664,840	1,717,940	1,597,002	1,413,366

[1] Includes Oklahoma, Oregon, Washington, and Wisconsin (1975).

Table 6.—Twenty-five leading copper-producing mines in the United States in 1975, in order of output

Rank	Mine	County and State	Operator	Source of copper
1	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp	Copper ore, copper precipitates.
2	Morenci	Greenlee, Ariz	Phelps Dodge Corp	Copper ore, copper precipitates, copper tailings.
3	San Manuel	Pinal, Ariz	Magma Copper Co	Copper ore.
4	Sierrita	Pima, Ariz	Duval Sierrita Corp	Do.
5	Tyrone	Grant, N. Mex	Phelps Dodge Corp	Copper ore, copper precipitates.
6	Pima	Pima, Ariz	Cyprus Pima Mining Co	Copper ore.
7	White Pine	Ontonagon, Mich	White Pine Copper Co	Do.
8	Berkeley Pit	Silver Bow, Mont	The Anaconda Company	Copper ore, copper precipitates.
9	Ray Pit	Pinal, Ariz	Kennecott Copper Corp	Do.
10	Pinto Valley	Gila, Ariz	Cities Service Co	Do.
11	Chino	Grant, N. Mex	Kennecott Copper Corp	Do.
12	Inspiration	Gila, Ariz	Inspiration Consolidated Copper Co.	Do.
13	Magma	Pinal, Ariz	Magma Copper Co	Copper ore.
14	Yerington	Lyon, Nev	The Anaconda Company	Copper ore, copper precipitates.
15	Metcalf	Greenlee, Ariz	Phelps Dodge Corp	Do.
16	New Cornelia	Pima, Ariz	do	Copper ore, gold ore.
17	Ruth Pit	White Pine, Nev	Kennecott Copper Corp	Copper ore.
18	Mission	Pima, Ariz	ASARCO Incorporated	Do.
19	Sacaton Unit	Pinal, Ariz	do	Do.
20	Bagdad	Yavapai, Ariz	Cyprus Bagdad Copper Co	Do.
21	Silver Bell	Pima, Ariz	ASARCO Incorporated	Copper ore, copper precipitates.
22	Continental	Grant, N. Mex	UV Industries, Inc	Do.
23	Mineral Park	Mohave, Ariz	Duval Corp	Do.
24	Twin Buttes	Pima, Ariz	Anamax Mining Co	Copper ore.
25	Esperanza	do	Duval Corp	Copper ore, copper precipitates.

the supply and demand of secondary copper were made available.[28]

New treatment techniques to remove copper from waste water streams, such as in metal-plating operations, have been reported.[29]

[28] Bonczar, E. S., and J. E. Tilton. An Economic Analysis of the Determinants of Metal Recycling in the United States: A Case Study of Secondary Copper (Research Grant G0133114). Bu-Mines Open File Rept. 79-75, 1975, 88 pp; available for consultation at the Bureau of Mines libraries in Juneau, Alaska, Denver, Colo., Pittsburgh, Pa., Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington D.C.; and from National Technical Information Service, U.S. Department of Commerce, Springfield, Va., PB 245 832/AS.

[29] Ricci, L. J. Heavy-Metals Recovery Promises To Pare Water-Cleanup Bills. Chem. Eng., v. 82, No. 27, December 1975, pp. 29-31.

Table 2.—Copper produced from domestic ores, by source
(Thousand short tons)

Year	Mine	Smelter	Refinery
1971	1,522	1,471	1,411
1972	1,665	1,649	1,680
1973	1,718	1,705	1,698
1974	1,597	1,532	1,421
1975	1,413	1,374	1,286

Table 3.—Copper ore and recoverable copper produced, by mining method
(Percent)

Year	Open pit		Underground	
	Ore	Copper [1]	Ore	Copper [2]
1971	88	82	12	18
1972	85	80	15	20
1973	89	78	11	22
1974	89	81	11	19
1975	89	80	11	20

[1] Includes copper from dump leaching.
[2] Includes copper from in-place leaching.

Table 4.—Mine production of recoverable copper in the United States, by month
(Short tons)

Month	1974	1975
January	135,170	131,272
February	131,063	117,793
March	144,461	117,595
April	143,290	123,219
May	150,399	126,890
June	142,163	111,476
July	99,435	95,488
August	102,124	114,510
September	132,438	118,701
October	145,366	128,568
November	135,934	111,658
December	135,159	116,196
Total	1,597,002	1,413,366

and Luilu in Shaba Province, produced 510,860 tons of copper including 160,750 tons of blister and 335,650 tons of copper refined shapes. Plans to increase annual production of copper to 628,000 tons by 1978 were still on schedule. Plans called for the construction of a 138,000-ton-per-year flash smelter and a 100,000-ton-per-year electrolytic copper refinery, all near Kolwezi, Shaba. As part of the expansion program, two new, open pit mines at Dikuluwe and Mashambe, with combined reserves estimated at 171 million tons of 4.1% copper and 0.3% cobalt, opened in late 1975 but operated at a low rate due to diesel fuel shortages. The Gécamines refinery at Lubumbashi was also scheduled to be expanded from 143,000 tons per year to 176,000 tons per year by 1980.

The joint Zairian Government-Japanese company Sociétè de Dévelopement Industriel et Minière du Zaire (SODIMIZA), operated the Mushoshi mine and mill in Shaba Province increasing mine production 12% to 1.68 million tons of ore in 1975. Production of 103,950 tons of concentrate with an average copper content of 34.4% yielded 35,760 tons of contained copper. SODIMIZA continued development of the Kinsenda mine during the year but production is not expected to begin before 1978.

Société Minière de Tenke Fungurume (SMTF), controlled by the Republic of Zaire (20%) and a consortium comprised of Charter Consolidated Ltd. and Associated Companies (28%), AMOCO Minerals Co. (28%), Mitsui and Co. Ltd. (14%), Bureau de Recherches Geologiques & Miniéres (3.5%), Omnium des Mines, S.A. (3.5%), and Leon Templesman & Son Inc. (3%), made substantial progress on the construction and development of the Tenke-Fungurume project up until August 1975. At that time regional fuel shortages and serious financial support problems threatened the continuation of the project. By yearend, consideration was being given to suspending work on the 165,000-ton-per-year mine-electrowinning refinery complex originally scheduled for completion in 1977 with cost estimates that increased from $600 million to $900 million.

Zambia.—The Government assumed full operational control over the Zambian copper industry during the year as the management and sales contracts with both AMAX Inc., and the Anglo-American Corp. of South Africa Ltd. were terminated. AMAX is to receive compensation of $34 million owing to the contract termination. A new Metal Marketing Corp. of Zambia, Ltd. (Memaco), has been set up to handle all copper sales on behalf of the Government. Low prices and export transportation problems precipitated by the Angolan Civil War left the industry in serious financial difficulties. The closure of the Benguela railroad to the port of Lobito, Angola, in August caused the declaration of "force majeur" on 20% of copper deliveries from early September with Roan Consolidated Mines Ltd. (RCM) increasing it to 30% and Nchanga Consolidated Copper Mines Ltd. (NCCM) to 40% in October. The new Tazara railroad began operations on a limited basis in September with shipments of copper to the port of Dar es Salaam. Mine production in 1975 decreased 3% to 746,200 tons of recoverable copper, and blister and refined copper output decreased 7% to 693,500 tons.

RCM mined 17.5 million tons of ore with an average grade of 2.01% yielding 318,100 tons of copper during the year from the Mufulira, Luanshya, Chambishi, Chibuluma, and Kalengwa mines. RCM also operated two smelters at Mufulira and Luanshya that produced 311,650 tons of anode copper. The Mufulira and Ndola Copper refineries produced 344,600 tons of copper cathodes, 304,200 tons of which was cast into wirebars. The electrowinning plant at Chambishi produced 16,270 tons of leach cathodes. Poor ground conditions continued to cause difficulties at Mufulira and Luanshya; production was suspended for 4½ months at Chambishi to concentrate on overburden stripping. Work continued on a $200 million development program to expand mine production at the Baluba section of Luanshya, Chibuluma, and Chambishi; to extend the Chambishi leach plant; and to build an anode slimes treatment plant at Ndola. Development of the Kalushi East mine has been deferred. Ore reserves at all RCM mines are estimated to total 375 million tons of ore with an average grade of 2.96% copper. The Mufulira and Luanshya mines contain 79% of this reserve total.

NCCM for the year ended March 31, 1975, produced 450,473 tons of finished copper from operations at its Rokana, Konkola, and Chingola mine divisions, its

smelter-refinery complex at Kitwe, and from the refinery at Chingola. At the Rokana division, mine output increased 8% to 157,500 tons of copper. The 14,000-ton-capacity Mindola open pit and oxide treatment plant were placed on a care and maintenance basis at the end of 1975 while expansion of the Mindola underground operations continued. At the Konkola division, mine production decreased 5% to 57,870 tons. Production of copper at the Chingola division decreased 4% to 366,180 tons, 60% of this from five open pit operations. A major low-grade tailings leach plant completed its first year of operation in April 1975 with low copper recovery rates still a problem. NCCM controls 578 million tons of ore reserves averaging 3.20% copper with 43% of these held within the Chingola division.

TECHNOLOGY

A study of porphyry copper occurrences in the Southwestern Pacific Island arc areas showed that, compared with Western Hemisphere porphyries, the deposits are geologically younger and have less discrete zones of alteration.[2] A similar study of copper porphyry occurrences in the Northern Caribbean region compared the associated intrusive rocks with those of the Southwest Pacific and continental porphyry deposits.[3] The generally assumed inverse tonnage-grade relationships for porphyry copper deposits have been challenged and, if true, have important implications for total resource estimates and future mining grades.[4]

A microscopic study on samples from a drill core yielded a detailed analysis of the mineralogy and paragenesis of a portion of the copper-nickel deposition in northern Minnesota.[5] Geologic descriptions of a porphyry copper deposit and several massive sulfide copper deposits were published.[6]

The technology and economic evaluation of processing ocean nodules, using hydrometallurgical techniques, was published.[7] Another article described the use of a pyrometallurgical method as an alternative approach for processing the nodules.[8] Use of petrography as an important tool to evaluate processing options for copper ores was described in an article on the subject.[9]

A pilot-scale test on injection of oxygen into a near dormant leach resulted in a significant reactivation of the leaching with the improvement attribute to stimulation of bacterial action, better oxidation, and increased permeability.[10] Experiments on crushing and sizing of copper-containing mine strip waste with the fines treated by flotation and the coarse treated by leaching resulted in a 71% copper recovery, compared with a 48% recovery by leaching the unsized material.[11] Field tests on fragmenting a copper deposit for potential in situ leaching showed suitable fragmentation for the tests of 15-, 20-, and 25-foot spacings to a depth of 110 feet.[12]

Cyprus Mines Corp. reported promising results from demonstration plant tests in the continuing development of its Cymet hydrometallurgical process for treating copper sulfide concentrate. New procedures

[2] Titley, S. R. Geological Characteristics and Environment of Some Porphyry Copper Occurrences in the Southwestern Pacific. Econ. Geol., v. 70, No. 3, May 1975, pp. 499–514.

[3] Kesler, S. E., L. M. Jones, and R. L. Walker. Intrusive Rocks Associated With Porphyry Copper Mineralization in Island Arc Areas. Econ. Geol., v. 70, No. 3, May 1975, pp. 515–526.

[4] Whitney, J. W. A Resource Analysis Based on Porphyry Copper Deposits and the Cumulative Copper Metal Curve Using Monte Carlo Simulation. Econ. Geol., v. 70, No. 3, May 1975, pp. 527–537.

[5] Boucher, M. L. Copper-Nickel Mineralization in a Drill Core From the Duluth Complex of Northern Minnesota. BuMines RI 8084, 1975, 55 pp.

[6] Franklin, J. M., J. Kasarda, and K. H. Poulsen. Petrology and Chemistry of the Alteration Zone of the Mattabi Massive Sulfide Deposit. Econ. Geol., v. 70, No. 1, January–February 1975, pp. 63–79.

Spence, C. D. Volcanogenic Features of the Vauze Sulfide Deposit, Noranda, Quebec. Econ. Geol., v. 70, No. 1, January–February 1975, pp. 102–114.

Spence, C. D., and A. F. DeRosen-Spence. The Place of Sulfide Mineralization in the Volcanic Sequence at Noranda, Quebec. Econ. Geol., v. 70, No. 1, January–February 1975, pp. 90–101.

Waterman, G. C., and R. L. Hamilton. The Sar Cheshmeh Porphyry Copper Deposit. Econ. Geol., v. 70, No. 3, May 1975, pp. 568–576.

[7] Agarwal, J. C., N. Beecher, D. S. Davies, G. L. Hubred, V. K. Kakaria, and R. N. Kust. Processing of Ocean Nodules: A Technical and Economic Review. J. Metals, v. 28, No. 4, April 1976, pp. 24–31.

[8] Sridhar, R., W. E. Jones, and J. S. Warner. Extraction of Copper, Nickel and Cobalt From Sea Nodules J. Metals, v. 28, No. 4, April 1976, pp. 32–37.

[9] Agarwal, J. C., N. Schapiro, and W. J. Mallio. Process Petrography and Ore Deposits. Min. Cong. J., v. 62, No. 3, March 1976, pp. 28–35.

[10] Madsen, B. W., and R. D. Groves. Using Oxygen To Reactivate a Nearly Dormant Copper Sulfide Leach. BuMines RI 8056, 1975, 9 pp.

[11] Madsen, B. W., R. D. Groves, L. G. Evans, and G. M. Potter. Prompt Copper Recovery From Mine Strip Waste. BuMines RI 8012, 1975, 19 pp.

[12] Steckley, R. C., W. C. Larson, and D. V. D'Andrea. Blasting Tests in a Porphyry Copper Deposit in Preparation for In Situ Extraction. BuMines RI 8070, 1975, 47 pp.

eliminated the electrorefining circuit and yielded a high-purity copper with a reduction from a high power consumption of 3.5 to less than 1 kilowatt-hour per pound of copper produced. Preliminary engineering and economic studies indicated that the process may result in a significant saving in capital and operating costs compared with conventional pyrometallurgical processes.[13]

Several review articles[14] evaluated developments in hydrometallurgy with respect to the relative economics of copper production and efficiencies of environmental controls. Another article presented information on the application of stainless steel as containment vessels and other equipment in hydrometallurgy.[15]

Research has shown that sulfur in copper concentrate can be converted into insoluble anhydrite by roasting the concentrate with lime. After leaching the calcine to recover the metal values, the residues may be discarded without harm to the environment.[16] Laboratory tests on copper concentrate utilizing a combined nitrogen roast—two stage leach—electrowinning approach show promise as a process for recovering copper, sulfur, iron oxide, and valuable minor metals with a minimum impact on the environment.[17] Recent research has improved on procedures to recover copper and iron from a leach solution and to recover sulfur from the residue resulting from a ferric chloride leach of chalcopyrite concentrate.[18] Chlorination rates of sulfide minerals for application to hydrometallurgy processes were determined and analyzed.[19] Research on the application of solvent extraction to alkaline leach solutions was published.[20] An article described the initial phase of a study to recover copper and elemental sulfur from copper concentrate by using a sulfur dioxide pressure leaching process.[21]

An article reviewed the history of reverberatory-converter smelting and the emerging new smelting processes in response to tightening energy supplies and stringent environmental controls.[22] Investigations by the Smelter Control Research Association to control sulfur dioxide emissions were described in an article with particular emphasis on the promising ammonia double-alkali process.[23] Bench-scale tests were conducted to demonstrate the use of hydrogen for a direct-reduction process of recovering copper from copper concentrate.[24]

A paper reviewed the theory of the electrocrystallization of copper and extrapolated the fundamental conclusions to practical problems in the electrodeposition of copper.[25] Other research determined parameters of resistance and current distributions in copper refinery tankhouses.[26] An article reviewed the economic and technical advantages causing a greater application of the use of titanium cathodes in the starter sheet sections of copper refineries.[27]

Results of a study to identify and assess the relative importance of factors affecting

[13] Cyprus Mines Corporation. 1975 Annual Report. Pp. 35–37.

[14] Jansen, M. L., and D. A. Milligan. Developments in Sulfur Disposal Techniques in Hydrometallurgy. J. Metals, v. 27, No. 1, January 1975, pp. 13–17, 23.

Rosenzweig, M. D. Copper Makers Look to Sulfide Hydrometallurgy. Chem. Eng., v. 83, No. 1, January 1976, pp. 79–81.

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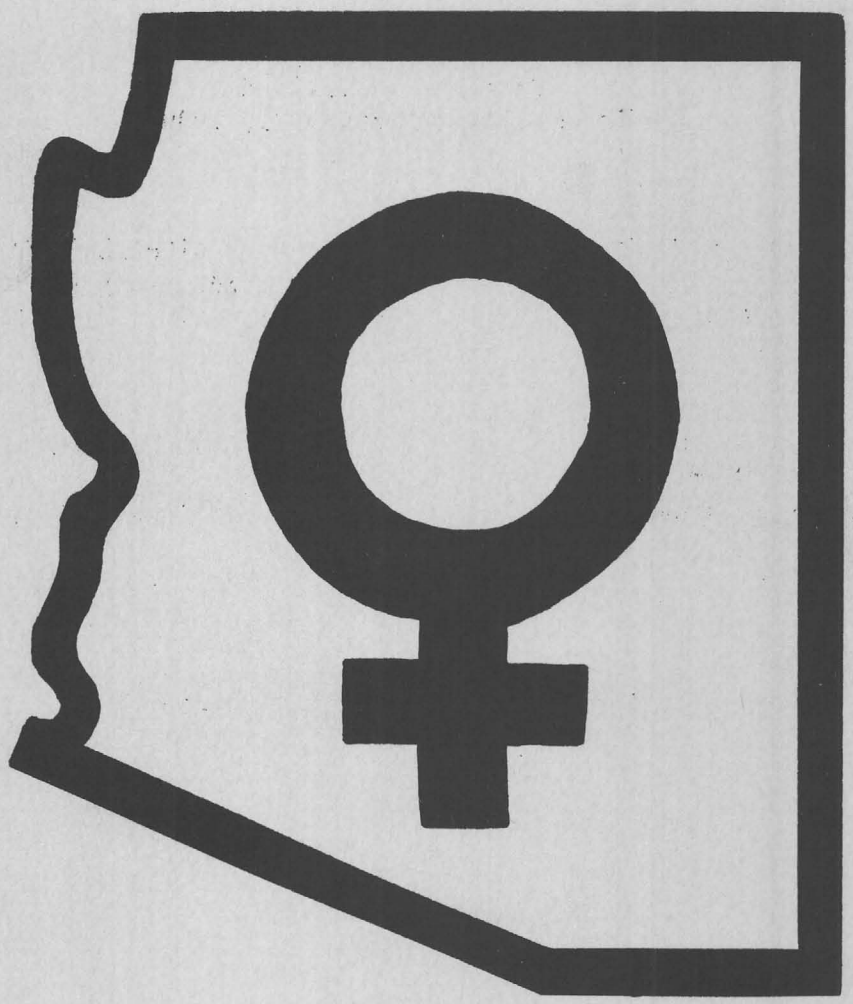
THE PRIMARY COPPER INDUSTRY OF ARIZONA IN 1975 - 1976

SPECIAL REPORT NO. 2



BY

MICHAEL N. GREELEY

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THE PRIMARY COPPER INDUSTRY
OF ARIZONA
IN
1975 & 1976

SPECIAL REPORT NUMBER 2

BY

MICHAEL N. GREELEY
DECEMBER 1978

ARIZONA DEPARTMENT OF MINERAL RESOURCES
JOHN H. JETT - DIRECTOR

PHOENIX OFFICE

MINERAL BUILDING
FAIRGROUNDS
PHOENIX, ARIZONA 85007
(602) 271-3791

TUCSON OFFICE

STATE OFFICE BUILDING
ROOM 208, 415 W. CONGRESS
TUCSON, ARIZONA 85701
(602) 882-5399

INTRODUCTION

The Arizona Department of Mineral Resources presents herein a report on the copper industry. This report discusses the economic conditions that prevailed during 1975 and 1976 and specifically profiles Arizona's copper production during this period. A short resume of the operational highlights reported by individual developers and producers in the state is also given.

The statistical tables in this report include various production and employment figures through 1976. In addition, the tables are expanded with historical compilations of leach-copper as a percentage of primary production, average grade of ore produced, recoveries, stripping ratios, and designed copper capacity. A table and location map of copper reserves in Arizona is also provided. It is hoped that the information is useful to the reader and a sincere request is extended for any corrections or suggestions deemed necessary for the accuracy or completeness of this report.

The Department maintains an extensive library of information concerning the copper industry, including earlier editions of reports similar to this one. Another copper report, with compilations through 1977, will be issued in early 1979.

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1/ Throughout this report a "Ton" means a short ton (2000 pounds or 1.1023 metric ton).

ECONOMIC CONDITIONS IN 1975 AND 1976

The recession of 1975 inflicted a great blow to the copper industry. In the United States, demand for copper was down 31% from 1974 and 38% from 1973. As demand dropped so did prices.

As 1975 opened the U. S. producer price was 68¢ per pound of copper. At the end of January Asarco led a general reduction to 63¢. Another cut to 60¢ per pound was instituted by Asarco and Phelps Dodge in June; other U. S. producers refused to lower their price. By late July, the market was slightly higher again and Asarco and Phelps Dodge rejoined the other producers at 63¢, where the price remained through the end of the year.

Although curtailments of mine production were initiated at many properties, the inventory of concentrates and refined copper increased enormously in 1975. There was a world excess, over normal levels, of approximately 800,000 tons of copper. In the U. S., production (including secondary recovery of unalloyed copper) exceeded consumption by about 15% (Table XIV). Primary refined stocks at U. S. refineries doubled during the year, rising from 101,000 tons to 207,000 tons (Table XVI). Net primary imports fell from almost 436,000 tons in 1974 to a little over 127,000 tons in 1975 (Table XV).

As the world and U. S. economies began to recover in 1976, consumers and commodity speculators took advantage of the low price. In late February, Cities Service raised its producer price from 63¢ to 66¢ but was the only supplier to do so. A week later, Cities Service reduced its price back to 63¢. But demand continued to strengthen and on March 19, Asarco, followed by other producers, raised its price to 66¢. In mid-April, Kennecott led another producer increase to 70¢. And again, in late June, Kennecott, and other producers, raised the price to 74¢ per pound.

Then a pause in the economic recovery set in and the copper market fell back to levels experienced in the 1975 recession. On October 6, Phelps Dodge led the producers with a reduction to 70¢ per pound and on December 1, Asarco led another reduction to 65¢, where the price remained until the end of 1976.

Many production curtailments at the mines were lifted during 1976 in response to increased demand. But, as the economy softened in the later part of the year, inventories of concentrates and refined copper continued to build throughout the free world. For 1976, U. S. primary production from mines and secondary recovery of unalloyed copper was slightly above consumption (Table XIV). A generally low free-market

price compared to the U. S. producer price presented a bargain to U. S. fabricators, and, as a result, net primary imports increased substantially over 1975 (Table XV). Zambia, a country that shipped little or no copper to the U. S. in 1975, exported over 127,000 tons of refined copper to this country in 1976. Substantial increases in imports were also recorded from Canada, Chile, Peru, and Yugoslavia. The primary refined stocks at U. S. refineries were reduced only slightly from the beginning of 1976, to 190,000 tons (Table XVI).

In summary, the copper industry, at least in the U. S., continued to lag behind other industry leaders as economic conditions generally improved. Consumption in the free world, including the U. S., increased from 1975. Production, however, at many foreign mines continued at a high rate, supplying the market with a surplus of low-cost copper. American producers found it difficult to compete effectively against these lower priced supplies; in fact many of them operated at a loss or break-even point.

The average annual price of copper per pound, at a high of 77¢ in 1974, declined to 64¢ in 1975 and rose slightly to 69¢ in 1976 (Table XVII).

COPPER PRODUCTION IN ARIZONA

The center of copper production in the United States is Arizona. In 1975 the state accounted for 57.5% of the Nation's newly mined copper. In 1976, the year of America's Bicentennial observance and perhaps as a fitting tribute to the revolutionaries' early use of the red metal, Arizona produced for the first time over a million tons of copper and accounted for 63.8% of the total primary production in the U. S. (Tables XII and XVII). Indeed Arizona produced more copper than any country in the world, except Chile (Table XVIII).

In 1976 the gross value of mineral production in Arizona was $1,726,621,000. Of this total value, copper production contributed 83% (Table VII). Other major contributors to the total mineral production of the state include molybdenum, gold, and silver. Virtually all the molybdenum and most of the gold and silver are byproducts of the treatment of copper ores (Table VI). As a result, Arizona ranks second in the United States in the production of molybdenum and silver, and fourth in the production of gold.

From a record employment high in 1974 of nearly 28 thousand persons working in the primary copper industry, the number of employees fell eight percent to approximately 25.6 thousand in 1976 (Tables XIX and XX). Employment and productivity figures for this same period, however, indicate the production worker's average hourly earnings rose roughly $1.50 (from $5.61/hr. to $7.14/hr) as his average hourly production rate increased about one ton (from 4.5 tons/man-hr. to 5.4 tons/man-hr).

There were 29 major Arizona copper mines producing in 1975 (Table I). The number of operating properties was reduced to 27 in 1976. The newest property to begin operations was the Lakeshore underground mine which came on-stream in early 1976 and added significantly to the state's production.

Interestingly, there was a sharp rise in the amount of copper produced by leaching methods (Table II). The Johnson and Lakeshore mines began supplying leach-copper during the 1975-76 period and in 1976 copper produced by leaching oxide-type minerals exceeded 16% of the total primary production. Generally the cost of producing leach-copper has been less than producing milled sulfide concentrates.

Over the years, the average grade of ore produced has declined. Between 1966 and 1975, the copper content of sulfide ores dropped 30% to a point where there was only about 11 pounds of copper in a ton of ore mined (Table III). There was a slight reversal in this downward trend when in 1976 Arizona's ore averaged 12 pounds of copper per ton.

A review of the copper recoveries listed in Table IV indicates little or no change during the past decade. Although no attempt was made to weight the recoveries according to the amount of material treated, it is obvious that, for an operation to maintain its copper metal production with leaner ore feeds, significant technological refinements must have been made.

With the cessation of mining at the Copper Cities mine in 1975, the number of open pit operations declined to 20 in 1976. The stripping ratio, or the amount of waste removed in comparison to the amount of ore mined, at these operations is given for the past decade (Table V). Even though the average annual stripping ratio has not fluctuated greatly from what it was in 1966 (2.3:1), the ratio does appear to be creeping upward. In 1976 the average ratio was 2.7:1.

Table XI shows an estimate of the capacity to produce primary copper at each of the state's principal operations. In total there is a designed capacity to produce slightly more than 1.25 million tons annually. The Arizona mines and their concentrators and leach-plant facilities operated at about 65% capacity during 1975 as a result of a major recession in the industry. As market conditions improved, albeit erratically, in 1976, production was raised to about 80% of capacity.

Many factors, some of which have been discussed above, affect the actual production of copper in Arizona. Most technological factors are so interwoven that to isolate one and describe its impact is extremely difficult and often misleading. An even more difficult task is to properly evaluate the rapidly enlarging domain of socio-political factors that influence daily the decisions made by the developers and producers of copper. Foremost, however, in any discussion of capacity is the availability of the natural resource, in this case the availability of deposits of copper mineralization. A chart showing most of Arizona's rich endowment of proven copper reserves is given in Table XXII.

An interesting development that recently improved the reserves held by Asarco should be mentioned. In 1976, an agreement signed with Anamax effectively unlocked over 200 million tons or ore. In addition to the new Palo Verde mine containing 156.5 million tons that will be developed by the partners, Asarco will extend the life of its Mission and San Xavier mines by adding to them 44.2 million tons. Moreover, there will be a significant improvement of ore grade at the Mission mine.

It should be emphasized that, although the reserves listed in Table XXII total more than 10 billion tons (generally as of December 31, 1977), the figures can move upward or downward

drastically with changes in technological skill or with changes in U. S. policy or economy. If, for example, socio-political factors such as capricious rules and regulations imposed by government become too burdensome, many of these deposits may never be developed and many of the existing mines may be closed. Arizona's, and therefore America's, capacity to produce copper will then be seriously harmed.

HIGHLIGHTS OF COMPANY OPERATIONS IN ARIZONA

The following is a resume of operational developments and accomplishments of major companies in Arizona concerned with production of copper.

Anamax Mining Company

A three-year expansion program was largely completed at the Twin Buttes mine in 1975. A new solvent extraction-electrowinning plant built to treat oxide ore began operation in August. The expansion program increased annual capacity to approximately 90,000 tons of copper contained in concentrates and 36,000 tons of cathode copper.

Due mainly to unanticipated poor ground conditions which severely limited access to ore, the sulfide concentrating facility was shut down on March 1, 1975 and ore mining suspended while an intensive program of overburden removal was pursued. A major reduction in the planned angle of slope walls in certain portions of the orebody resulted in the elimination of some ore carried as reserve. A comparison of reserves published as of December 31, 1974 and 1975 shows that although the oxide tonnage was increased 15%, the sulfide tonnage was reduced by 80 million tons (426M tons to 346M tons). Fortunately the average grade of the sulfide ore was improved eight percent.

In July 1975, stripping operations were reduced to five days per week and the work force temporarily reduced. In January 1976, mining of ore was resumed and the sulfide concentrator renewed operations at a reduced rate of 30,000 tons of ore per day, for five days per week. Milling of ore from the northeast orebody was initiated during the first quarter. The reduced production schedule, approximately 60% of capacity, was maintained through the year. During this first full year of operation the oxide plant was the largest single producer of cathode copper from oxide ores in Arizona, producing 57,925,000 pounds.

Asarco Inc.

Except for a three-week vacation shutdown, operations were normal at the Sacaton and San Xavier mines in 1975. Production at Sacaton during its first complete year of operation exceeded full capacity of 21,000 tons of copper. Development work began for the mining of the Sacaton East orebody by underground methods. A head frame and hoist house were installed at the surface and the main shaft was collared to bedrock. Mining of oxide ore from the south pit of the

San Xavier mine began at midyear; this ore is treated with the oxide ore obtained from the north pit at the San Xavier vat-leach plant.

A reduced operational schedule of five days per week continued from late 1974 through June 1975 at the Mission and Silver Bell mines. After a complete shutdown for a three-week vacation in July, work schedules were reduced further to four days per week. This production schedule, approximately 57 % of normal capacity, was maintained through the year.

The Hayden smelter operated at about 65% effective capacity during 1975. Installation of a sophisticated air monitoring and meteorological measurement system at the smelter was essentially completed and in full operation by December 1, 1975. This installation and major repair to one smelting furnace caused the reduced smelter production.

In 1976, operations at the Sacaton and San Xavier mines continued normally with the exception that development of the underground East orebody at Sacaton was suspended. Mining of oxide ore at the north pit of the San Xavier mine was completed during the year and shipment commenced of the underlying sulfide ore to the Mission concentrator. The south pit at San Xavier continued to contribute oxide ore to the vat-leach plant. Production levels at Mission and Silver Bell were finally restored to normal in August 1976.

During the year the smelter at Hayden again operated at about 65% capacity. Major repairs and modifications were made to the sulfuric acid plant originally built in 1971 to control sulfur dioxide emissions.

Big Hole Mining Company

Since 1954 production at the United Verde mine was contracted by Phelps Dodge, the owner, to the Big Hole Mining Company. Copper was produced from both sulfide and oxide ores. Operations at the mine were brought to a close in June 1975.

During its period of operation, Big Hole produced in excess of 25 million pounds of copper recoverable from sulfide ore alone. Between 1966 and 1975 the average (weighted) sulfide grade was 5.55 percent Cu.

Casa Grande Copper Company

An announcement of a major discovery of copper mineralization was made in late 1976 by the Getty Oil Company and Hanna Mining Company. These two companies were equal participants

in the joint exploration venture managed by the Coastal Mining Company, a subsidiary owned entirely by Hanna. The mineralization is in the vicinity of the Santa Cruz river drainage west of Casa Grande, Arizona, and occurs at depths of 1600 to 3300 feet. The deposit is only a few miles southwest of Asarco's Sacaton mine.

Eventually a new company, the Casa Grande Copper Company, was formed to further explore and develop the Casa Grande deposit. The new company is owned equally by Getty and Hanna.

Cities Service Company

During 1975, the first complete year of operation, the Pinto Valley mine and mill operated at about 90% of design capacity. Under normal conditions the facility should produce annually 62,500 tons of copper contained in concentrates. In addition, there is a molybdenum circuit. The open-pit mine will eventually encompass the old Castle Dome mine area.

Ore extraction at the Copper Cities and Diamond H open-pit mines was terminated on May 9, 1975. Milling of stockpiled low-grade material was stopped on September 12, 1975. Leaching of dumps, however, and production of precipitate-copper at the Copper Cities unit continued through the year.

In-situ leaching of the old Miami orebody and production of precipitate-copper also continued through 1975. A new solvent extraction-electrowinning plant to produce cathode copper directly from leach solutions was being constructed.

Poor economic conditions forced a postponement of production originally scheduled for early 1976 at the Miami East orebody. Underground development work, however, was conducted to verify mining conditions. In addition, a drilling program to assist in detailed planning of eventual ore extraction continued through the year.

In 1976 the Pinto Valley mine and mill operated at six percent over design capacity. Design modifications were begun to increase capacity from 40,000 tpd to 50,000 tpd. This expansion program was scheduled for completion in late 1978.

Leaching continued through 1976 at the Copper Cities and Miami units. The new solvent extraction-electrowinning plant went on stream during the second quarter of the year. The plant has a design capacity of 6,000 tons per year of high quality cathode copper.

The Miami East underground mine remained on standby during 1976. A test mine opening was excavated, however, and the development drilling program was completed.

Continental Oil Company

Conoco continued to evaluate its Poston Butte deposit approximately three miles northwest of Florence, Arizona. During 1975, underground work to obtain bulk ore samples, accumulate rock mechanics data, and confirm ore reserve estimates was completed. Also, all major operations were completed at a pilot recovery plant where performance and design criteria for oxide and sulfide ore treatment were determined.

In 1976, Conoco announced the indefinite postponement of development of the Poston Butte deposit. Comprehensive studies completed during the year, however, showed that the deposit can be developed by standard techniques of open-pit mining and ore processing.

Cyprus Mines Corporation

At Bagdad, a major expansion program begun in mid-1974 was on schedule throughout 1975. Approximately one third of the pre-production stripping was completed. Eleven of 20 new 170-ton trucks were operating by the end of 1975 as well as one of four new 20 cubic yard shovels. A new mine maintenance and machine shop and warehouse facilities were finished by July. Site preparation for the primary crusher and new concentrator was completed by the end of the year. New employee housing was under construction and drilling to expand reserves further was underway. In 1975, the Cyprus Bagdad Copper Company was the first company to receive certification of its electrowon cathodes for New York Commodity Exchange contracts.

During the year, Cyprus reduced costs and improved operational efficiency at the underground Bruce mine by putting into service a new, large mobile drilling machine. An intensive exploration program to deliniate additional ore was not successful. The Johnson open-pit mine and solvent extraction-electrowinning plant went into production in March 1975. This operation is designed to produce approximately 5,000 tons of high quality cathode copper annually.

The Cyprus Pima Mining Company (owned 50.01 % by Cyprus Mines Corporation) produced at near capacity level during 1975. Fifteen new 170-ton trucks were delivered to the Pima mine by October.

During 1976 expansion at the Bagdad mine continued on schedule. Site preparation for the overland conveyor, water reservoir, and tailings dam was finished in the first quarter. Drilling to expand ore reserves continued.

Production in 1976 at the Bruce mine was difficult to maintain because of support problems in stopes which neared completion. It was reported that the mine had a life expectancy of a little more than one year, and that exploratory drilling had not increased reserves.

The Johnson operation completed its first full year of production in 1976 and produced above capacity. It was the second U. S. producer of electrowon cathodes to receive certification for New York Commodity Exchange contracts. Cyprus reported that at the current rate of production the mine had eight years of operation remaining after 1976.

The Cyprus Pima Mining Company again produced at near capacity level during 1976. A new large drill began operating in April, seven new 170-ton trucks were delivered in the third quarter, and a new 20 cubic yard shovel began working in December. Cyprus reported that after 1976 the Pima mine had a life expectancy of about eight years.

The CYMET process, a hydrometallurgical technique to reduce copper directly from copper sulfides, was tested and improved during 1976. The pilot plant is operated at the Pima mine site.

Duval Corporation

Operations at the Esperanza and Mineral Park mines were curtailed in February 1975 from a seven-day week to a five-day week. This curtailment reduced total copper production about 17%.

During the year, production at the Sierrita mine was essentially at full capacity. In addition to being the second largest producer of copper in Arizona during 1975, Sierrita was the single largest source of molybdenum in the state, producing 47 % of the total. By December, the total amount of copper required to be delivered to the General Services Administration had been made available for delivery. These final deliveries completed Duval's committment to repay a GSA loan with 38-cent copper.

In February 1975, the construction of new facilities to produce ferro-molybdenum was completed. This plant, adjacent to the Esperanza property, is designed to produce 3.5 million pounds of ferro-molybdenum annually.

During the year, construction of the new CLEAR plant near the Sierrita property, was completed. This hydrometallurgical plant is designed to produce 40,000 tons of copper crystals (equivalent to a high-grade blister copper) per year. It will treat concentrates produced at the Esperanza and Sierrita properties and precipitates produced at the Esperanza and Mineral Park properties.

In 1976, operational curtailments imposed at Esperanza and Mineral Park were finally relaxed in September and the properties resumed a seven-day week. Sierrita again produced at full capacity; the mine produced 17,608,678 pounds of recoverable molybdenum, 57% of Arizona's total production.

The CLEAR plant commenced production during the first quarter of 1976. It operated at about 85% of design capacity during the year.

Eisenhower Mining Company

The Eisenhower Mining Company was formed in August 1976 as a general partnership between the Anamax Mining Company and Asarco Inc., to develop and mine the Palo Verde ore deposit. This ore body lies between Asarco's Mission and South San Xavier open-pit mines and is leased from the State of Arizona on claims located in the 1950's.

Stripping of overburden at the Palo Verde began in late 1976 and production will begin in early 1979. Asarco is the mine operator. Anamax's share of the ore will be concentrated at the Twin Buttes mill, Asarco's at the Mission mill. The planned production is 27,000 tons per year of copper contained in concentrates.

Hecla Mining Company

Hecla is the operating member of a general partnership formed with the El Paso Natural Gas Company to develop, mine, and produce copper at the Lakeshore underground mine. The mine and sophisticated plant facilities are designed to produce 65,000 tons per year of copper contained in cathodes and precipitates. The property is leased from the Papago Indian Tribe on a royalty basis. Preproduction mine development was 95% complete by the end of 1975.

Lakeshore began operations officially on April 1, 1976, although the first cathode-copper shipment was made earlier on January 26, 1976. Oxide ore production reached full capacity in August 1976. Production of sulfide ore was difficult to maintain at full capacity, however, because of dilution

problems. Although all plant facilities operated according to expectations except the copper precipitate pelletizing plant, the high start-up costs, low mine production rates, and low copper prices resulted in substantial losses for the year.

Inspiration Consolidated Copper Company

Overall production by Inspiration was curtailed 25% in February 1975. Another reduction in October brought production down to about 65% of capacity.

At the beginning of the year, the Inspiration Area mines were operated seven days per week and were producing all three major classes of ore, oxide, sulfide, and a mixture of the two (dual process), at the rate of 27,500 tpd. In February the work week was reduced to five days; however, the production rate was maintained. In April the seven-day week was resumed but production was reduced to 20,000 tpd. Mining of oxide ore was stopped at this time. In October, the work week was again reduced to five days and production was maintained at 20,000 tpd for the rest of the year.

Similar curtailments were imposed at the other operations. At the Christmas mine the work week was reduced in February from seven days to five days and there were complete shutdowns from November 24, to December 7, and from December 20, to the end of the year. Operations were reduced throughout the year at the Ox Hide mine from 20 shifts to 10 shifts per week.

There were intermittent shutdowns at the smelter and acid plant due to repairs of pollution control facilities. The failure of a furnace wall at the smelter caused a major halt of production from December 19, to January 21, of the following year (1976). Operations at the fabricating division were also reduced during the year from three shifts to two shifts per day, with a five-day week.

On the brighter side, in June 1975, the Inspiration smelter passed required air quality tests and was issued an operating permit by the Arizona State Department of Health Services. In addition, a new method of dump leaching that increases rate of copper extraction and recovery was developed, tested and put into practice late in the year. In June, Inspiration sold 850,000 shares of common stock to the Hudson Bay Mining and Smelting Company, Ltd., of Canada, and the Minerals and Resources Corporation, Ltd., of Bermuda, for $31,450,000.

In 1976, most of the company's mining operations were at about 70% of capacity. The Inspiration Area mines maintained a production rate of 20,000 tpd on a schedule of five days per week. The Christmas mine resumed operations on January 20, with a five-day week until August when work was scheduled seven days per week. A work schedule of 10 shifts per week continued at the Ox Hide mine. In July, operations at the fabricating division were increased to 14 shifts per week and then reduced again in early September to 10 shifts per week.

Production records were set in 1976 at both the acid plant and the smelter. The smelter produced 127,000 tons of copper.

Kennecott Copper Corporation

On February 16, 1975, operations at the Ray Mines Division were reduced to a five-day week. There was a 12-week shutdown during the summer. The reverberatory furnace at the Hayden smelter was rebuilt during this shutdown. An expansion project to increase silicate copper leaching capacity by 40% continued at a reduced rate.

In 1976, although production schedules remained below full capacity levels, a substantial increase in copper production was realized. In addition, the expansion of capacity at the silicate copper leaching facility was completed early in the year and overall performance of the new plant exceeded design projections.

Kennecott reported that operations at Ray should continue for 70 years at current production levels. Engineering plans progressed during the year in anticipation of possible expansion of production capacity.

During 1975 and 1976, evaluation of the company's Safford deposit continued. Experiments were performed to test the applicability of a solution mining process on the deposit.

McAlester Fuel Company

McAlester began production of leach-copper at the Zonia mine in 1966. Oxide ore was taken from the open-pit mine and heap leached until 1973 when operations were changed and the deposit was leached in place. Slightly more than 31 million pounds of copper were produced before operations were suspended in March 1975.

Newmont Mining Corporation

Production during 1975 at the San Manuel division was reduced by 23% with a temporary reduction in the work force. Nevertheless, it remained the largest underground metal mining operation in the U. S. and it was the largest single producer of copper in Arizona. It produced 187,487,000 pounds of recoverable copper during the year. Production at the high-grade Magma (Superior) mine was increased 33%.

During 1975, equipment and storage facilities were installed at the San Manuel smelter to utilize oil as smelter fuel during periods of natural gas scarcity. Subsequently, as the cost of oil rose, plans were drawn to modify the installations so that coal could be used as the primary fuel.

During 1976, the San Manuel mine continued to operate at a curtailed level. At mid-year, a gradual step-up of mine development was started but later, in view of recurrent unfavorable market conditions, the development work was again temporarily reduced. Production at the Magma mine was maintained at full capacity.

An abnormally high number of intermittent curtailments required for air pollution control at the San Manuel smelter adversely affected operations during the fourth quarter. The curtailments caused deterioration in the physical condition of the reverberatory furnaces and consequent lower efficiencies and throughput. As a result, concentrate inventories were built above normal and copper had to be purchased to meet sales obligations. During the year, however, the smelter did process old slag, enhancing substantially the total copper production.

The ammonia double alkali gas-scrubbing pilot plant at San Manuel continued operating during 1976. This plant was established by the Smelter Control Research Association, of which Newmont is a founding member.

Occidental Petroleum Corporation

For several years, Occidental's mineral division, Occidental Minerals Corp. (Oxymin), has drilled and delineated the Van Dyke oxide copper deposit that lies beneath much of the town of Miami, Arizona. The mineralization is 1100 to 2000 feet deep and varies from about 100 feet to 370 feet thick. In 1976, the company began preparations to test an in-situ copper solution mining process.

Oracle Ridge Mining Partners

The Oracle Ridge mine, formerly known as the Control mine, is in the vicinity of Marble Peak on the northeast slope of the Santa Catalina Mountains. Between 1968 and 1974, the Continental Copper Co., a subsidiary of the Continental Materials Corp., drilled and defined the ore reserves on the property, began underground development, ran metallurgical tests and initiated feasibility studies.

In 1975, the company continued underground development and engineering studies for a comprehensive operating plan. Negotiations for the acquisition of rights-of-way and tailings storage area were made during the year and discussions were held with several companies interested in becoming a partner in the mine development.

During 1976, the general mine plan was completed and a second mine adit established. The underground development work was continued and a ventilation shaft begun. In August, an announcement was made that Union Miniere, S. A., a Belgium-based natural resources company had agreed in principle to take a 45% interest, in exchange for investing additional capital and arranging for necessary financing. Eventually, a new company, 55% owned by Continental and named the Oracle Ridge Mining Partners, was formed with Union Miniere to bring the mine into production.

Phelps Dodge Corporation

The new Metcalf mine and concentrator began production in January 1975. Operations during the year showed that the concentrator, designed to treat 30,000 tpd, has an actual capacity of 40,000 tpd.

Work schedules at the Metcalf, Morenci, and New Cornelia mines and concentrators were reduced on January 9, from the equivalent of a 5½-day week to a 5-day week. On February 20, operations at these mines, as well as the underground mines at Bisbee, were reduced further to a four-day week. On June 13, 1975, the underground mines at Bisbee were shut down. During the week of July 13, operating schedules equivalent to a five-day week were resumed at the other properties and continued through the year.

Despite these operational curtailments and closure of the Bisbee mines, Phelps Dodge remained the leading producer of copper in Arizona. The company produced 345,688,981 pounds of recoverable copper, approximately 21% of the state's total production.

Installation of facilities to control air quality at the company smelters was essentially completed in 1975. Operations were generally on a seven-day week schedule except from February 20, to mid-July and during the three-week vacation shutdown at Morenci and New Cornelia.

The second of two units designed to dispose of most of the sulfuric acid produced at the Morenci smelter was completed and put in operation in November 1975. These facilities are used in leaching concentrator tailings produced at Metcalf and Morenci.

Construction of underground and surface installations and other development work at the company's Dos Pobres deposit near Safford, Arizona, continued during 1975. The No. 1 shaft was deepened about 240 feet to a final depth of 2,150 feet and the No. 2 shaft reached a depth of 1,439 feet.

In March 1976, work schedules at Metcalf, Morenci, and New Cornelia were increased to a six-day week. This schedule continued until December when it was reduced to the equivalent of a 5½-day week. Operations at the smelters were generally on a seven-day week schedule except during the normal three-week vacation shutdown at Morenci and New Cornelia.

Mine production of copper was greater than in any prior year resulting from longer work schedules and greater production from the new Metcalf mine. In 1976, Phelps Dodge produced 475,731,242 pounds of recoverable copper from its Arizona mines, about 23% of the state's total production.

Development of the Dos Pobres deposit continued at a reduced rate in 1976. Most of the work was on underground access and haulage drifts around the extremities of the orebody. Sinking of the No. 2 shaft was suspended on February 15, when a depth of 1,570 feet was reached.

Ranchers Exploration and Development Company

During 1975 and 1976, the Bluebird property was operated essentially at full capacity. A record production of 17,875,534 pounds of cathode copper was obtained in 1976. Four new 120-ton ore trucks were purchased during 1976 to reduce mining costs as haulage distances and lifts increase.

In-place leaching and production of copper precipitates at the Old Reliable mine were suspended in July 1975.

TABLE I

COPPER AND MOLYBDENUM PRODUCTION OF LARGE ARIZONA COPPER MINES

Company Mine	1975 Tons Copper Ore Mined	1975 Pounds Recoverable Copper	1975 Pounds Recoverable Molybdenum	1976 Tons Copper Ore Mined	1976 Pounds Recoverable Copper	1976 Pounds Recoverable Molybdenum
ANAMAX:						
Twin Buttes	2,307,331	18,306,894	273,228	8,851,000	133,396,000	1,223,000
Cathode Cu		13,461,772			57,925,000	
Total	2,307,331	31,768,666	273,228	8,851,000	191,321,000	1,223,000
ASARCO						
Silver Bell	2,541,900	28,037,459		3,076,400	35,939,534	
Precipitate Cu		8,496,533			8,627,066	
Mission	5,089,800	53,891,133	432,304	6,407,300	70,380,563	268,679
San Xavier						
Precipitate Cu	1,368,600	19,384,305		1,317,400	22,771,705	
Sacaton	3,606,400	43,835,162		3,781,800	44,042,241	
Total	12,606,700	153,644,592	432,304	14,582,900	181,761,109	268,679
CITIES SERVICE - MIAMI OPERATIONS						
Miami-Copper						
Cities Operations						
Copper Cities 1/	1,670,090	19,055,546	19,760			
Precipitate Cu		3,561,559			3,370,154	
Miami						
Precipitate Cu		13,075,798			6,036,812	
Cathode 2/					7,472,083	
Pinto Valley Opns. 3/	13,895,820	107,498,466	159,136	15,630,585	128,743,605	440,643
Total	15,565,910	143,191,369	178,896	15,630,585	145,622,654	440,643

TABLE I (Continued)

COPPER AND MOLYBDENUM PRODUCTION OF LARGE ARIZONA COPPER MINES

Company Mine	1975 Tons Copper Ore Mined	1975 Pounds Recoverable Copper	1975 Pounds Recoverable Molybdenum	1976 Tons Copper Ore Mined	1976 Pounds Recoverable Copper	1976 Pounds Recoverable Molybdenum
CYRUS MINES:						
Bagdad	2,082,099	23,599,989	716,792	2,043,988	20,983,134	652,590
Cathode Cu		14,320,802			14,606,474	
Bruce 4/	94,609	6,536,000		90,278	5,889,420	
Pima	19,630,974	154,541,515	1,814,263	19,554,407	154,986,103	1,906,318
Johnson 5/						
Cathode Cu	1,709,804	6,143,024		1,311,590	10,059,608	
Total	23,515,486	205,141,330	2,531,055	23,000,263	206,524,739	2,558,908
DUVAL:						
Esperanza	5,490,362	24,914,864	3,194,830	5,486,238	28,623,378	2,986,930
Precipitate Cu		3,960,323			6,412,177	
Mineral Park	5,573,875	27,472,411	2,781,954	4,726,075	19,498,473	2,645,471
Precipitate Cu		6,915,242			6,817,415	
Sierrita	31,430,788	186,727,062	13,286,923	34,022,842	202,927,887	17,608,678
Total	42,495,025	249,989,902	19,263,707	44,235,155	264,279,330	23,241,079
HECLA MINING COMPANY:						
Lakeshore Mine 6/						
Sulfide Ore				1,209,340	18,426,880	
Oxide Ore				1,410,228	28,407,483	
Total				2,619,568	46,834,363	

TABLE I (Continued)

COPPER AND MOLYBDENUM PRODUCTION OF LARGE ARIZONA COPPER MINES

Company Mine	1975 Tons Copper Ore Mined	1975 Pounds Recoverable Copper	1975 Pounds Recoverable Molybdenum	1976 Tons Copper Ore Mined	1976 Pounds Recoverable Copper	1976 Pounds Recoverable Molybdenum
INSPIRATION:						
Inspiration	6,288,363	68,527,498		4,610,227	51,193,292	
Precipitate Cu		21,266,570			20,677,690	
Christmas Division	1,403,835	11,729,139		1,558,165	13,942,431	
Ox Hide Mine	2,302,230	10,107,194		2,189,565	7,915,445	
Total	9,994,428	111,630,401		8,357,957	93,728,858	
KENNECOTT:						
Ray	6,692,267	86,516,592	330,032	10,243,750	136,258,061	743,037
Precipitate Cu		24,338,397			24,374,253	
Total	6,692,267	110,854,989	330,032	10,243,750	160,632,314	743,037
McALESTER FUEL COMPANY:						
Zonia Mine 7/						
Precipitate Cu		619,263				
Total		619,263				
MAGMA:						
San Manuel	16,778,247	187,487,000	3,182,298	15,016,263	176,115,000	2,616,237
Reprocessed smelter slag				2,818,353	42,334,000	
Superior	1,087,694	78,048,000		971,109	79,791,000	
Reprocessed smelter slag				19,588	138,000	
Total	17,865,941	265,535,000	3,182,298	18,825,313	298,378,000	2,616,237

TABLE I (Continued)

COPPER AND MOLYBDENUM PRODUCTION OF LARGE ARIZONA COPPER MINES

Company Mine	1975 Tons Copper Ore Mined	1975 Pounds Recoverable Copper	1975 Pounds Recoverable Molybdenum	1976 Tons Copper Ore Mined	1976 Pounds Recoverable Copper	1976 Pounds Recoverable Molybdenum
PHELPS DODGE:						
Morenci Branch						
Morenci Mine	16,173,658	177,767,689		18,705,450	208,986,329	
Metcalf Mine 8/	5,556,145	58,389,398		11,327,506	105,316,201	
Precipitate Cu		23,777,527			53,136,295	
New Cornelia Branch	7,270,059	66,045,992		9,481,855	100,399,483	
Copper Queen Branch						
Lavender Pit 9/						
Precipitate Cu 10/		8,376,532			7,892,934	
Copper Queen Mine 11/	108,167	11,331,843				
Total	29,108,029	345,688,981		39,514,811	475,731,242	
RANCHERS EXPLORATION AND DEVELOPMENT CORPORATION:						
Bluebird Mine						
Cathode Cu	4,375,485	15,121,572		3,449,771	17,875,534	
Old Reliable 12/						
Precipitate Cu		466,506				
Total	4,375,485	15,588,078		3,449,771	17,875,534	
TOTAL LARGE COMPANIES 13/	164,526,602	1,633,652,571 14/	28,312,423	189,311,073 15/	2,082,689,143 14/	31,091,583

Source: Arizona Department of Mineral Resources

TABLE I (Continued)

COPPER AND MOLYBDENUM PRODUCTION OF LARGE ARIZONA COPPER MINES

1/ Copper Cities open-pit mine shutdown May 9, 1975, however, leaching operations continued through 1976.
2/ Cities Service's new solvent extraction-electrowinning plant came on stream in May, 1976.
3/ Pinto Valley's initial start-up was in July, 1974.
4/ Cyprus Bruce Copper and Zinc Company's copper production from copper-zinc ore. The Company's zinc production for 1976 amounted to 19,376,966 pounds of zinc.
5/ Cyprus Johnson came on-stream March 15, 1975.
6/ The Lakeshore mine came on-stream early in 1976.
7/ No production since March 1975.
8/ Phelps Dodge's Metcalf mine and concentrator began production in January 1975.
9/ The Lavender Pit and Bisbee concentrator operations were terminated December 14, 1974. However, leaching operations continued through 1976.
10/ This figure represents production from the dumps, the Lavender Pit and the Copper Queen mine.
11/ Phelps Dodge's Bisbee underground mines ceased operations on June 13, 1975, thus ending approximately 100 years of production. However, leaching operations continued through 1976.
12/ Leaching operations at Old Reliable were suspended July, 1975.
13/ For a comparison to all copper produced in Arizona, with a classification of source material, reported by the U.S. Bureau of Mines, see Tables IX & X. Specific comparisons may differ due to times and methods of reporting.
14/ Includes 142,636,824 pounds of copper produced in 1975 and 259,820,353 pounds of copper produced in 1976 from material not classified generally as ore (see detail by company in this table). A more detailed, recent, historical record of leach production only is given in Table II.
15/ Includes 2,837,941 tons of smelter slag reprocessed by Magma (see detail in this table).

TABLE II
ARIZONA LEACH COPPER PRODUCTION 1/
(Thousand Pounds)

Property	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Bagdad 2/	11,066	14,258	14,781	7,281	14,681	13,391	14,267	13,508	14,321	14,606
Bisbee 3/	4,443	7,285	7,002	7,407	8,345	10,000	8,532	6,402	8,377	7,893
Bluebird 4/	7,690	1,449	9,921	11,520	12,458	14,680	15,005	15,344	15,122	17,876
Castle Dome	2,122	2,431	1,831	934	-	-	-	-	-	-
Copper Cities	2,792	4,356	3,799	4,491	4,376	4,577	4,570	3,295	3,562	3,370
Emerald Isle	275	1,611	4,180	3,713	3,822	3,629	2,180	-	-	-
Esperanza	6,132	4,478	3,619	4,428	4,454	2,094	2,268	1,817	3,960	6,412
Inspiration	27,969	30,930	45,108	48,097	45,588	56,487	50,401	47,765	52,470	45,545
Johnson	-	-	-	-	-	-	-	-	6,143	10,060
Lakeshore	-	-	-	-	-	-	-	-	-	28,407
Miami	8,726	11,077	13,756	14,965	12,806	12,170	11,988	11,969	13,076	13,509
Mineral Hill	-	4,901	2,887	-	-	-	-	-	-	-
Mineral Park	7,005	7,051	6,221	7,710	7,315	8,936	6,431	6,801	6,915	6,817
Morenci	27,780	23,162	22,754	16,950	14,188	24,493	25,668	22,704	23,778	53,136
Old Reliable	-	-	-	-	-	-	5,992	2,175	467	-
Ox Hide	-	744	7,243	13,298	7,962	9,673	8,950	9,679	10,107	7,915
Peacock	-	-	-	NA	NA	NA	NA	NA	NA	NA
Ray 5/	21,188	21,742	29,968	43,971	31,622	31,472	28,369	25,478	24,338	24,374
Red Hills	-	-	-	-	46	-	-	-	-	-
San Xavier	-	-	-	-	-	-	4,955	11,762	19,384	22,772

TABLE II
ARIZONA LEACH COPPER PRODUCTION 1/ (Continued)
(Thousand Pounds)

Property	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Silver Bell 6/	5,017	4,909	5,226	5,614	6,297	7,897	8,092	7,860	8,497	8,627
Twin Buttes	-	-	-	-	-	-	-	-	13,462	57,925
United Verde	190	307	248	232	165	140	214	44	32	-
Zonia	3,264	3,928	3,576	4,456	4,769	4,778	2,991	2,717	619	-
TOTAL	135,659	144,619	182,120	195,067	178,894	204,417	200,873	189,320	224,630	329,244
PERCENT OF PRIMARY COPPER PRODUCED 7/	13.5	11.5	11.4	10.6	10.9	11.2	10.8	11.0	13.8	16.1

Source: Arizona State Dept. of Mineral Resources

1/ Copper recovered from precipitate and/or by solvent extraction from material dump, heap, vat or in situ leached.
2/ Precipitation replaced by solvent extraction in 1971
3/ Lavender Pit and Copper Queen
4/ Precipitation replaced by solvent extraction in 1969
5/ Includes only copper contained in precipitates from dump leaching. Does not include copper produced by electrowinning.
6/ San Xavier discontinued production of Siliceous Flux and commenced production of copper precipitate as of 5/1/73.
7/ Leach copper compared to total copper produced from all primary sources as reported in "Minerals Yearbook-Area Reports: Domestic", U. S. Bureau of Mines.

NA Not Available

TABLE III

AVERAGE CU CONTENT OF ORE PRODUCED AT ARIZONA COPPER MINES
(Percent Total Copper)

MINE OPERATION	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
ANAMAX MINING CO.											
Twin Buttes											
Sulfide	-	-	-		1.24	0.99	0.98	0.82	0.63	0.60	1.12
Oxide	-	-	-	-	-	-	-	-	-	1.27	1.31
ARIZONA RANCH & METALS CO.											
Mineral Hill											
Oxide	-	-			-	-	-	-	-	-	-
ASARCO INC.											
Mission											
Sulfide	.90	.88	.70	.67	.67	.67	.61	.60	.61	.60	.62
Sacaton											
Sulfide	-	-	-	-	-	-	-	-	.63	.74	.71
San Xavier											
Sulfide	-	-	-	-	-	-	-	-	-	-	-
Oxide	-	- Cu-bearing Silica Flux Mined 1968-72						.61	.77	1.05	1.12
Silver Bell											
Sulfide	.83	.79	.86	.70	.68	.65	.60	.64	.65	.72	.72
Oxide											
BIG HOLE MINING CO.											
United Verde											
Sulfide	4.9	5.2	5.4	6.4	6.3	5.2	4.9	5.1	4.8	5.7	-
Oxide											-

TABLE III (Continued)

AVERAGE CU CONTENT OF ORE PRODUCED AT ARIZONA COPPER MINES
(Percent Total Copper)

MINE OPERATION	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
CITIES SERVICE CO.											
Castle Dome											
Oxide						-	-	-	-	-	-
Copper Cities											
Sulfide							(.50)			(.50)	-
Oxide											
Miami											
Oxide											
Pinto Valley											
Sulfide	-	-	-	-	-	-	-	-		(.45)	(.45)
CYPRUS MINES CORP.											
Bagdad											
Sulfide	.94	.77	.65	.66	.75	.81	.70	.70	.74	.70	.60
Oxide											
Bruce											
Sulfide	-	-	2.66	3.45	3.33	3.75	3.92	3.68	3.86	3.73	3.54
Johnson											
Oxide 1/	-	-	-	-	-	-	-	-	-	.42	.42
Old Dick (and Copper Queen)											
Sulfide	3.15	-	-	-	-	-	-	-	-	-	-
Pima											
Sulfide	.73	.58	.58	.54	.54	.54	.53	.51	.50	.48	.47

TABLE III (Continued)

AVERAGE CU CONTENT OF ORE PRODUCED AT ARIZONA COPPER MINES
(Percent Total Copper)

MINE OPERATION	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
EL PASO NATURAL GAS CO.											
Emerald Isle											
Oxide	-								-	-	-
HECLA MINING CO.											
Lakeshore											
Sulfide	-	-	-	-	-	-	-	-	-	-	.76
Oxide 1/	-	-	-	-	-	-	-	-	-	-	1.03
INSPIRATION CONSOLIDATED COPPER CO.											
Christmas (underground)											
Sulfide	1.14	-	-	-	-	-	-	-	-	-	-
Christmas (open pit)											
Sulfide				.77	.63	.65	.80	.74	.57	.57	.58
Inspiration Area Mines											
Sulfide	.47				.73	.69	.71	.67	.63	.65	.63
Oxide	.36										
Ox Hide											
Oxide 1/	-	-			.37	.36	.30			.29	.27
KENNECOTT COPPER											
Ray											
Sulfide					.97	.90	.89	.91	.83	.90	.86
Silicate					1.17	1.39	1.25	1.35	1.19	1.23	1.15
Oxide											

TABLE III (Continued)

AVERAGE CU CONTENT OF ORE PRODUCED AT ARIZONA COPPER MINES
(Percent Total Copper)

MINE OPERATION	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
MCALESTER FUEL CO.											
Zonia											
Oxide			.70			(.53)	(.53)			(.53)	-
NEWMONT MINING CORP.											
Magma											
Sulfide	4.70	4.77	4.63		(4.4)	(4.4)	(4.5)			(4.5)	(4.5)
San Manuel											
Sulfide 2/	.77	.76	.70			(.7)	(.7)		.70	.64	(.7)
PENNZOIL CO. (Duval Corp.)											
Esperanza											
Sulfide	.59	.52	.50	.48	.45	.40	-	.34	.31	.26	.29
Oxide											
Mineral Park											
Sulfide	.51	.52	.51	.52	.50	.50	.41	.38	.36	.30	.28
Oxide											
Sierrita											
Sulfide	-	-			.28	.27	.29	.28	.29	.33	.35
PHELPS DODGE CORP.											
Copper Queen											
Sulfide	4.23	4.18	4.08	4.23	4.36	4.31	4.41	4.06	3.48	5.70	-
Oxide											
Lavender											
Sulfide	.70	.76	.67	.81	.77	.68	.64	.60	.47	-	-
Oxide											
Metcalf											
Sulfide	-	-	-	-	-	-	-	-	-	.84	.86
Oxide	-	-	-	-	-	-	-	-	-		

TABLE III (Continued)

AVERAGE CU CONTENT OF ORE PRODUCED AT ARIZONA COPPER MINES
(Percent Total Copper)

MINE OPERATION	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
PHELPS DODGE CORP. (Continued)											
Morenci											
Sulfide	.86	.86	.84	.86	.85	.85	.83	.82	.82	.79	.80
Oxide											
New Cornelia											
Sulfide	.74	.75	.74	.73	.68	.67	.70	.61	.57	.57	.66
RANCHERS EXPLORATION & DEVELOPMENT CORP.											
Bluebird											
Oxide						.46	.44			.48	.58
Old Reliable											
Oxide	-	-	-	-	-	-	.74	.74	.74	.74	-
STANDARD METALS CORP.											
Antler											
Sulfide	-	-	-	-		-	-	-	-	-	-
WEIGHTED AVERAGE SULFIDE GRADE 3/	.80	.75	.72	.73	.73	.64	.64	.60	.57	.56	.61

Source: Company Annual Reports, Form 10-K's, and Prospectus; "International Directory of Mining and Mineral Processing Operations", E/MJ; Az. Dept. of Mineral Resources.

( ) Percentage in parenthesis is approximate; not used in calculation of weighted average.
1/ Acid soluble copper.
2/ Sulfide copper.
3/ Weighted average grade of ore milled; based generally on an assay of total copper.

TABLE IV
CONTAINED CU RECOVERIES AT ARIZONA COPPER MINES 1/
(Percent of Total Copper)

MINE OPERATION		1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Twin Buttes	Sulfide	-	-	-		80	72	76	72	71	63	68
	Oxide	-	-	-	-	-	-	-	-	-	65	75
Mineral Hill	Oxide	-	-			-	-	-	-	-	-	-
Mission	Sulfide	87	88	90	91	86	88	89	88	88	88	89
Sacaton	Sulfide	-	-	-	-	-	-	-	-	78	82	82
San Xavier	Sulfide	-	-	-	-	-	-	-	-	-	-	-
	Oxide	-	-	-	-	-	-	-	49	63	67	77
Silver Bell	Sulfide	72	74	65	74	75	78	85	80	78	77	81
Copper Cities	Sulfide											-
Pinto Valley	Sulfide	-	-	-	-	-	-	-	-			
Bagdad	Sulfide	69	80	81	76	73	77	88	82	77	81	86
Bruce	Sulfide	-	-	85	85	85	85	90	90	90	93	92
Johnson	Oxide 2/	-	-	-	-	-	-	-	-	-	43	91
Old Dick	Sulfide	96	-	-	-	-	-	-	-	-	-	-
Pima	Sulfide	89	86	85	86	84	86	84	85	85	82	84
Emerald Isle	Oxide	-								-	-	-
Lakeshore	Sulfide	-	-	-	-	-	-	-	-	-	-	
	Oxide 2/	-	-	-	-	-	-	-	-	-	-	
Christmas (UG)	Sulfide		-	-	-	-	-	-	-	-	-	-
Christmas (OP)	Sulfide				72	75	68	76	66	70	73	77
Inspiration Area	Sulfide 3/					39	47	47	45	48	46	45
	Oxide											
Ox Hide	Oxide 2/	-	-			47	42	67			76	67
Ray	Sulfide											
	Oxide 4/	-	-	-								
Zonia	Oxide								In-situ Leach 1973-75			-
Magma	Sulfide	97	91	95								
San Manuel	Sulfide 5/	92	93	93						90	87	

TABLE IV (Continued)
CONTAINED CU RECOVERIES AT ARIZONA COPPER MINES 1/
(Percent of Total Copper)

MINE OPERATION		1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Esperanza	Sulfide	80	81	81	78	83	87	-	87	89	90	91
Mineral Park	Sulfide	82	80	79	82	80	80	77	81	72	81	73
	Oxide											
Sierrita	Sulfide	-	-	-	-	84	91	84	90	89	90	88
Copper Queen	Sulfide	87	89	88	89	87	88	95	90	90	92	-
Lavender	Sulfide	73	73	67	65	70	64	69	67	52	-	-
Metcalf	Sulfide	-	-	-	-	-	-	-	-	-	63	54
	Oxide	-	-	-	-	-	-	-	-	-		
Morenci	Sulfide	77	72	73	76	74	76	75	71	74	70	70
	Oxide											
New Cornelia	Sulfide	88	88	88	87	87	86	84	85	85	80	80
Bluebird	Oxide						45	35			36	45
Antler	Sulfide	-	-	-	-		-	-	-	-	-	-

Source: Company Annual Reports and Form 10-K's; Az. Dept. of Mineral Resources.

1/ Recoveries are based on available reported production and average grade of material treated. A number of oxide operations are not listed because of inadequate data.
2/ Percent recovery of acid soluble copper.
3/ Percent recovery in flotation-concentration treatment, after ore has been leached.
4/ Silicate treatment.
5/ Percent recovery of sulfide copper.

TABLE V

STRIPPING RATIOS AT ARIZONA OPEN-PIT COPPER MINES 1/
(Waste: Ore)

MINE	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Twin Buttes	-	-	-	20.1:1 2/	7.3:1	10.2:1	5.3:1	7.6:1	10.8:1	71.6:1 3/	5.5:1
Mission	4.9:1	3.1:1	2.7:1	2.6:1	2.3:1	3.1:1	3.1:1	2.5:1	2.3:1	1.5:1	1.5:1
Sacaton	-	-	-	-	-	-	-	-	..	6.3:1	5.9:1
San Xavier	-	-									5.1:1
Silverbell	2.5:1	2.4:1	1.9:1	2.2:1	2.7:1	2.6:1	2.5:1	3.5:1	3.4:1	2:1	1.6:1
Copper Cities	1.9:1	1.9:1	1.7:1	1.8:1	3.1:1	2:1	1.1:1	1:1.3	1:3.1		-
Pinto Valley	-	-	-	-	-	-	-	-		1.8:1	1.7:1
Bagdad	4.1:1	3.9:1	3.7:1	4:1	4.1:1	4.4:1	5.2:1	5.2:1	4.5:1	1.2:1	9.8:1
Johnson	-	-	-	-	-	-	-	-	.	1:1.8	1.5:1
Pima								1.6:1	2.8:1	2:1	2:1
Christmas	1.6:1	3.6:1	5.1:1	4.4:1	5.5:1	4.1:1	4.9:1	5.8:1	5.1:1	3.4:1	3.1:1
Inspiration Area	1.3:1	1.3:1	1:1	1.3:1	1.5:1	1.7:1	1.8:1	1.9:1	2.2:1	3.1:1	1.9:1
Ox Hide	-	-	0	1:11.4	1:4.8	1:391.4	1:2.3	1:35.6	1:3.1	1:2.6	1:2.6
Ray	2:1	1.9:1	2.8:1	2.3:1	2.1:1	1.7:1	2.7:1	2.6:1	3:1	3.5:1	2.6:1
Esperanza	2.3:1	1.8:1	1.4:1	1.7:1	1.5:1	1.4:1	-	1.5:1	1.5:1	1:1.4	1.1:1
Mineral Park	1.7:1	2.2:1	1.8:1	1.8:1	1.4:1	1.4:1	1:1.2	1:1.5	1:1.1	1:1.5	2.1:1
Sierrita	-	-	-	70.7:1 2/	3.3:1	1.8:1	1.7:1	1.5:1	1.7:1	1.4:1	1.5:1
Lavender	4.1:1	4.4:1	4.5:1	4:1	2.7:1	1.5:1	1:2.1	1.1:1	1:1.2	-	-
Metcalf	-	-	-	-	-	-	-	-	-	2.8:1	1.8:1

TABLE V (Continued)

STRIPPING RATIOS AT ARIZONA OPEN-PIT COPPER MINES 1/
(Waste:Ore)

MINE	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Morenci	1.5:1	1.6:1	1.8:1	1.8:1	1.8:1	2.2:1	1.9:1	2:1	1.8:1	1.3:1	1.5:1
New Cornelia	1.4:1	1.6:1	1.9:1	1.6:1	1.5:1	2:1	1.9:1	1.9:1	1.5:1	1.5:1	1.1:1
Bluebird 4/	1:4.5	1:4.8	1:3.4		1:1.5	1:1	1:1.2		1:1	1.3:1	1.3:1
AVERAGE	2.3:1	2.3:1	2.2:1	2.3:1 5/	2.6:1	2.6:1	2.3:1	2.5:1	2.6:1	2:1 6/	2.7:1

Source: "Minerals Yearbook-Area Reports: Domestic", U. S. Bureau of Mines; Company Annual Reports; Az. Dept. of Mineral Resources.

1/ Leachable rock included with waste (except at solely leach operations).
2/ Includes preproduction stripping.
3/ Stripping continued as sulfide concentrator was shut down from March, 1975, to January, 1976.
4/ Fiscal year from Jul. 1 to June 30.
5/ Excludes ratios at Twin Buttes and Sierrita.
6/ Excludes ratio at Twin Buttes.

TABLE VI

ARIZONA PRODUCTION AND VALUE OF COPPER, MOLYBDENUM, GOLD, AND SILVER

RECOVERED FROM COPPER ORE

Year	Copper Ore 1/ Tons	Gold 2/ Troy Ounces Value 5/	Silver 2/ Troy Ounces Value 6/	Molybdenum 3/ 1,000 lbs Value (in $1,000)	Copper 4/ Pounds Value	Copper 4/ Lbs./Ore-Ton Ave.¢/lb. 7/	Value of Copper Gold, Silver & Molybdenum
1966	101,558,298	127,431 $4,460,085	5,595,644 $7,235,168	10,161 $17,812	1,359,481,200 $ 491,724,350	13.39 36.170	$ 521,231,603
1967	74,289,203	66,933 $2,342,655	3,996,587 $6,193,431	9,261 $15,385	901,853,500 $ 344,742,519	12.14 38.226	$ 368,663,605
1968	101,293,963	89,419 $3,510,600	4,697,394 $10,074,000	12,127 $19,207	1,146,313,600 $ 479,697,900	11.32 41.847	$ 512,489,500
1969	127,848,828	108,718 $4,586,800	5,899,843 $10,564,700	12,699 $20,947	1,477,520,000 $ 702,324,400	11.56 47.534	$ 738,422,900
1970	150,240,842	107,292 $3,904,400	7,130,261 $12,626,700	15,672 $26,700	1,694,294,000 $ 977,608,000	11.28 57.700	$1,020,839,100
1971	149,293,547	93,617 $3,820,510	6,106,204 $9,437,749	22,684 $39,872	1,529,780,500 $ 786,812,004	9.76 51.433	$ 839,942,263

TABLE VI (Continued)

ARIZONA PRODUCTION AND VALUE OF COPPER, MOLYBDENUM, GOLD, AND SILVER RECOVERED FROM COPPER ORE

Year	Copper Ore 1/ Tons	Gold 2/ Troy Ounces Value 5/	Silver 2/ Troy Ounces Value 6/	Molybdenum 3/ 1,000 lbs Value (in $1,000)	Copper 4/ Pounds Value	Lbs./Ore-Ton Ave. ¢/lb. 7/	Value of Copper Gold, Silver & Molybdenum
1972	165,914,825	102,526 $5,987,518	6,614,957 $11,143,226	27,216 $46,791	1,695,858,000 $ 858,392,446	10.22 50.617	$922,314,190
1973	181,311,945	102,376 $10,013,397	7,164,988 $18,325,173	37,657 $59,372	1,735,012,000 $1,021,314,814	9.57 58.865	$1,109,025,384
1974	178,913,296	90,206 $14,488,424	6,308,721 $29,701,332	28,346 $57,067	1,609,808,000 $1,233,901,735	9.00 76.649	$1,335,158,491
1975	168,750,152	82,759 $13,364,751	6,190,805 $27,354,196	25,030 $61,411	1,502,978,000 $ 954,917,072	8.91 63.535	$1,057,047,019
1976	194,136,559	97,961 $12,276,473	7,308,395 $31,816,805	31,073 $89,148	1,912,430,000 $1,316,210,823	9.85 68.824	$1,449,452,101

Source: "Minerals Yearbook-Area Reports: Domestic", U. S. Bureau of Mines.

1/ Includes some copper-zinc and/or lead-zinc ore in 1972 and thereafter. 2/ Excludes gold and silver recovered from vat or heap leaching of copper ores and from copper tailings or copper cleanup in 1969 and thereafter. 3/ Molybdenum content of recovered concentrate. 4/ Excludes precipitate copper from dump and in-place leaching. 5/ At average domestic, free-market gold price in 1968 and thereafter: year 1968, $39.26 per oz.; 1969, $42.19; 1970, $36.39; 1971, $40.81; 1972, $58.40; 1973, $97.81; 1974, $159.73; 1975, $161.49; 1976, $125.32. 6/ At E/MJ average N. Y. market price for .999 fine silver. 7/ At E/MJ average price, domestic, f.c.b. refinery.

TABLE VII

MINERAL PRODUCTION IN ARIZONA 1/

Mineral		1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)
Asbestos	short tons	1,676	W	NA	W
Clays 2/	thousand short tons	129	$483	28	$361
Coal (bituminous)	do	6,986	W	10,420	W
Copper (recoverable content of ores, etc.)	short tons	813,211	1,044,162	1,024,421	1,425,994
Gem stones		NA	5,000	NA	4,000
Gold (recoverable content of ores, etc.)	troy ounces	85,790	13,854	102,062	12,790
Gypsum	thousand short tons	117	419	139	529
Lead (recoverable content of ores, etc.)	short tons	420	181	338	156
Lime	thousand short tons	512	12,444	546	16,115
Mica, scrap	do	2	65	NA	W
Molybdenum (content of concentrate)	thousand pounds	25,030	61,411	31,073	89,148
Natural gas	million cubic feet	208	58	262	74
Petroleum (crude)	thousand 42-gallon barrels	635	3,332	519	2,724
Pumice	thousand short tons	856	1,294	802	1,240
Sand and gravel 3/	do	17,222	36,490	18,131	40,184
Silver (recoverable content of ores, etc.)	thousand troy ounces	6,286	27,783	7,615	33,126
Stone	thousand short tons	3,404	11,030	4,147	13,921

TABLE VII (Continued)

MINERAL PRODUCTION IN ARIZONA 1/

Mineral	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)
Zinc (recoverable content of ores, etc.) short tons	8,655	$ 6,751	9,501	$ 7,030
Value of items that cannot be disclosed: Asbestos, Cement, Clays (ball and common), Feldspar, Flourspar, Helium (high purity), Iron ore, Mica (crude) 4/, Perlite, Pyrite, Salt, Sand and gravel (industrial), Tungsten, and values indicated by symbol W	XX	63,666	XX	79,229
Total	XX	$1,288,423	XX	$1,726,621
Total 1967 constant dollars	XX	$ 509,829	XX	$ 620,720 p/

Source: "The Mineral Industry of Arizona", U. S. Bureau of Mines, Jan. 1978.

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed." XX Not applicable. p/ Preliminary. NA Not available.

1/ Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
2/ Excludes ball clay and common clay.
3/ Excludes industrial sand and gravel.
4/ Crude mica includes figures listed previously under both scrap mica and sheet mica, where applicable.

TABLE VIII

ARIZONA MINE PRODUCTION OF COPPER, LEAD, ZINC, GOLD AND SILVER

1858 To Present - In terms of Recoverable Metals

	COPPER		LEAD		ZINC	
	Short Tons	Value (Thousands)	Short Tons	Value (thousands)	Short Tons	Value (thousands)
1858 - 1974	27,585,417	$16,306,217	656,251	$130,673	1,075,450	$271,274
1975	813,211	1,044,162	420	181	8,655	6,751
1976	1,024,421	1,425,994	338	156	9,501	7,030
Total 1858 - 1976	29,423,049	$18,776,373	657,009	$131,010	1,093,606	$285,055

	GOLD		SILVER		COMBINED VALUE COPPER, LEAD, ZINC, GOLD AND SILVER
	Ounces	Value (thousands)	Ounces	Value (thousands)	
1858 - 1974	14,251,601	$408,365	442,900,226	$509,500	$17,626,029,000 r/
1975	85,790	13,854	6,286,000	27,783	1,092,731,000
1976	102,062	12,790	7,615,000	33,126	1,479,096,000
Total 1858-1976	14,439,453	$435,009	456,801,226	$570,409	$20,118,725,000

Est. Value of other Metals & Non-Metallics produced through 1974	$1,658,348,000	
Value of Other Metals & Non-Metallics Produced in 1975 a/	195,692,000	
Value of Other Metals & Non-Metallics Produced in 1976 a/	247,525,000	
Total Est. Value of Other Metals & Non-Metallics Produced through 1976		2,101,565,000
GRAND TOTAL ESTIMATED VALUE OF ARIZONA MINERAL PRODUCTION THROUGH 1976		$22,220,290,000

Source: Arizona Bureau of Geology and Mineral Technology; U. S. Geological Survey; "Minerals Yearbook-Area Reports: Domestic", U. S. Bureau of Mines

r/ Revised; a/ For Production detail see Table VII.

TABLE IX

ARIZONA MINE PRODUCTION (RECOVERABLE) OF GOLD, SILVER, COPPER, LEAD, AND ZINC IN 1975, BY CLASS OF ORE OR OTHER SOURCE MATERIAL

Source	Number of Mines 1/	Material sold or treated (short tons)	Gold (troy ounces)	Silver (troy ounces)	Copper (short tons)	Lead (short tons)	Zinc (short tons)
Lode ore:							
Gold, gold-silver and silver 2/	5	340,261	2,692	62,466	225	2	(3/)
Copper	29	168,655,544	82,385	6,155,669	748,352	223	22
Copper-zinc	1	94,608	374	35,136	3,137	-	8,367
Lead and lead-zinc 2/	3	3,130	11	7,106	-	188	267
Total 4/	33	168,753,282	82,770	6,197,911	751,489	412	8,655
Other lode material:							
Gold-silver tailings	1	65,216	320	24,286	80	-	-
Copper tailings, silver cleanup and lead cleanup 2/	1	558 5/	8	1,191	5,568	7	-
Copper precipitates	14	85,170	-	-	55,848	-	-
Total	15	150,944	328	25,477	61,496	7	-
Grand Total 4/	39	169,244,487	85,790	6,285,854	813,211	420	8,655

Source: "Minerals Yearbook-Area Reports: Domestic", U. S. Bureau of Mines

1/ Detail will not add to total because some mines produce more than one class of material.
2/ Combined to avoid disclosing individual company confidential data.
3/ Less than 1/2 unit.
4/ Data may not add to total shown because of independent rounding.
5/ Excludes newly generated tailings.

TABLE X

ARIZONA MINE PRODUCTION (RECOVERABLE) OF GOLD, SILVER, COPPER, LEAD, AND ZINC IN 1976, BY CLASS OF ORE OR OTHER SOURCE MATERIAL

Source	Number of mines 1/	Material sold or treated (short tons)	Gold (troy ounces)	Silver (troy ounces)	Copper (short tons)	Lead (short tons)	Zinc (short tons)
Lode ore:							
Gold, gold-silver, and silver 2/	10	993,177	3,860	289,065	25	2	-
Copper	27	194,046,281	97,636	7,276,850	953,447	280	36
Copper-zinc	1	90,278	325	31,545	2,768	-	9,349
Lead and lead-zinc 2/	3	1,313	18	2,554	1	56	115
Total 3/	31	194,137,872	97,979	7,310,949	956,216	336	9,501
Other lode material:							
Gold-silver tailings and copper tailings 2/	3	40,985 4/	223	15,098	18,868	-	-
Copper precipitates	11	70,117	-	-	49,313	-	-
Total 3/	14	111,102	223	15,098	68,180	-	-
Grand Total 3/	45	195,242,151	102,062	7,615,112	1,024,421	338	9,501

1/ Detail will not add to total because some mines produce more than one class of material.
2/ Combined to avoid disclosing individual company confidential data.
3/ Data may not add to total shown because of independent rounding.
4/ Excludes newly generated tailings.

Source: "Minerals Yearbook-Area Reports: Domestic", U. S. Bureau of Mines

TABLE XI
MAJOR DESIGNED COPPER CAPACITY IN ARIZONA 1/
(Short Tons of Recoverable Copper/Year)

OPERATOR	MINE	CAPACITY
Phelps Dodge	Morenci	150,000
Newmont	San Manuel	140,000
Anamax	Twin Buttes	126,000
Kennecott	Ray	95,000
Pennzoil (Duval)	Sierrita	90,000
Cyprus	Pima	80,000
Cyprus	Bagdad	75,000
Hecla	Lakeshore	65,000
Cities Service	Pinto Valley	62,500
Phelps Dodge	Metcalf	60,000
Inspiration	Inspiration Area	55,000
Phelps Dodge	New Cornelia	50,000
ASARCO	Mission	45,000
Newmont	Magma (Superior)	40,000
ASARCO	Silver Bell	25,000
ASARCO	Sacaton	21,000
Pennzoil (Duval)	Mineral Park	20,000
Pennzoil (Duval)	Esperanza	18,000
ASARCO	San Xavier	12,000
Ranchers	Bluebird	8,000
Cities Service	Miami	6,000
Inspiration	Christmas	6,000
Cyprus	Johnson	5,000
Inspiration	Ox Hide	5,000
Phelps Dodge	Copper Queen/Lavender	4,000
Cities Service	Copper Cities	1,500
TOTAL		1,265,000

Source: Az. Dept. of Mineral Resources file data; Company Annual Reports and Form 10-K; Professional Publications.

1/ Figures generally represent a current estimate of the potential productive capacity of primary recoverable copper in concentrates, precipitates, and cathodes. The estimates are based on recent production figures and on capacities of concentrator and leach-plant facilities. Other factors affecting actual production include, for example, grade of ore and recovery. Some capacities have been published by the reporting company.

TABLE XII

MINE PRODUCTION OF RECOVERABLE COPPER IN THE UNITED STATES

(Short Tons)

STATE	1974	1975	1976	RANK IN 1976
Arizona	858,783	813,211	1,024,421	1
California	194	344	375	12
Colorado	3,012	3,560	2,431	10
Idaho	2,841	3,192	3,362	9
Maine	1,522	2,024	1,766	11
Michigan	67,012	73,690	43,707	6
Missouri	12,665	14,258	11,050	8
Montana	131,131	87,959	91,111	4
Nevada	84,101	81,210	58,160	5
New Mexico	196,585	146,263	172,360	3
Pennsylvania	-	-	240	13
Tennessee	6,304	10,041	11,131	7
Utah	230,593	177,155	185,458	2
Washington	-	-	14	14
Other States 1/	2,259	459	-	
TOTALS	1,597,002	1,413,366	1,605,586	

Source: "Minerals Yearbook-Metals, Minerals, and Fuels", U. S. Bureau of Mines.

1/ Includes: Oklahoma, Oregon and Washington in 1974;
Oklahoma, Oregon, Washington, and Wisconsin 1975.

TABLE XIII

UNITED STATES PRODUCTION AND VALUE OF COPPER, GOLD, AND SILVER

RECOVERED FROM COPPER ORE

Year	Copper Ore Tons	Gold 1/ Troy Ounces Value 3/	Silver 1/ Troy Ounces Value 4/	Copper 2/ Pounds Value	Lbs./Ore Ton Ave. ¢/lb. 5/	Value of Copper, Gold and Silver
1966	186,966,042	547,327 $19,156,445	13,230,411 $17,106,921	2,499,863,100 $ 904,200,483	13.37 36.170	$ 940,463,849
1967	127,066,097	321,398 $11,248,930	8,351,423 $12,942,033	1,608,078,200 $ 614,703,973	12.66 38.226 6/	$ 638,894,936
1968	170,054,065	405,863 $15,934,200	9,532,341 $20,443,000	2,055,156,700 $ 860,021,400	12.09 41.847 7/	$ 896,398,600
1969	223,751,510	579,297 $24,440,500	13,581,516 $24,320,000	2,691,376,400 $1,279,318,900	12.03 47.534	$1,328,079,400
1970	257,729,000	552,140 $21,080,600	15,728,600 $27,852,500	3,025,021,000 $1,745,437,000	11.74 57.700	$1,794,370,000
1971	242,656,000	478,281 $19,518,648	13,142,041 $20,312,339	2,677,569,000 $1,377,073,737	11.03 51.433	$1,416,904,724
1972	266,831,000	484,552 $28,297,837	14,655,772 $24,688,381	2,922,127,000 $1,479,180,687	10.95 50.617	$1,532,166,905

TABLE XIII (Continued)

UNITED STATES PRODUCTION AND VALUE OF COPPER, GOLD, AND SILVER

RECOVERED FROM COPPER ORE

Year	Copper Ore Tons	Gold 1/ Troy Ounces Value 3/	Silver 1/ Troy Ounces Value 4/	Copper 2/ Pounds Value	Lbs./Ore Ton Ave. ¢/lb. 5/	Value of Copper, Gold and Silver
1973	273,025,000	479,366 $46,886,788	15,910,462 $40,691,961	2,902,524,000 $1,708,425,626	10.63 58.865	$1,796,004,375
1974	293,443,000	410,866 $65,626,804	14,106,821 $66,414,631	2,852,933,000 $2,186,744,615	9.80 76.649	$2,318,786,050
1975	263,003,000	325,620 $52,584,374	12,132,645 $53,608,335	2,483,524,000 $1,577,906,973	9.44 63.535	$1,684,099,682
1976	283,736,000	325,781 $40,826,875	13,632,135 $59,346,954	2,914,601,000 $2,005,944,992	10.27 68.824	$2,106,118,821

Source: "Minerals Yearbook-Metals, Minerals, and Fuels", U. S. Bureau of Mines.

1/ Excludes gold and silver recovered from vat or heap leaching of copper ores and from copper tailings or copper cleanup in 1969 and thereafter. 2/ Excludes precipitate copper from dump and in-place leaching. 3/ At average domestic free-market gold price in 1968 and thereafter (note 5/ in Table VI). 4/ At E/MJ average N.Y. market price for .999 fine silver. 5/ At E/MJ average price, domestic, f.o.b. refinery. 6/ Based on first 8 months of 1967. 7/ Based on last 9 months of 1968.

TABLE XIV

UNITED STATES PRODUCTION AND CONSUMPTION OF COPPER

(Short Tons)

Year	PRODUCTION			CONSUMPTION	Total Production As % of Consumption
	Mine 1/	Secondary 2/	Total	Total 3/	
1950	909,343	260,704	1,170,047	1,424,434	82.2
1951	928,330	186,462	1,114,792	1,416,865	78.7
1952	925,359	173,904	1,099,263	1,479,732	74.3
1953	926,448	242,855	1,169,303	1,494,215	78.3
1954	835,472	212,241	1,047,713	1,254,729	83.5
1955	998,570	246,928	1,245,498	1,502,004	82.9
1956	1,104,156	273,060	1,377,216	1,521,389	90.5
1957	1,086,141	248,015	1,334,156	1,347,815	99.0
1958	979,329	255,121	1,234,450	1,250,677	98.7
1959	824,846	261,588	1,086,434	1,463,031	74.3
1960	1,080,169	300,259	1,380,428	1,349,896	102.3
1961	1,165,155	290,805	1,455,960	1,462,830	99.5
1962	1,228,421	301,374	1,529,795	1,599,676	95.6
1963	1,213,166	314,643	1,527,809	1,744,273	87.6
1964	1,246,780	366,197	1,612,977	1,825,281	88.4

TABLE XIV (Continued)

UNITED STATES PRODUCTION AND CONSUMPTION OF COPPER

(Short Tons)

	PRODUCTION			CONSUMPTION	Total Production As % of Consumption
Year	Mine 1/	Secondary 2/	Total	Total 3/	
1965	1,351,734	462,811	1,814,545	2,004,623	90.5
1966	1,429,152	509,084	1,938,236	2,359,954	82.1
1967	954,064	423,054	1,377,118	1,935,592	71.1
1968	1,204,621	433,041	1,637,662	1,880,300	87.1
1969	1,544,579	514,593	2,059,172	2,142,218	96.1
1970	1,719,657	521,137	2,240,794	2,043,303	109.7
1971	1,522,183	429,095	1,951,278	2,019,507	96.6
1972	1,664,840	447,409	2,112,249	2,238,867	94.3
1973	1,717,940	484,623	2,202,563	2,437,048	90.3
1974	1,597,002	513,308	2,110,310	2,194,168	96.2
1975	1,413,366	355,512	1,768,878	1,534,508	115.3
1976	1,605,586	390,729	1,996,315	1,991,885	100.2

Source: "Minerals Yearbook-Metals, Minerals, and Fuels", U. S. Bureau of Mines.

1/ Recoverable copper.
2/ Copper recovered as unalloyed copper only.
3/ Refined copper in cathodes, wire bars, etc.; reported by consumers.

TABLE XV

IMPORTS OF PRIMARY COPPER INTO THE UNITED STATES BY COUNTRY OF ORIGIN

Source of Import	Copper Content (Short tons)				
	1972	1973	1974	1975	1976
Ore, Concentrate, Matte:					
Australia	2,091	1,531	2,379	2,134	465
Botswana	-	-	625	5,489	14,224
Canada	12,118	11,583	20,062	39,033	47,289
Chile	71	1,654	7	37	-
Honduras	-	-	4,595	2,094	-
Mexico	8	1,113	2,069	2,461	4
Nicaragua	95	200	2,771	410	533
Papua New Guinea	-	-	-	-	1,949
Peru	9,486	8,697	7,284	6,077	4,323
Philippines	30,122	19,042	14,244	12,601	15,047
Poland	-	-	-	117	-
Rhodesia	-	-	-	-	1,025
South Africa, Republic of	-	-	1,754	3,153	3,949
United Kingdom	761	23	166	1	-
Other Countries	261	238	89	364	162
Total Ore, etc.	55,013	44,081	56,045	73,971	88,970

TABLE XV (Continued)

IMPORTS OF PRIMARY COPPER INTO THE UNITED STATES BY COUNTRY OF ORIGIN

Source of Import	Copper Content (Short tons)				
	1972	1973	1974	1975	1976
Blister Copper:					
Canada	5,871	1,181	3	4	158
Chile	33,208	29,617	65,093	26,283	30,817
Kenya	1,804	-	3,081	-	-
Mexico	9,544	8,799	7,644	8,822	3,144
Peru	81,559	86,896	94,686	30,951	6,726
South Africa, Republic of	23,053	26,279	37,211	2,470	-
South West Africa	-	-	-	20,414	2,521
Yugoslavia	2,205	937	-	-	-
Zambia	-	-	-	-	1,108
Other Countries	188	395	112	7	10
Total Blister	157,432	154,104	207,830	88,951	44,484
Refined, Cathodes and Shapes:					
Australia	388	498	83	1,273	1,329
Belgium-Luxemburg	-	9,982	8,024	7,405	3,664
Brazil	370	-	-	-	-
Canada	124,983	130,553	118,429	70,747	94,025
Chile	26,598	27,492	66,549	28,626	69,873
France	8	805	664	-	-
Germany, West	1	8,627	7,177	-	-
Italy	-	-	-	-	3,307
Japan	1,125	22	73,055	8,259	-

TABLE XV (Continued)

IMPORTS OF PRIMARY COPPER INTO THE UNITED STATES BY COUNTRY OF ORIGIN

Source of Import	Copper Content (Short tons)				
	1972	1973	1974	1975	1976
Refined, Cathodes and Shapes:(Cont'd)					
Mexico	7,620	2,132	873	912	424
Netherlands	-	2,110	3,253	-	-
Norway	208	306	294	242	-
Peru	2,204	4,384	6,913	6,864	29,034
Poland	-	689	2,192	-	-
South Africa, Republic of	556	81	110	-	992
Tanzania	-	901	-	-	-
U.S.S.R.	-	-	1,102	-	-
United Kingdom	3,938	7,726	6,643	771	3,316
Yugoslavia	24,379	716	14,844	21,494	44,984
Zaire	-	-	-	-	2,582
Zambia	-	5,455	2,825	-	127,162
Other Countries	1	476	539	212	832
Total Refined	192,379	202,955	313,569	146,805	381,524
Total: Primary Copper Imports	404,824	401,140	577,444	309,727	514,978
Less: Primary Copper Exports (ore, conct., matte blister & refined)	208,924	220,266 r/	141,674 r/	182,278	129,463
Net Primary Imports	195,900	180,874 r/	435,770 r/	127,449	385,515

Source: "Minerals Yearbook-Metals, Minerals, and Fuels", U. S. Bureau of Mines
r/ Revised

TABLE XVI

SALIENT COPPER STATISTICS

In short tons

	1974	1975	1976
Mine Production			
Arizona	858,783	813,211	1,024,421
United States	1,597,002	1,413,366	1,605,586
World	8,047,959 r/	7,671,661	8,212,779
Primary Refined Stocks at U.S. Refineries a/			
Beginning of Year	37,000	101,000	207,000
End of Year	101,000	207,000	190,000
Primary Refined Prod. of U.S. Refineries			
From Domestic Ores	1,420,905	1,286,189	1,422,723
From Foreign Ores, Matte, etc. a/	233,753	157,189	116,585
Total	1,654,658	1,443,378	1,539,308
Secondary Copper Produced from Scrap			
Recovered as Unalloyed Copper	513,308	355,512	390,729
Recovered in Alloys b/	831,012	616,453	754,545
Total Secondary Copper	1,344,320	971,965	1,145,274
Imports:			
Copper In Ores, Concentrates, Matte	56,045	73,971	88,970
Copper in Blister	207,830	88,951	44,484
Refined Copper a/	313,569	146,805	381,524
Total Imports	577,444	309,727	514,978

TABLE XVI

SALIENT COPPER STATISTICS (Continued)

	1974	In short tons 1975	1976
Exports:			
Copper in Ores, Concs., Matte, Blister	15,148 r/	9,852	17,576
Refined Copper a/	126,526	172,426	111,887
Total Exports	141,674 r/	182,278	129,463
EXCESS OF IMPORTS OVER EXPORTS	435,770 r/	127,449	385,515
Consumption:			
Apparent, New Refined (Primary)	1,778,000	1,312,000	1,823,000
Actual, Total Refined	2,194,168	1,534,508	1,991,885
U.S. MINE PRODUCTION VS. U. S. CONSUMPTION			
Production as a Percent of Apparent Consumption	89.8	107.7	88.1
Average Price of Copper c/	76.65¢	63.54¢	68.82¢

Source: "Minerals Yearbook-Metals, Minerals, and Fuels", U. S. Bureau of Mines

r/ Revised
a/ May include some from scrap.
b/ Includes copper in chemicals: 1974-2,649; 1975-2,480; 1976-4,007
c/ At E/MJ average price, domestic, f.o.b. refinery.

TABLE XVII

MINE PRODUCTION OF COPPER IN
ARIZONA, THE UNITED STATES, AND THE WORLD
WITH DOMESTIC PRICE OF COPPER

1874 - 1976

	ARIZONA			UNITED STATES			WORLD
Period	Short Tons	% of U. S. Prod.	% of World Prod.	Short Tons	% of World Prod.	Price ¢ Per Pound a/	Short Tons
1874							
1911	1,758,000	22.0	9.3	7,989,735 b/	49.1	14.40 c/	16,260,000
1912	182,519	29.2	16.2	624,547	55.5	16.341	1,125,656
1913	203,962	33.0	18.6	617,755	56.2	15.269	1,099,366
1914 1/	196,509	34.2	19.0	574,216	55.5	13.602	1,034,487
1915 1/	229,986	30.9	19.6	744,036	63.4	17.275	1,173,150
1916 1/	360,917	36.0	23.2	1,002,938	64.6	27.202	1,553,498
1917 1/	356,083	37.6	22.2	947,717	59.1	27.180	1,602,914
1918 1/	382,428	40.0	24.2	955,011	60.5	24.628	1,579,246
1919	269,050	44.4	24.6	606,167	55.3	18.691	1,095,697
1920	279,128	45.6	26.4	612,275	58.0	17.456	1,056,014
1921 2/	92,517	39.7	15.1	233,095	38.0	12.502	613,987
1922	200,022	41.5	21.4	482,292	48.2	13.382	935,374
1923	309,464	41.9	22.8	738,870	54.5	14.421	1,355,327
1924	338,876	42.2	23.0	803,083	54.5	13.024	1,472,712
1925	356,678	42.5	22.6	839,059	53.2	14.042	1,576,998

TABLE XVII (Continued)

Period	ARIZONA Short Tons	ARIZONA % of U. S. Prod.	ARIZONA % of World Prod.	UNITED STATES Short Tons	UNITED STATES % of World Prod.	UNITED STATES Price ¢ Per Pound a/	WORLD Short Tons
1926	361,648	41.9	22.7	862,638	54.0	13.795	1,596,147
1927	341,095	41.3	20.5	824,980	49.5	12.920	1,666,694
1928	366,138	40.5	19.2	904,898	47.5	14.570	1,903,672
1929	415,314	41.6	19.3	997,555	46.4	18.107	2,150,587
1930 3/	288,095	40.9	16.2	705,074	39.7	12.982	1,775,805
1931 3/	200,672	37.9	13.0	528,875	34.2	8.116	1,545,425
1932 3/	91,246	38.3	8.0	238,111	20.9	5.555	1,138,676
1933 3/	57,021	29.9	4.9	190,643	16.4	7.025	1,159,000
1934 3/	89,041	37.5	6.3	237,401	16.8	8.428	1,415,353
1935 3/	139,015	36.0	8.4	386,491	23.5	8.649	1,647,939
1936 3/	211,275	34.4	11.1	614,516	32.4	9.474	1,899,263
1937	288,475	34.3	11.2	841,998	32.8	13.167	2,567,916
1938 4/	210,797	37.8	9.3	557,763	24.5	10.000	2,274,145
1939 5/	262,117	36.0	10.6	728,320	29.4	10.965	2,481,277
1940 5/	281,169	32.0	10.5	878,086	32.7	11.296	2,688,510
1941 5/	326,317	34.1	11.2	958,149	33.0	11.797	2,903,458
1942 5/	393,387	36.4	12.9	1,080,061	35.5	11.775	3,039,041
1943 5/	403,181	37.0	13.2	1,090,818	35.6	11.775	3,064,394
1944 5/	358,303	36.8	12.5	972,549	33.9	11.775	2,866,000
1945	287,203	37.2	12.0	772,894	32.2	11.775	2,400,000

TABLE XVII (Continued)

Period	ARIZONA Short Tons	ARIZONA % of U. S. Prod.	ARIZONA % of World Prod.	UNITED STATES Short Tons	UNITED STATES % of World Prod.	UNITED STATES Price ¢ Per Pound a/	WORLD Short Tons
1946	289,223	47.5	14.1	608,737	29.6	13.820	2,056,000
1947	366,218	43.2	14.6	847,563	33.9	20.958	2,500,000
1948 6/	375,121	44.9	14.4	834,313	32.1	22.038	2,600,000
1949 6/	359,010	47.7	14.4	752,750	30.1	19.202	2,500,000
1950 7/	403,301	44.4	14.4	909,343	32.5	21.235	2,760,000
1951 7/	415,870	44.8	14.3	928,330	32.0	24.200	2,900,000
1952 7/	395,719	42.8	13.1	925,359	30.6	24.200	3,020,000
1953 7/	393,525	42.5	12.9	926,448	30.4	28.798	3,050,000
1954 8/	377,927	45.2	12.2	835,472	27.0	29.694	3,100,000
1955	454,105	45.5	13.3	998,570	29.2	37.491	3,420,000
1956	505,908	45.7	13.4	1,104,156	29.1	41.818	3,790,000
1957 9/	515,854	47.5	13.3	1,086,859	27.9	29.576	3,890,000
1958 9/	485,839	49.6	12.9	979,329	25.9	25.764	3,780,000
1959 10/	430,297	52.2	10.7	824,846	20.4	31.182	4,040,000
1960	538,605	49.9	11.6	1,080,169	23.2	32.053	4,650,000
1961	587,053	50.4	12.1	1,165,155	24.0	29.921	4,850,000
1962	644,242	52.4	12.7	1,228,421	24.2	30.600	5,085,000
1963	660,977	54.5	13.0	1,213,166	23.8	30.600	5,088,000
1964	690,988	55.4	13.0	1,246,780	23.5	31.960	5,297,000
1965	703,377	52.0	12.7	1,351,734	24.4	35.017	5,549,000

TABLE XVII (Continued)

Period	ARIZONA Short Tons	ARIZONA % of U.S. Prod.	ARIZONA % of World Prod.	UNITED STATES Short Tons	UNITED STATES % of World Prod.	UNITED STATES Price - ¢ Per Pound a/	WORLD Short Tons
1966	739,569	51.7	12.8	1,429,152	24.6	36.170	5,800,000
1967 11/	501,741	52.6	9.0	954,064	17.2	28.226*	5,552,000
1968 11/	627,961	52.1	10.4	1,204,621	20.0	41.847**	6,012,000
1969 12/	801,363	51.9	12.9	1,544,579	24.8	47.534	6,225,000
1970 13/	917,918	53.4	13.8	1,719,657	25.9	57.700	6,638,042
1971 14/	820,171	53.9	12.3	1,522,183	22.9	51.433	6,688,634
1972	908,612	55.2	12.4	1,644,840	22.5	50.617	7,321,950 r/
1973	927,271	54.0	11.8	1,717,940	21.9	58.865	7,844,901 r/
1974 15/	858,783	53.8	10.7 r/	1,597,002	19.8 r/	76.649	8,063,457 r/
1975 15/	813,211	57.5	10.6	1,413,366	18.4	63.535	7,678,948
1976	1,024,421	63.8	12.5	1,605,586	19.5	68.824	8,212,779
Total 1874 - 1976	29,421,469	43.0	13.0	68,343,917	30.3		225,740,245

Source: Mineral Resources of the U. S., U. S. Geological Survey (Years 1882-1923)
U. S. Bur. Mines (Years 1923-1931); Minerals Yearbooks and other reports.
U. S. Bur. Mines (Years 1932-1976); Ariz. Bur. Mines Bull. 140 (1936).

a/ At E/MJ average price, domestic, f.o.b. refinery.
b/ Smelter production from domestic ores prior to and including 1911.
c/ Average price for Arizona copper only prior to and including 1911; calculated from total of values reported or estimated by sources, amounting to $506,283,000.

TABLE XVII (Continued)

r/ Revised.
Based on first 8 months of 1967. **Based on the last 9 months of 1968.

1/ World War I 1914-1918.

2/ Post World War I Recession (1921). Lasted about one year.

3/ Depression began in 1930; was at its worst in 1933; gradually improved to 1937.

4/ Recession in 1938. Recovery in 1939 caused by War demand.

5/ World War II began in 1939; highest copper consumption in 1944.

6/ In 1948 and early 1949, copper was being produced in the U. S. at the rate of 68,000 short tons per month, imports ran 40,000 tons per month of blister and refined copper, exports ran 12,000 tons per month and the price of copper averaged 22.5 cents.

In March, 1949, Congress suspended the copper import tax, and in the ensuing months domestic demand fell drastically while imports continued at practically the same rate. The price dropped to 16 ½ cents. Many mines were forced to close. Production dropped to 56,000 tons per month from a high of 78,000.

7/ Korean War 1950-53.

8/ Curtailment early in the year (1954), and a series of strikes in August and September caused a loss in production of over 100,000 tons. Consumption in the U. S. was reduced but the reduction was offset by an appreciable rise in consumption in other countries, chiefly in Europe. Result: a short supply of copper at the end of the year.

9/ Recession 1957-58. Import tax restored 7/1/58 after 7-year suspension.

10/ First U. S. troops killed in Vietnam in mid-1959. Record copper production rate first half of 1959 but 75% of U. S. output halted in August by strikes which lasted into 1960.

11/ A major Copper Strike started in the U. S. on July 16, 1967, and ended in March, 1968. A loss of 855,000 tons of copper production is estimated as a result of the strike.

12/ 1969, Highest annual production in U. S. history.

13/ 1970, Highest annual production in U. S. history and supply catches up with demand.

14/ A copper strike started in the U. S. on July 1, 1971, and ended in August, 1971. A loss of 250,000 tons of copper production is estimated as a result of the strike.

15/ Copper strikes lasting maximum of 42 days in 1974; strong inflation coupled with worldwide business recession gave copper industry its worst period since the 1930's.

TABLE XVIII

WORLD MINE PRODUCTION OF COPPER BY COUNTRY 1/
(Short Tons)

Country	1974	1975	1976 p/
North and Central America:			
Canada 2/	r/905,417	808,094	823,570
Cuba e/	r/3,200	r/3,300	3,300
Dominican Republic	e/500	-	-
Guatemala	1,994	2,822	3,185
Mexico	91,128	86,196	98,073
Nicaragua 3/	1,957	711	696
United States 2/	1,597,002	1,413,366	1,605,586
South America:			
Argentina	347	202	e/220
Bolivia 4/	r/8,962	7,045	5,277
Brazil	3,390	2,119	e/2,200
Chile	994,394	913,043	1,108,042
Colombia e/	80	80	80
Ecuador	197	263	e/300
Peru	233,241	2/197,340	2/221,331
Europe:			
Albania e/ 5/	8,540	8,540	8,800
Austria	2,962	2,186	1,254
Bulgaria	55,160	60,583	59,525
Czechoslovakia e/	r/5,200	r/5,500	5,500
Finland	39,850	42,770	42,118
France	432	551	e/550
Germany, East	-	e/1,700	e/1,700
Germany, West 2/ 6/	1,911	2,162	1,778
Greece	883	1,533	1,080
Hungary e/	1,300	1,300	1,300
Ireland 3/	r/13,942	10,803	4,519
Italy 6/	915	1,011	1,010
Norway 6/	26,587	30,991	34,728
Poland e/	218,300	r/260,000	300,000
Portugal 6/	6,226	5,577	4,955
Romania 5/	e/r/ 37,500	e/r/41,000	44,644
Spain 6/7/	37,807	43,344	e/44,000
Sweden	44,795	44,791	51,987
U.S.S.R/ e/2/5/	816,000	843,000	880,000
United Kingdom	478	504	e/550
Yugoslavia	123,587	126,649	132,409
Africa:			
Algeria e/	410	440	440
Botswana	2,623	7,154	13,759
Congo (Brazzaville) 3/	1,025	1,010	450

TABLE XVIII (Continued)
WORLD MINE PRODUCTION OF COPPER BY COUNTRY 1/
(Short Tons)

Country	1974	1975	1976 p/
Africa (Continued):			
Ethiopia e/	440	440	440
Kenya e/	80	80	80
Mauritania	22,133	17,861	10,396
Morocco 3/	5,952	5,291	e/4,400
Mozambique 3/	689	755	e/770
Rhodesia, Southern 8/	43,315	43,531	34,969
South Africa, Republic of	197,436	197,233	217,023
South-West Africa, Territory of 3/9/	35,801	e/43,000	e/48,500
Uganda	13,496	9,370	9,921
Zaire	550,524	547,111	490,098
Zambia	769,364	746,177	781,391
Asia:			
Burma 10/	77	94	101
China, People's Republic of e/	110,000	110,000	110,000
Cyprus 6/	12,346	10,913	11,023
India	30,953	42,990	54,895
Indonesia	71,210	69,997	75,398
Iran 11/	1,980	1,980	1,631
Israel	12,100	8,270	-
Japan 3/12/	90,538	93,674	89,618
Korea, North e/	14,000	14,000	14,000
Korea, Republic of	3,080	2,944	2,486
Malaysia	e/55	4,189	20,062
Philippines	r/249,077	249,366	255,185
Taiwan e/	2,760	2,100	2,200
Turkey	42,765	40,319	e/35,800
Oceania:			
Australia	277,055	241,363	239,683
Papua New Guinea 3/	r/202,491	190,123	193,793
Total	r/8,047,959	7,671,661	8,212,779

Source: "Minerals Yearbook-Metals, Minerals, and Fuels", U. S. Bureau of Mines.

TABLE XVIII (Continued)

WORLD MINE PRODUCTION OF COPPER BY COUNTRY 1/
(Short Tons)

e/ Estimate p/ Preliminary r/ Revised

1/ Data presented represents copper content (recoverable where indicated) of ore mined wherever possible. If such data was not available, the nonduplicative total copper content of ores, concentrates, matte, metal and/or other copper-bearing products measured at the least stage of processing for which data was available has been used.
2/ Recoverable.
3/ Copper content of concentrate produced.
4/ Corporation Minera de Bolivia (COMIBOL) production plus exports by medium and small mines.
5/ Smelter production.
6/ Includes copper content of cupriferous pyrites.
7/ Excludes an unreported quantity of copper in iron pyrites which may or may not be recovered.
8/ Year ending September 30 of that stated.
9/ Data was compiled from operating company reports of Tsumeb Corp. Ltd., General Mining and Finance Corp. Ltd. for Klein Aub Koper Maatskappy Ltd.'s mine near Rehoboth, and Falconbridge Nickel Mines Ltd. for Oamites Mining Company (Pty.) Ltd., Oamites mines. Data for General Mining and Finance Corp. Ltd. are for fiscal years ending June 30 of that stated, while data from other countries are for calendar years.
10/ Copper content of matte produced.
11/ Year beginning March 21 of that stated.
12/ Copper content of run-of-mine production is as follows in short tons: 1974--90,985; 1975--93,952; 1976--90,181.

TABLE XIX

"COVERED EMPLOYMENT" AND WAGES IN ARIZONA COPPER MINING AND SMELTING

Year	Average No. Covered Employees 1/	Total Wages	Average Annual Wage	Average Weekly Wage	Tons Copper Ore 2/
1947	11,340	$ 36,365,277	$ 3,207	$ 61.67	37,810,448
1948	11,493	41,318,524	3,595	69.13	39,072,204
1949	11,001	40,612,224	3,692	71.00	37,365,611
1950	10,181	41,994,321	4,125	79.33	41,757,273
1951	10,754	47,825,698	4,447	85.52	42,784,388
1952	11,365	54,950,235	4,835	93.14	44,472,522
1953	12,068	62,742,982	5,199	99.98	45,187,838
1954	12,502	65,518,853	5,241	100.79	43,072,894
1955	12,399	71,293,263	5,750	110.58	52,189,728
1956	14,008	83,568,996	5,966	114.73	60,468,580
1957	14,652	85,125,320	5,809	111.71	59,571,834
1958	14,100	74,726,972	5,300	101.93	56,255,809
1959	11,568	72,095,130	6,232	119.85	53,121,545
1960	13,764	90,312,848	6,562	126.19	66,032,439
1961	14,275	97,271,286	6,814	131.04	71,918,991
1962	14,408	101,920,108	7,074	136.04	78,868,147
1963	14,303	104,291,588	7,292	140.23	80,615,132
1964	14,720	113,792,031	7,730	148.65	86,132,039

TABLE XIX (Continued)

"COVERED EMPLOYMENT" AND WAGES IN ARIZONA COPPER MINING AND SMELTING

Year	Average No. Covered Employees 1/	Total Wages	Average Annual Wage	Average Weekly Wage	Tons Copper Ore 2/
1965	15,239	$ 122,163,124	$ 8,016	$154.16	92,859,535
1966 1/	17,018	137,187,611	8,061	155.02	101,558,298
1967	13,426	108,427,206	8,076	155.31	74,289,203
1968	15,734	136,089,579	8,649	166.33	101,293,963
1969	19,459	173,183,018	8,900	171.15	127,848,828
1970	21,479	201,665,064	9,389	180.56	150,241,000
1971	21,231	211,978,597	9,984	192.00	149,294,000
1972	23,233	254,717,341	10,964	210.85	165,914,825 2/
1973	25,494	291,294,328	11,426	218.89	181,311,945
1974	27,894	340,832,096	12,219	234.98	178,913,296
1975	25,950	363,349,178	14,002	269.27	168,750,152
1976	25,631	405,289,034	15,812	304.08	194,136,559

Source: This report, Table XX; "Minerals Yearbook-Area Reports: Domestic", U. S. Bureau of Mines.

1/ "Covered Employment" by law includes all employees of employers of three or more persons. Since the "Average No. of Covered Employees" in this table generally includes practically all workers in copper mining and processing (see Table XX), the number of employees is greater than that number tabulated under "All Employees" in Table XXI. Prior to 1966 only a portion of the workers in smelting, refining, and rod fabrication were included in this table; the rest of the end-processing workers were separated and classified under "Manufacturing" in Table XX.

2/ Mine production in short tons from "Lode ore: Copper" reported by the U. S. Bureau of Mines. In 1972 and thereafter the tonnage may include copper-zinc and lead-zinc ore combined to avoid disclosing individual company confidential data.

TABLE XX

ARIZONA INDUSTRIES COVERED BY SOCIAL SECURITY

AVERAGE NUMBER OF COVERED EMPLOYEES, TOTAL WAGES, AVERAGE ANNUAL WAGE

AND AVERAGE WEEKLY WAGE

Industry	Average No. of Employees 1/	Total Wages	Average Annual Wage	Average Weekly Wage
		YEAR 1974		
Copper Mining 2/	25,022	$ 304,910,987	$12,186	$234.34
Copper Smelting, Refining & Rod Fabrication 3/	2,872	35,921,109	12,507	240.53
Total Copper Mng. & Processing	27,894	$ 340,832,096	$12,219	$234.98
Other Mng., Quarry'g & Processing	2,186	28,417,674	13,000	250.00
All Mng., Quarry'g & Processing	30,080	$ 369,249,770	$12,276	$236.07
Mfg., Ex. Copper Processing	109,376	1,140,261,044	10,425	200.48
Construction	57,242	731,039,190	12,771	245.60
Transp., Utilities, etc. 4/	35,843	407,689,297	11,374	218.74
Wholesale-Retail Trade	175,192	1,198,454,445	6,841	131.55
Services, Finance and Misc.	168,053	1,289,728,390	7,675	147.59
Agriculture & Related Services	3,528	25,546,524	7,241	139.25
State & Local Government	41,932	342,323,902	8,164	157.00
TOTALS AND AVERAGES	621,246	$5,504,292,562	$ 8,860	$170.39

TABLE XX

ARIZONA INDUSTRIES COVERED BY SOCIAL SECURITY (Continued)

Industry	Average No. of Employees 1/	Total Wages	Average Annual Wage	Average Weekly Wage
		YEAR 1975		
Copper Mining	22,884	$ 322,316,026	$14,085	$270.87
Copper Smelting, Refining & Rod Fab.	3,066	41,033,152	13,383	257.37
Total Copper Mng. & Processing	25,950	$ 363,349,178	$14,002	$269.27
Other Mng., Quarry'g & Processing	2,161	30,756,582	14,233	273.71
All Mng., Quarry'g & Processing	28,111	$ 394,105,760	$14,020	$269.62
Mfg., Ex. Copper Processing	95,995	1,108,798,254	11,551	222.13
Construction	43,792	585,315,551	13,366	257.04
Transp., Utilities, etc. 4/	35,040	437,807,314	12,495	240.29
Wholesale - Retail Trade	174,177	1,251,845,153	7,187	138.21
Services, Finance and Misc.	170,270	1,401,445,541	8,231	158.29
Agriculture & Related Services	3,553	26,631,463	7,495	144.13
State and Local Government	42,903	364,876,641	8,505	163.56
TOTALS AND AVERAGES	593,841	$5,570,825,677	$9,381	$180.40

TABLE XX (Continued)

Industry	Average No. of Employees 1/	Total Wages	Average Annual Wage	Average Weekly Wage
		YEAR 1976		
Copper Mining	22,381	$ 352,299,634	$15,741	$302.71
Copper Smelting, Refining and Rod Fabrication	3,250	52,989,400	16,304	313.54
Total Copper Mng. & Processing	25,631	$ 405,289,034	$15,812	$304.08
Other Mng., Quarry'g & Processing	2,291	37,537,967	16,385	315.10
All Mng., Quarry'g & Processing	27,922	$ 442,827,001	$15,859	$304.98
Mfg., Ex. Copper Processing	100,860	1,226,228,098	12,158	233.81
Construction	41,744	562,180,983	13,467	258.98
Transp. Utilities, etc..4/	36,035	499,131,900	13,851	266.37
Wholesale - Retail Trade	184,014	1,409,551,301	7,660	147.31
Services, Finance and Misc.	180,814	1,555,911,623	8,605	165.48
Agriculture & Related Services	3,715	29,616,436	7,972	153.31
State & Local Government	46,362	409,075,808	8,824	169.69
TOTALS AND AVERAGES	621,466	$6,134,523,150	$ 9,871	$189.83

Source: Research & Statistics Unit, Unemployment Insurance Bureau, Arizona Dept. of Economic Security.

1/ Includes all covered employees. Figures relating to copper mining and smelting, and manufacturing, are adjusted as described in the following footnotes.

2/ In 1974, the employee figure includes all covered workers in copper mining and milling and probably those in one smelter. In 1975 and thereafter, this figure excludes copper smelting & refining and copper rod fabrication.

3/ In 1974, the employee figure includes all covered workers in smelting (and other end processing) except probably one smelter (see note 2/).

4/ Transportation exclusive of railroads.

TABLE XXI

EMPLOYMENT, EARNINGS AND HOURS IN COPPER MINING

IN THE UNITED STATES AND ARIZONA 1/

	All employees		Production Workers											
	Ave. No. (Thousands)		Ave. No. (Thousands)		Ave. Weekly Earnings		Ave. Weekly Hours		Ave. Hourly Earnings		Ave. Earnings per Man per Year		Aggregate Man-hours (Thousands)	
	2/	3/	4/	3/	5/				6/		7/		8/	
Period	Ariz.	U. S.	Ariz.	U.S.	Ariz.	U.S.	Ariz.	U. S.	Ariz.	U. S.	Ariz.	U.S.	Ariz.	U. S.
1966	15.2	31.9	12.4	26.2	$150.06	$140.07	45.2	43.5	$3.32	$3.22	$ 7,803	$7,284	29,145	59,264
1967	12.2	25.4	9.0	19.1	141.43	140.18	42.6	43.0	3.32	3.26	7,354	7,284	19,937	42,708
7 Mos.	15.7	33.2	12.4	27.3	149.41	142.76	44.6	43.5	3.35	3.28				
5 Mos.	7.3	14.4	3.8	7.5	130.05	127.95	39.9	40.4	3.27	3.16				
1968	13.8	28.1	11.1	21.3	149.21	161.68	43.0	47.0	3.47	3.44	7,759	8,407	24,820	52,057
3 Mos.	7.5	14.9	4.3	8.3	118.17	129.06	36.7	40.2	3.22	3.21				
9 Mos.	15.8	32.5	13.0	25.6	160.11	165.28	45.1	47.8	3.55	3.46				
1969	17.0	33.7	13.9	26.9	166.50	169.00	44.4	46.3	3.75	3.65	8,658	8,788	32,092	64,764
1970	18.8	37.0	14.9	29.5	173.01	175.67	43.8	44.7	3.95	3.93	8,997	9,135	33,936	68,570
1971	18.9	34.7	14.9	26.8	178.50	178.46	42.4	42.9	4.21	4.16	9,282	9,280	32,852	59,785
1972	20.5	38.9	16.1	30.7	194.69	192.19	41.6	41.6	4.68	4.62	10,124	9,994	34,827	66,410
1973	21.5	42.3	17.6	33.7	206.75	206.42	41.6	42.3	4.97	4.88	10,751	10,734	38,072	74,127
1974	24.0	42.8	19.1	33.8	222.16	226.46	39.6	41.1	5.61	5.51	11,552	11,776	39,331	72,237
1975	22.5	37.1	17.9	28.4	247.43	247.14	38.6	39.2	6.41	6.33	12,866	12,903	35,929	57,891
1976	21.7	35.5	17.2	27.0	286.31	280.70	40.1	40.1	7.14	7.00	14,888	14,596	35,865	56,300

TABLE XXI (Continued)

EMPLOYMENT, EARNINGS AND HOURS IN COPPER MINING

IN THE UNITED STATES AND ARIZONA 1/

	Copper Ore Shipped or Treated (Thousand Short Tons) 9/		Copper in Copper Ore (Recoverable Content) (Thousand Pounds 10/		Worker Productivity: Copper Ore Mined per Man-hour (Tons)		Worker Productivity: Recoverable Copper Mined per Man-hour (Pounds)	
Period	Ariz.	U. S.	Ariz.	U. S.	Ariz.	U. S.	Ariz.	U. S.
1966	101,558	186,966	1,474,447	2,805,136	3.485	3.155	50.590	47.333
1967	74,289	127,066	1,000,572	1,866,087	3.726	2.975	50.187	43.694
1968	101,294	170,054	1,252,919	2,349,046	4.081	3.267	50.480	45.124
1969	127,849	223,752	1,593,544	3,021,590	3.984	3.455	59.656	46.655
1970	150,241	257,729	1,826,734	3,368,957	4.427	3.759	53.829	49.132
1971	149,294	242,656	1,633,568	2,986,599	4.544	4.059	49.725	49.996
1972	165,815	266,831	1,816,618	3,264,113	4.761	4.017	52.161	49.151
1973	173,605	289,998	1,847,635	3,386,357	4.872	3.912	48.530	45.683
1974	178,821	293,443	1,710,744	3,145,148	4,547	4.062	43.496	43.539
1975	168,656	263,003	1,619,535	2,772,111	4.694	4.543	45.076	47.885
1976	194,046	283,736	2,043,168	3,166,889	5.410	5.040	56.968	56.250

Source: Research & Analysis Section, Labor Market Information Group, Bureau of Employment and Training, Arizona Dept. of Economic Security; "Employment and Earnings", U. S. Dept. of Labor; "Minerals Yearbook - Metals, Minerals, and Fuels", U. S. Bureau of Mines.

TABLE XXI (Continued)

EMPLOYMENT, EARNINGS AND HOURS IN COPPER MINING

IN THE UNITED STATES AND ARIZONA 1/

1/ Statistics do not reflect workers in copper smelting, refining and rod fabrication (see Table XX for comparison).

2/ These figures are estimates made by the Az. Dept. of Economic Security, in cooperation with the U. S. Bureau of Labor Statistics, and they include all full and part-time wage and salary workers who were employed in copper mining in any part of the pay periods which included the 12th of each month of the year.

3/ Estimates made by the U. S. Bur. of Labor Statistics, in cooperation with the 50 states, and based upon monthly samplings similar to those in 2/ above, adjusted periodically to census benchmarks.

4/ Estimates of production (non-supervisory) workers based upon samplings as in 2/ above. Since 1975 figures have been calculated by the Az. Dept. of Mineral Resources dividing the annual number of "All Employees-Arizona" by a factor of 1.26. This factor was derived by comparing the annual number of "All Employees-Arizona" with "Production Workers-Arizona" from 1970 to 1974.

5/ Earnings figure for a particular year is the product of "Ave. Hourly Earnings" and "Av. Weekly Hours" for that year.

6/ Gross payroll aggregates, exclusive of irregular bonuses and other pay not earned in a sample pay period, are divided by gross man-hour aggregates of production and related workers for the period in order to determine average hourly earnings.

7/ "Ave. Weekly Earnings" times 52 weeks.

8/ Number of production workers times "Ave. Weekly Hours" times 52 weeks.

9/ Copper ore mined and shipped or treated by concentration, smelting or leaching.

10/ Recoverable copper from copper ore (see 9/) and from copper precipitates produced from dump and in-place leaching. Prior to 1968 copper from precipitates was not included in this table or similar Dept. tables. The recoverable-copper figure did, however, include an equivalent copper value of byproduct gold and silver; since 1968 no copper equivalents of any metal have been included.

TABLE XXII
PROVEN COPPER RESERVES IN ARIZONA 1/

COMPANY	DEPOSIT	MAJOR MINERAL TYPE	MILLIONS OF TONS	AVERAGE CU CONTENT (%)	REMARKS
ANAMAX MINING CO.	Twin Buttes	Sulfide	329	0.67	With 0.03% Mo; cutoff @ 0.2% Cu
	"	"	300	0.80	Pub. 1973; "outside current mine plans"; cutoff @ 0.4% Cu
	"	Oxide	57	1.10	Cutoff @ 0.6 Cu
	"	"	28	0.49	Pub. 1973; cutoff @ 0.4% Cu
	Helvetia	Sulfide	320	0.64	Pub. 1973; cutoff @ 0.3% Cu
	"	Oxide	20	0.55	Pub. 1973; acid soluble Cu; cutoff @ 0.3% acid soluble Cu
	Peach Elgin	Mixed	23	0.75	Pub. 1973; cutoff @ 0.4% Cu
ASARCO INC.	Mission	Sulfide	104.455	0.73	Excludes contribution of 31.5M tons to Eisenhower Mining Co.
	Sacaton (OP)	"	21.140	0.70	
	Sacaton East (UG)	"	14.898	1.25	
	San Xavier	"	166.902	0.52	
	"	Oxide	1.050	1.48	
	Silver Bell	Sulfide	26.059	0.66	
	"	Oxide			
AZTEC MINING CORP.	Aztec	Oxide	2	1.00	Unpublished est.
BS & K MINING CO.	Atlas	Mixed			
CASA GRANDE COPPER CO.	Casa Grande	Mixed	350	1.00	

TABLE XXII (Continued)
PROVEN COPPER RESERVES IN ARIZONA 1/

COMPANY	DEPOSIT	MAJOR MINERAL TYPE	MILLIONS OF TONS	AVERAGE CU CONTENT (%)	REMARKS
CITIES SERVICE CO.	Cactus	Oxide	20	0.70	Unpublished est.
	Copper Cities	"		0.50	Pub. 1976
	Miami	"			
	Miami East	Mixed (?)	55	1.95	Pub. 1973
	Old Dominion	Sulfide			
	Pinto Valley	"	350	0.44	Pub. 1972 "recoverable Cu"
	Red Hill	Mixed			
CRANE CO.	Dragoon	Mixed			
CONTINENTAL OIL CO.	Poston Butte	Mixed	500	0.50	Pub. 1972
CYPRUS MINES CORP.	Bagdad	Sulfide	290	0.49	
	"	Oxide	21	0.35	Acid soluble Cu
	"	"	95	0.22	Stockpile; acid soluble Cu after prior leaching
	Bruce	Sulfide	0.1276	3.73	Pub.1976;with 12.8%
	I-10	Mixed	100	0.52	Unpublished est.;with 0.02% Mo
	Johnson	Oxide	9.9	0.50	Acid soluble Cu
	Johnson	Mixed	10	0.60	Pub. 1974
CYPRUS PIMA MINING CO.	Pima	Sulfide	146	0.48	
EL PASO CO.	Emerald Isle	Oxide	1.5	0.40	Pub. 1977; 3Mt @0.1% Cu
EISENHOWER MINING CO.	Palo Verde (Anamax)	Sulfide	125	0.61	
	Palo Verde (ASARCO)	Sulfide	31.5	0.70	
FREEPORT MINERALS CO.	Santa Cruz	Sulfide			

TABLE XXII (Continued)
PROVEN COPPER RESERVES IN ARIZONA 1/

COMPANY	DEPOSIT	MAJOR MINERAL TYPE	MILLIONS OF TONS	AVERAGE CU CONTENT (%)	REMARKS
HECLA MINING CO.	Lakeshore	Sulfide (dissm)	241	0.70	Pub. 1969
	"	" (tactite)	23.6	1.69	"
	"	Oxide	207	0.71	"
INSPIRATION CONSOLIDATED COPPER CO.	Christmas	Sulfide	33.413	0.905	Pub. 1977; "recoverable Cu"
	"	Oxide			
	Inspiration Area Mines	Mixed	180.136	0.481	" "
	Ox Hide	Oxide	31.328	0.147	" "
	Sanchez	"	79.362	0.180	" "
KENNECOTT COPPER CORP.	Chilito	Sulfide			
	Ray	Mixed	650	0.80	Reported 1977
	Safford	"	2,000	0.41	"
	Safford Ext.	"			
KERR-MCGEE CORP.	Red Mountain	Sulfide		0.71	Pub. 1970; 100Mt. possible
KEYSTONE MINERALS INC.	Korn Kob	Oxide	8	0.50	Pub. 1973
MCALESTER FUEL CO.	Zonia	Oxide	1	0.53	Unpublished est.
MULTIPLE OWNERS	Bisbee-North	Mixed (?)	20	0.80	"
NEWMONT MINING CORP.	Copper Creek	Sulfide			
	Kalamazoo	"			
	Magma	"	9.8	4.80	Reported 1978
	San Manuel	"	474	0.67	
	"	Mixed	130	0.70	Pub. 1969
	Vekol Hills	Sulfide	105	0.56	Pub. 1978; minable by open pit; with 0.014% Mo; 26% oxide Cu

TABLE XXII (Continued)
PROVEN COPPER RESERVES IN ARIZONA 1/

COMPANY	DEPOSIT	MAJOR MINERAL TYPE	MILLIONS OF TONS	AVERAGE CU CONTENT (%)	REMARKS
NAVAHO TRIBE (?)	White Mesa	Oxide	2	0.75	Pub. 1955
OCCIDENTAL PETROLEUM CO.	Van Dyke	Oxide	100	0.50	Pub. 1977
ORACLE RIDGE MINING PARTNERS	Oracle Ridge	Mixed (?)	11	2.25	Reported 1977; with 0.5oz Ag/ton(pub.1975)
PENNZOIL CO. (Duval Corp.)	Esperanza	Sulfide	21.850	0.42	With 0.022% Mo
	"	Oxide			
	Mineral Park	Sulfide	49.541	0.30	With 0.036% Mo
	"	Oxide			
	Sierrita	Sulfide	459.842	0.32	With 0.033% Mo
PHELPS DODGE CORP.	Copper Basin	Sulfide	175	0.55	Pub. 1973: minable by open pit; with 0.02% Mo
	Copper Queen	Mixed			
	Dos Pobres	Sulfide	400	0.72	Pub. 1977
	Lavender	"			
	Metcalf	"	415.970	0.77	Pub.1975
	Morenci	"	662.462	0.80	"
	New Cornelia	"	126.623	0.63	"
	United Verde	"			
	"	Oxide			
PRODUCERS MINERALS CORP.	San Juan	Oxide	20	0.50	Unpublished est.
RANCHERS EXPLORATION & DEVELOPMENT CO.	Bluebird	Oxide	75	0.52	Pub. 1971
	Old Reliable	"	4	0.74	"

TABLE XXII (Continued)

PROVEN COPPER RESERVES IN ARIZONA 1/

COMPANY	DEPOSIT	MAJOR MINERAL TYPE	MILLIONS OF TONS	AVERAGE CU CONTENT (%)	REMARKS
V. B. SMITH ESTATE	Dynamite	Sulfide			
STANDARD METALS CORP.	Antler	Sulfide	5.1		With Zn values
STRONG & HARRIS	Strong & Harris	Mixed	60	0.60	Unpublished est.; with 0.70% Zn
SUPERIOR OIL	Pine Flats	Sulfide	12	0.50	Unpublished est.
UNDETERMINED	Mineral Hill	Mixed			
UNION OIL	Turquoise	Oxide	10	0.50	Pub. 1970
UNITED STATES GOVERNMENT	Park Hill	Mixed (?)	30	0.45	Unpublished est.
UNITED STATES GOVERNMENT AND U. S. METALS CORP.	Apex	Mixed (?)			

Source: Company Annual Reports, Form 10-K's, and Prospectus; Professional Publications.

1/ Reserves are given with a grade of average total copper content as of December 31, 1977, unless stated otherwise under "Remarks". As used in this table, reserves generally mean those estimated quantities of ore which under presently and reasonably foreseen technical and economic conditions may be profitably mined and sold or processed for the extraction of their constituent values.

* COPPER RESERVES OF ARIZONA

ANAMAX MINING CO.
1. Twin Buttes
2. Helvetia
3. Peach Elgin

ASARCO INC.
4. Mission
5. Sacaton
6. Sacaton East
7. San Xavier
8. Silver Bell

AZTEC MINING CO.
9. Aztec (Mame)

BS & K MINING CO.
10. Atlas

CASA GRANDE COPPER CO.
11. Casa Grande

CITIES SERVICE CO.
12. Cactus
13. Copper Cities
14. Miami
15. Miami East
16. Old Dominion
17. Pinto Valley
18. Red Hill

CRANE CO.
19. Dragoon

CONTINENTAL OIL CO.
20. Poston Butte

CYPRUS MINES CORP.
21. Bagdad
22. Bruce
23. I-10
24. Johnson

CYPRUS PIMA MINING CO.
25. Pima

EL PASO CO.
26. Emerald Isle

EISENHOWER MINING CO.
27. Palo Verde

FREEPORT MINERALS CO.
28. Santa Cruz

HECLA MINING CO.
29. Lakeshore

INSPIRATION CONSOLIDATED COPPER CO.
30. Christmas
31. Inspiration Area Mines
32. Ox Hide
33. Sanchez

KENNECOTT COPPER CORP.
34. Chilito
35. Ray
36. Safford
37. Safford Extension

KERR-MCGEE CORP.
38. Red Mountain

KEYSTONE MINERALS INC.
39. Korn Kob

McALISTER FUEL CO.
40. Zonia

MULTIPLE OWNERS
41. Bisbee North

NEWMONT MINING CORP.
42. Copper Creek
43. Kalamazoo
44. Magma (Superior)
45. San Manuel
46. Vekol Hills

NAVAJO TRIBE (?)
47. White Mesa

OCCIDENTAL PETROLEUM CO.
48. Van Dyke

ORACLE RIDGE MINING PARTNERS
49. Oracle Ridge

PENNZOIL CO. (DUVAL CORP.)
50. Esperanza
51. Mineral Park
52. Sierrita

PHELPS DODGE CORP.
53. Copper Basin
54. Copper Queen
55. Dos Pobres
56. Lavender
57. Metcalf
58. Morenci

PHELPS DODGE cont.
59. New Cornelia
60. United Verde

PRODUCERS MINERALS CORP.
61. San Juan

RANCHERS EXPLORATION & DEVELOPMENT CO.
62. Bluebird
63. Old Reliable

V. B. SMITH ESTATE
64. Dynamite

STANDARD METALS CORP.
65. Antler

STRONG & HARRIS
66. Strong & Harris

SUPERIOR OIL
67. Pine Flats

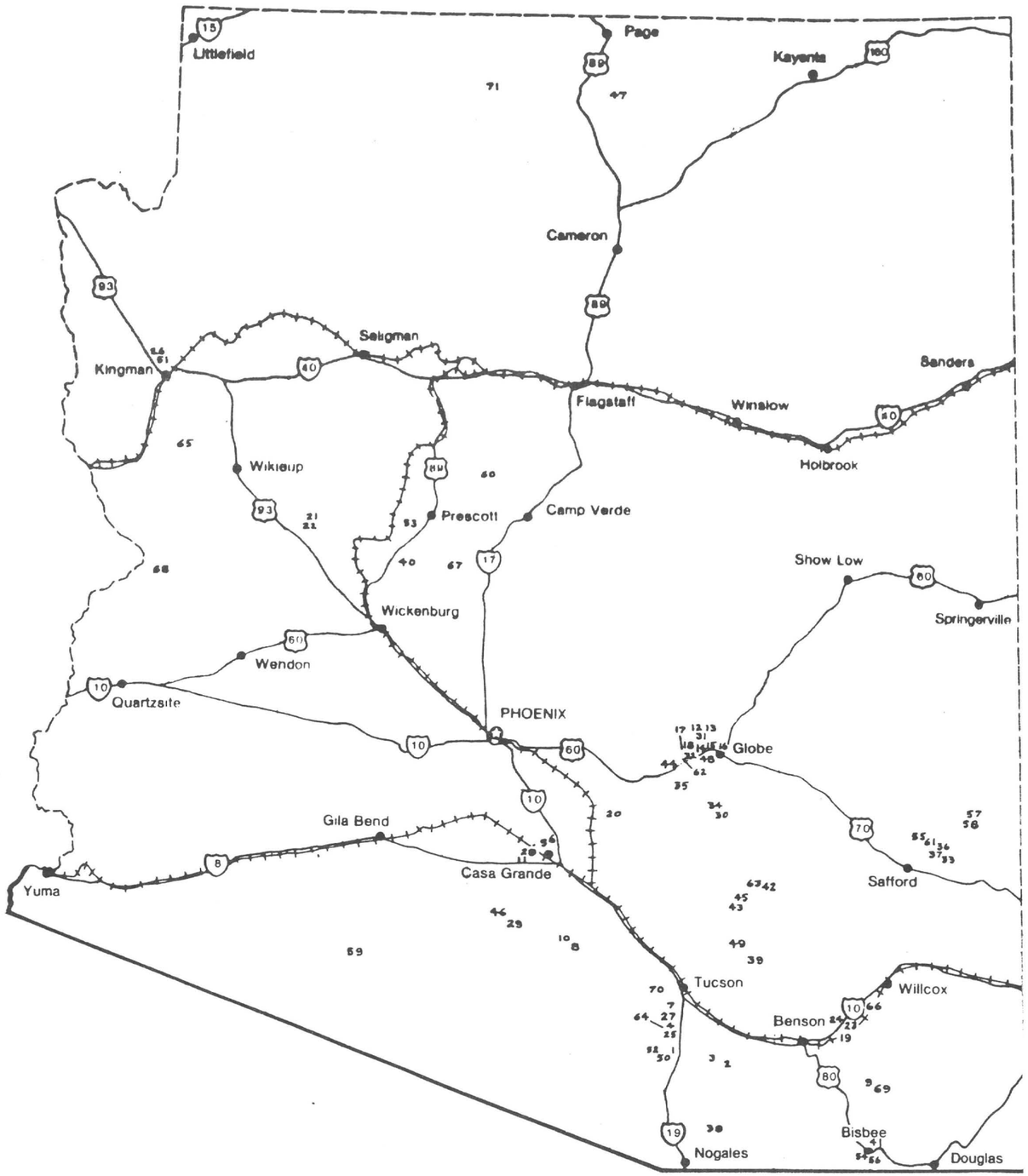
UNDETERMINED
68. Mineral Hill

UNION OIL
69. Turquoise

UNITED STATES GOVERNMENT
70. Park Hill

UNITED STATES GOVERNMENT & U. S. METALS CORP.
71. Apex

*Ownership data is based on best source available to the Department and is subject to revision or change.



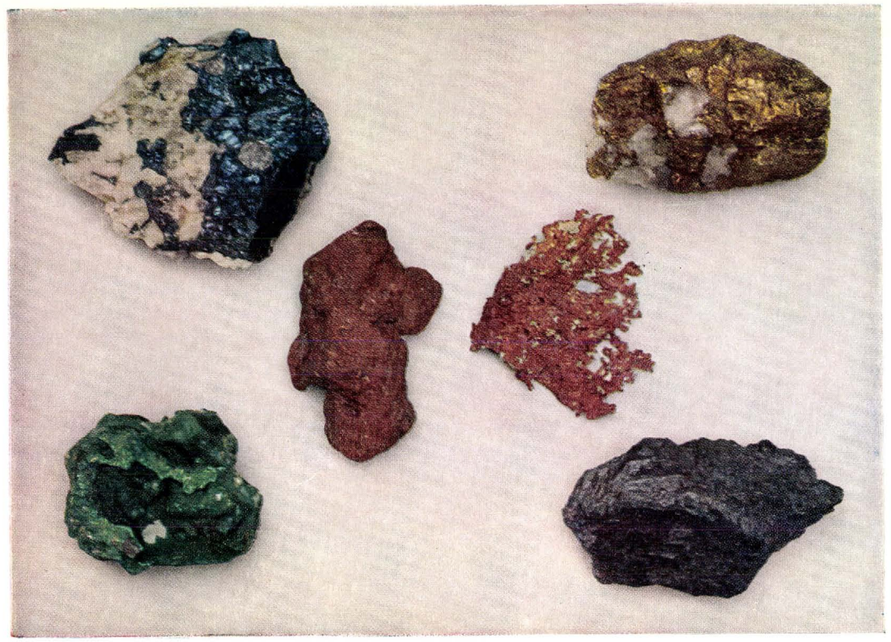
ARIZONA DEPARTMENT OF MINERAL RESOURCES

The Department was created to aid in the promotion, development, and conservation of the mineral resources of the State. Particular emphasis is placed on providing prospectors and small miners with semi-technical assistance and economic information.

The general goal of the Department is developed by working with the following objectives:

- Provide technical assistance to prospectors and operators of small mines.
- Disseminate comprehensive mining and mineral information to the citizens and government officials of Arizona counties.
- Study conditions regarding small mine activity and seek solutions to problems.
- Serve as the State's public bureau of mining and mineral information.
- Maintain and expand the Department's mine file library.
- Provide educational services in the field of mineral resources and mining.
- Analyse proposed Federal and State administrative actions.
- Develop interagency cooperation between the Department and other local State and Federal offices.
- Gather all information available on mineral occurrences, prospects, partially developed properties and known mines in the State in order to promote further exploration.
- Provide publications in the form of mineral reports, annual directories, technical reports, annual mineral industry surveys, information circulars, and media articles.

Courtesy of Copper Development Association (England)



Bornite
Malachite

Native Copper

Chalcopyrite
Chalcocite

COPPER

Old as Time . . . modern as tomorrow

The ores pictured above represent the beginning of the copper story. A continuing story that has been unfolding for centuries. And the end is nowhere in sight. Copper has served man faithfully throughout his existence, yet today it is on the threshold of even greater service. New horizons loom for the "ancient red metal."

When man tapped the energy that lights the sun and the stars, he set the world of science to bubbling and boiling with unprecedented ideas and daring research. And copper, as always, is prepared to play its traditional role in this new era. It was the key to many great discoveries in the past; it will be the key to many new ones in the future.

The students of today, will be the scientists of tomorrow who will venture still further, penetrating into new areas of knowledge beyond comprehension at this time. In the course of such explorations, most certainly new applications will be found for copper; new demands will be made upon it. And so the versatile red metal will continue to provide for and safeguard man's welfare.

Issued by

COPPER & BRASS RESEARCH ASSOCIATION

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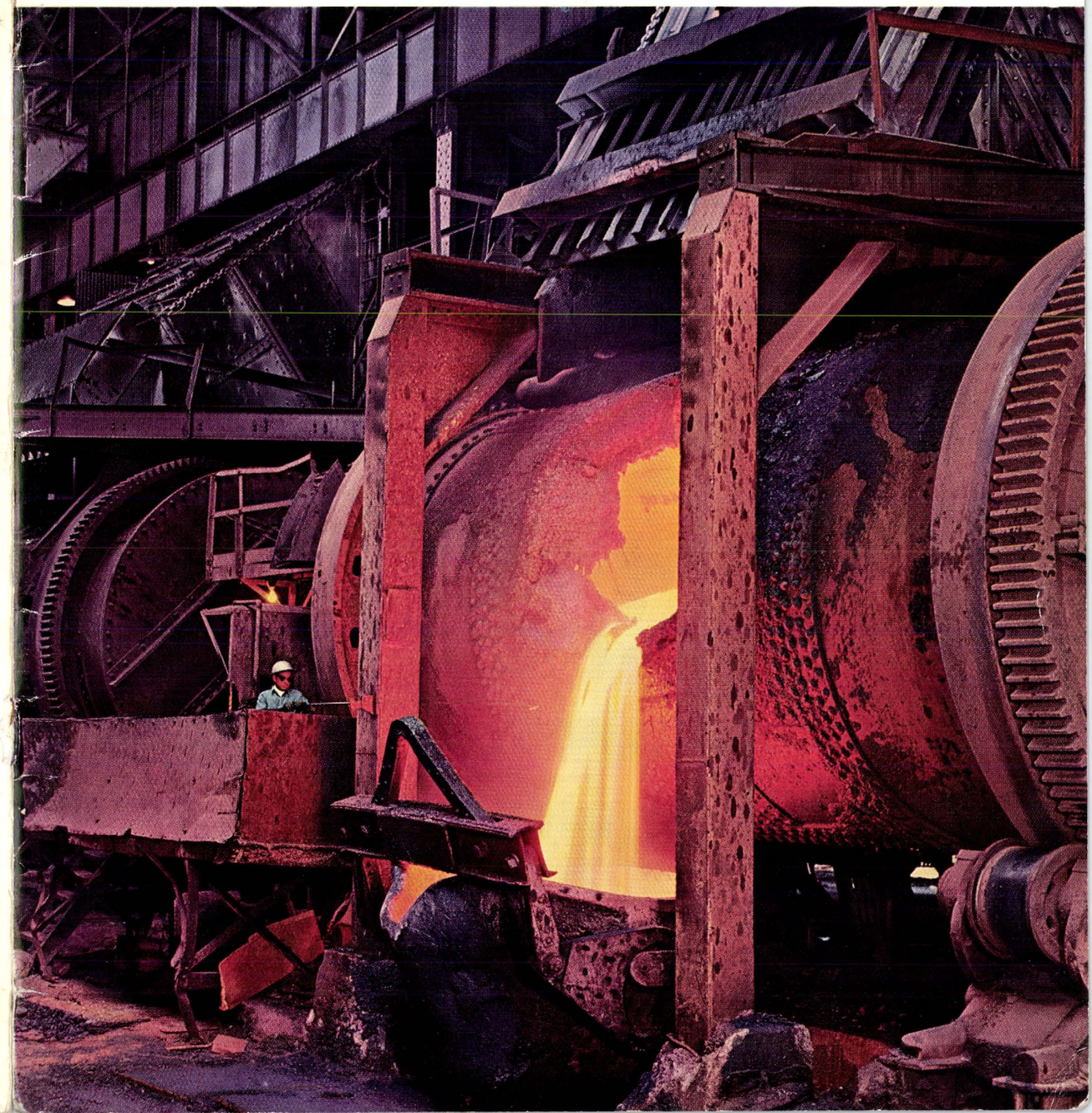
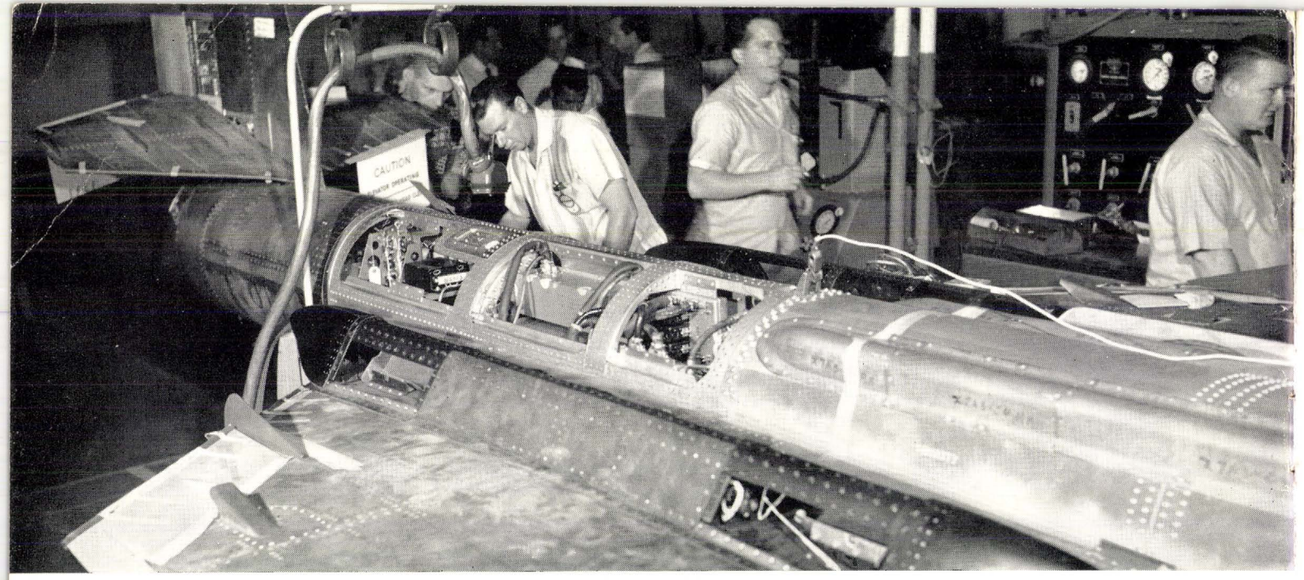
Copper

The Cornerstone of Civilization

DOUGLAS K. MARTIN
315 W. MONTEROSA
PHOENIX, ARIZONA 85013





A bright future has been created for copper by the new miracle age of electronics.

Copper — *The Cornerstone of Civilization*

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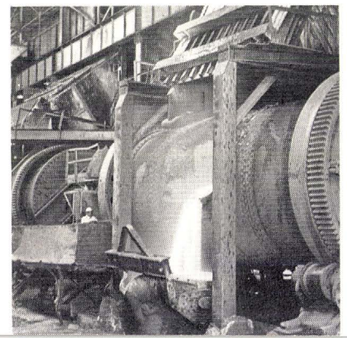

Cover depicts pouring of blister copper from a giant converter of Phelps Dodge Corporation.

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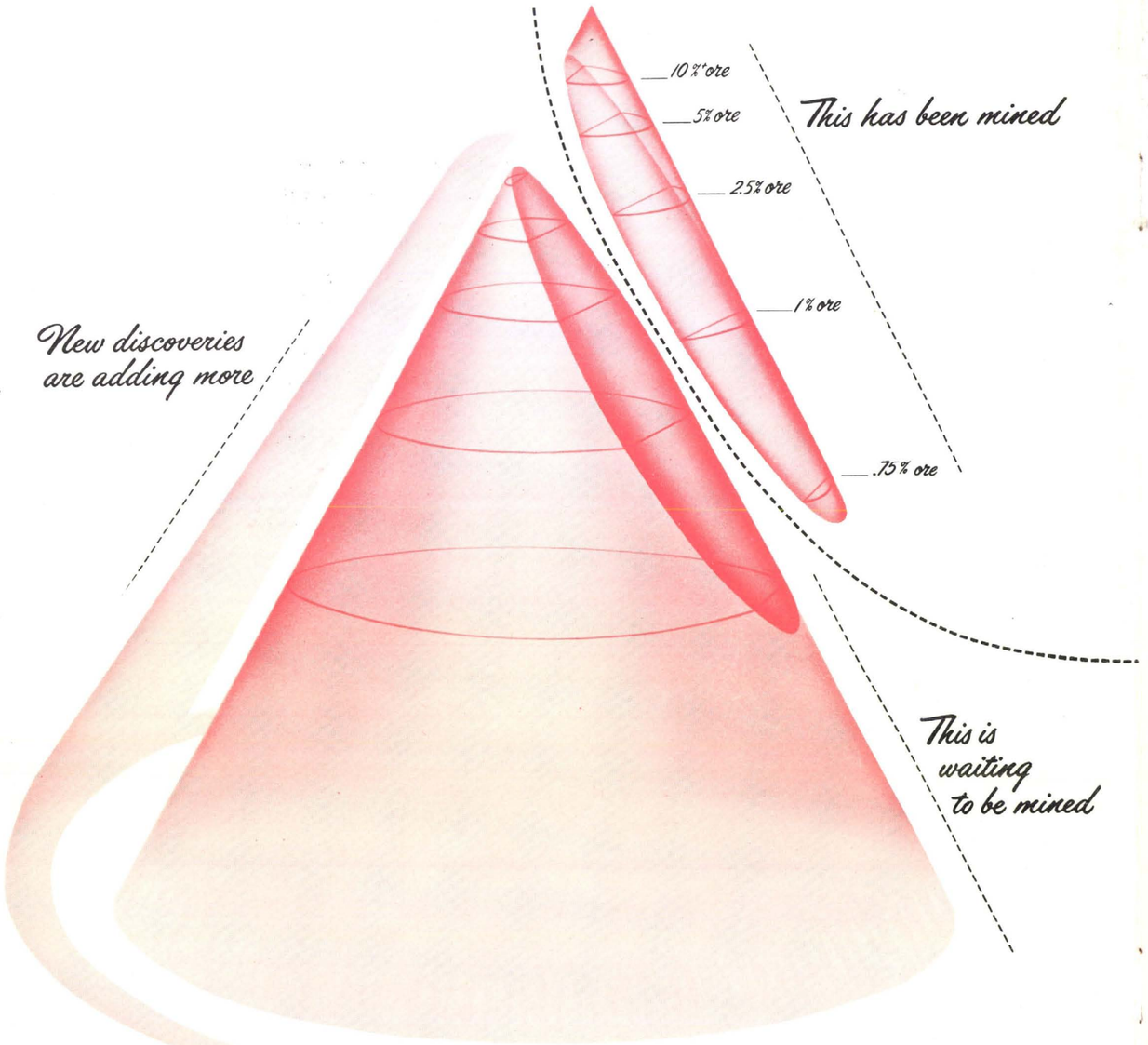
° ° °

The copper and brass mill industry in the United States maintains the Copper & Brass Research Association (420 Lexington Avenue, New York 17, N. Y.) a central source organization that coordinates standards, publicizes the merits of copper and its alloys, and publishes general information and a variety of specialists' reports concerning this vital metal. Information on modern applications of copper and its alloys is published regularly in *Copper & Brass Bulletin.* Staffed by qualified technicians, possessing an extensive library on the subject, CABRA is prepared to answer questions, technical or otherwise, relating to copper, and its numerous alloys.

There's Plenty of Copper for Today and Tomorrow



"If you're worrying about the amount of available copper that's in the ground, you're wasting your time!"

—Alvin W. Knoerr.
Address, Copper & Brass Research Assn. 1958

"A recent meeting of the International Geological Congress calculated that indicated copper reserves of the world might be of the order of 190 million tons of recoverable copper . . ."

—Sir Ronald Prain.
Lecture, University of London, 1957

COPPER . . . an old friend with a bright future

Augusta, Ga., Feb. 1—"Dr. J. Wallace Joyce, head of the International Geophysical Year office of the National Science Foundation, has just informed me that the United States has successfully placed a scientific earth satellite in orbit around the earth."—PRESIDENT EISENHOWER.

This brief announcement summed up the years of intensive research and production effort that was necessary before this scientific achievement could occur. Immense, complicated problems had to be solved. Countless mathematical formulas had to be processed, fuels tested, intricate instruments designed and special metals devised to form the numerous components of the Jupiter-C multi-stage rocket that exploded this first U. S. satellite into space in 1958.

It is significant that to fulfill specific wiring needs and special metal needs for some of the rocket mechanisms and satellite instruments, the designers relied on man's oldest metal—"the ancient red metal"—copper and its alloys. This is as it should be, for man's past, as well as his present, always has been linked to copper. It is eminently fitting that this valued old friend should share his future and help him probe tomorrow.

The link has been a tenacious one. For thousands of years, in war and peace, copper has been indispensable to man's development, consistently serving him in numerous applications, first for utensils, tools, weapons and ornaments; then in construction, transportation and communications. It has protected his home, contributed to his health, and provided for his welfare.

From the axehead of prehistoric man, to the water pipe of Egypt, the surgical instrument of Rome, the engraving plate of fifteenth century Germany, and so on, upward through the successive ages of man's progress to the present day of the atom, this versatile, timeless metal has steadfastly proved more than adequate to

meet changing needs and serve in new applications. Truly it has been the cornerstone of civilization.

Copper is a friendly mixer. It enlarges its field of usefulness by readily joining with other metals. Though the art of producing bronze, the first copper alloy, was known to antiquity, alloying knowledge was immeasurably increased through the efforts of the ancient alchemists in their ceaseless quest to convert plentiful copper and other metals into rare gold. They experimented with hundreds of combinations of copper, other metals, salt, sulfur and additional ingredients (often of an odd nature, such as crab's eyes), melting and blending the strange concoctions, sometimes to the accompaniment of weird

incantations. They failed to produce gold, but they fostered the science of copper metallurgy and discovered and pioneered many interesting and successful copper alloys in the process.

Today, descendants and offspring of these early alloys, together with copper itself, are working in minor or major capacities for man every second of every day. Just gaze around. Observe the electric lamp you may be reading by. The telephone nearby. The television set, the clock on the wall, the thermostat of your heating system; perhaps the knob on the door, the lock on the window. All contain copper or one or more of its alloys; all are testimony to the aptitude, the capability of copper in application; and all proclaim man's ever present need for this enduring workhorse of the metals world.

The miracle of electronics depends on copper as on no other metal. For no other non precious metal carries the electrical impulses that activate the complex parts of radio and television sets, and radar and sonar equipment, as well as copper. The concept of automation depends, in large measure, on copper's unique ability to transmit undisturbed signals to recording instruments, control devices and feedback circuits.

No other material can match the remarkable combination of rust and corrosion resistance, durability and ease of installation of copper pipe and tube. Copper's superb heat conductivity assures efficient operation of modern radiant heating and cooling systems. Copper roofs and roofing products outlast all other kinds as attested by many centuries-old installations. No other commercial metal lends itself so readily to such a variety of manufacturing operations—drawing, forming, shaping or stamping.

Modern copper alloys are busier than ever. It would be impossible to list here the many merits and qualifications of the hundreds of copper-base alloys participating in present scientific and industrial activities. In one form or another they can be found in tiny relays of rockets and guided missiles, in fine springs of recording devices, in particle accelerators (cyclotrons, bevatrons, and Van de Graaf generators), necessary for basic atomic research. They can be found in huge bearing and expansion plates for bridges, in the curtain wall of a towering skyscraper, or in the steam condensers of a great ocean liner.

Old as time itself, the red metal is as modern as tomorrow. It is a fitting tribute that it was the material chosen for the construction of the Statue of Liberty, symbol of freedom and progress throughout the world.

Cold-rolled sheet copper roof covers uniquely designed terminal building of Lambert—St. Louis Airport.

World ore reserves. It has been determined, at the current rate of consumption of approximately 4 million tons a year, the free world has available a conservatively estimated 50-year reserve of copper. The long-term studies revealing a pattern of ever-increasing demand for copper, however, gives rise to the speculation that future reserves may be insufficient to meet this ascending curve of demand.

There is no actual basis for this gloomy outlook. The present ore reserve growth appears adequate to maintain mine production in the United States and abroad at a high level indefinitely. In support of this view, new discoveries, aided by modern geophysical techniques, are adding millions of tons to the reserve. In 1957, for example, two large new deposits were discovered in this country, in Michigan and Arizona. Amazing new finds have been made in Peru and Chile, and additional extensive deposits in South America, Africa and Canada must await the development of more adequate transportation facilities for fullest exploitation.

In addition, ore reserves increase as technological advances permit the mining of lower grades of ore. In the United States the copper mining industry is literally moving mountains of ore as low in average grade as 0.85 percent copper and profitably extracting the copper from it. Continual progress in methods will make possible the mining of still lower grades of ore of which there is a vast amount.

Because the grade of ore mined is also dependent on the market price of copper, a rise in the price will automatically make available supplies of ore previously uneconomical to mine. Steady increases in the recovery of secondary copper also progressively extends total copper supply.

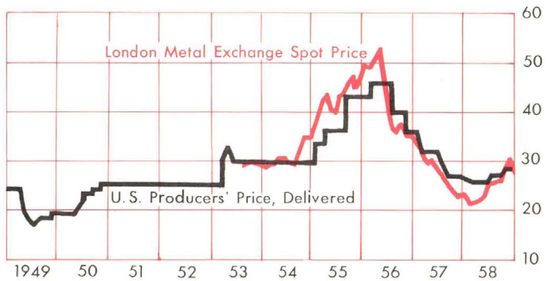
In summary, the copper reserve picture is stable; the free world does not face a serious shortage in the forseeable future. The United States with large reserves, strong production of primary and secondary copper, and available imports, is assured of a plentiful supply of copper for years to come.

Prices and stability. Copper is a world commodity, and its price is controlled by supply and demand. Generally speaking, producers are usually confronted with either an excess or a dearth of demand for the metal, and prices react accordingly, rarely holding firm for extended periods. So sensitive is the price reaction to supply and demand controls that even a small unbalance between the two can result in world fluctuation. In 1955-56, when demand exceeded supply by an estimated 6 percent, prices spiralled from 30 cents to 55 cents per pound. In the succeeding two years, when overproduction, due to a heavy increase in new mine output, combined with a lag in consumption by the automobile and construction industries caused supply to rise about 4 percent over demand, the price per pound gradually slipped from 55 to 20 cents in the world market and from 46 to 23 cents in the domestic market.

Prospecting. Today's copper prospector has traveled a long way from the old-timer who ambled around until he stumbled on mineral outcroppings and made a rich "strike." That era has passed. The contemporary prospector is aware that the ore he seeks has become elusive, and that rarely are two exploration programs identical. Each will have its own peculiarities such as the general physical nature of the surrounding area, type of rock, depth of cover, and so on, requiring special considerations.

He is scientifically trained to explore the earth's crust and equipped to cope with problems that arise in the process. At his disposal are tested, specialized geophysical, geological, and geochemical techniques. These are employed in combination with a varied assortment of constantly improving instruments such as the gravimeter, spectrograph, scintilation counter, the magnetometer, and high and low frequency electromagnetic transmitters and receivers. Some success has recently been attained by a method that employs the last three instruments installed in an airplane for aerial prospecting surveys.

COPPER—cents per pound



WORLD PRODUCTION, CONSUMPTION

From a Figure of about 1,000,000 short tons just prior to World War I, the annual World production of newly mined copper climbed (irregularly, because of the fluctuating impacts of wars and depressions) to an estimated 3,864,778 tons in 1957. During this expansion period, despite rising domestic production, the United States percentage of world totals declined from considerably more than one-half to about one-third. The first half of this span also witnessed the transition of the United States from a copper exporting nation to an importing one because of a rapid and heavy growth of copper consumption, the demand outstripping the supply. In 1957, for example, the American Bureau of Metal Statistics revealed that this country led the world copper production with a total of 1,092,744 short tons, but its consumption was 1,227,946 tons, necessitating an importation of more than 594,000 tons (both crude and refined).

LEADERS IN COPPER PRODUCTION BY COUNTRIES OF ORIGIN

(short tons)

	1951	1953	1955	1957
United States	938,133	948,509	1,014,442	1,092,744
Chile	419,626	400,284	477,869	533,855
No. Rhodesia	352,048	410,810	395,307	480,313
U.S.S.R.*	280,000	334,500	372,500	465,000
Canada	269,971	253,252	325,994	360,745
Belgian Congo	211,596	236,020	259,158	267,026
Japan	47,134	65,860	80,466	89,394
Mexico	74,241	66,301	60,269	66,799
Un. So. Africa	36,364	38,656	47,484	47,752
Totals	2,917,700	3,066,998	3,388,331	3,864,778

*A.B.M.S.—(estimated in part)

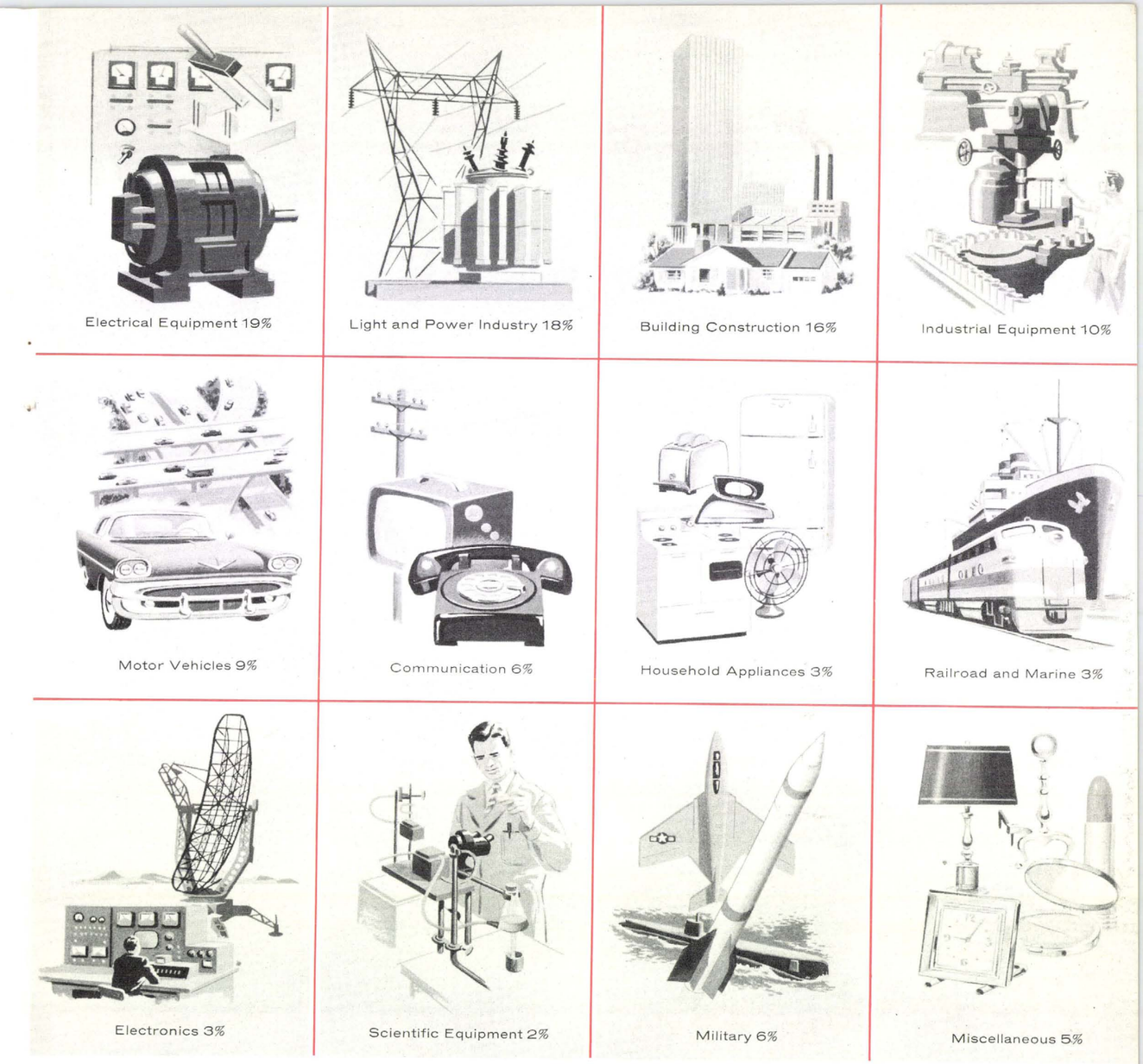
Consumption. Though the United States mines about 30 percent of the world's copper production, it consumes 45 percent and must rely on imports to complete its requirements. It is presently impossible to assemble a breakdown of the remaining 55 percent of copper consumed outside the United States. If it were, a country-by-country comparison would probably reveal a wide divergence from the proportionate uses in the United States (listed on page 3). For instance, the percentage of military usage in Holland or Switzerland would be much lower; similarly, the percentage of industrial usage would be lower in Spain and Norway, and so on.

Refinery shapes consumption. The breakdown of refinery shapes consumption in the United States is as follows: Wire bars, 60 percent of total; Cakes 15 percent; Billets 12 percent; Ingots and Ingot Wire Bars 7 percent; Cathodes 6 percent. Wire mills absorb about 50 percent of refined copper production; brass mills about 45 percent, and the remainder by foundries, secondary smelters and chemical plants.

WORLD COPPER CONSUMPTION (short tons)

	1951	1953	1955	1957
Americas	1,612,916	1,613,551	1,663,636	1,483,326
Europe	1,012,422	990,365	1,581,821	1,687,215
Asia	141,800	133,215	147,300	245,999
Africa	25,131	13,059	22,535	34,400
Australia	35,600	15,000	49,800	41,200
U.S.S.R.* & Satellites	300,000	359,500	408,000	509,000
Totals	3,130,869	3,124,681	3,873,092	4,001,041
*A.B.M.S. (Estimated in part)				
United States	1,367,800	1,443,700	1,446,400	1,277,946

Future consumption. Copper consumption is strongly related to population growth. The present world population is well over 2¾ billion and increasing by more than 35 million each year. It should pass the three billion mark in 1965. The free world will probably account for about 2¼ billion of this number. In view of past performance, it is reasonable to assume that copper demand will keep pace with this expansion and increase accordingly. Employing the 1955 per capita consumption figures of 18 lbs. (all copper) for the United States, and 2.9 lbs. (all copper) for the free world as a base, it is possible to estimate the probable effect of this population rise. Obviously, the free world per capita consumption is much lower than the United States' per capita. Hence there is little question that world per capita use of copper, under the impetus of rising living standards and industrialization of undeveloped countries, will rise sharply, contrasted with more modest gains in the United States where per capita use will continue to make gains as our technology becomes more complex.



Courtesy of Kennecott Copper Corporation

WHERE COPPER IS USED

Varying somewhat according to type, versatile copper can be worked hot or cold, fabricated into plate, sheet, strip, bar, rod and tube, stamped, die pressed, hammered, machined, spun, drawn into wire and sections of regular and irregular shapes, soldered, brazed, welded, plated, lacquered and polished. Through the sum of its unusual physical and mechanical properties, it has established a reputation for proficiency in practically every field of engineering, construction and manufacture. So endless are its specific uses that merely to compile a categorical listing of all of them would fill pages. However, the illustration above reveals the approximate percentages of total copper consumption on an industry-wide basis.

COPPER GENESIS

PREHISTORIC MAN possessed three characteristics that separated his barbarous existence from the complete animal state: the ability to think on a higher plane and store knowledge for future use; vocal chords capable of making speech sounds necessary for transmitting information; and those marvelous instruments, hands.

From the dawn of his time, he relied on these aids to make the long, groping climb toward the plateau of civilization. At the close of a period spanning hundreds of thousands of years, late in the Neolithic Age, he had gradually developed sufficient skills to laboriously create weapons and utensils from stone, bone, clay, shell and wood. His most significant contributions were the discovery of fire and the invention of the bow and arrow.

At this stage, unwittingly standing on the threshold of a new era, he paused. Progress then —as today—was determined by the efficiency of tools; and his crude implements limited further advancement. Then there occurred an epochal event destined to up-end his world, catapult him into a new period of development, and set into motion a chain reaction which is still vibrating in the wonders of our own age. He discovered copper.

First Knowledge. Exactly when, where or how this enduring metal became known to man is conjectural. It is generally believed to have been discovered (in its native form, i.e., in a free metallic state) about 8000 B. C. in the valleys of the Tigris and Euphrates rivers, sites of the earliest civilizations.

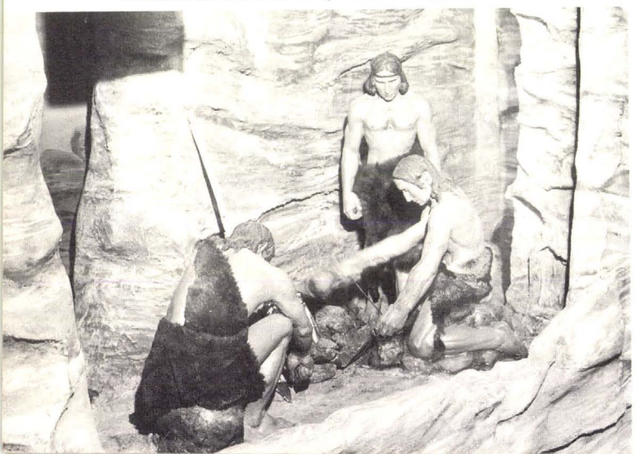
Possibly a hunter seeking a properly shaped rock to fashion into an axehead, picked up a likely one, dark brown or green in color. When he attempted to form it with a stone hammer, it failed to chip, but softly dented instead. The scraped surface of the strange rock exposed its true color – lustrous, fire-like. Further experimentation revealed that this malleable substance could be flattened into thin sheets, or hammered to shape a variety of weapons and domestic articles; and that continued hammering work-hardened it.

Either coincidental with his original discovery of copper, or at a later date, he made another one when by chance he employed several similar rocks to make a fire shelter. The reducing action of the fire's heat magically transformed the rocks into tough red metal, the nuggets taking the form of the shapes of the hollows of the fireplace. And so he learned in one disclosure that the new substance – copper – could be melted and cast into shapes.

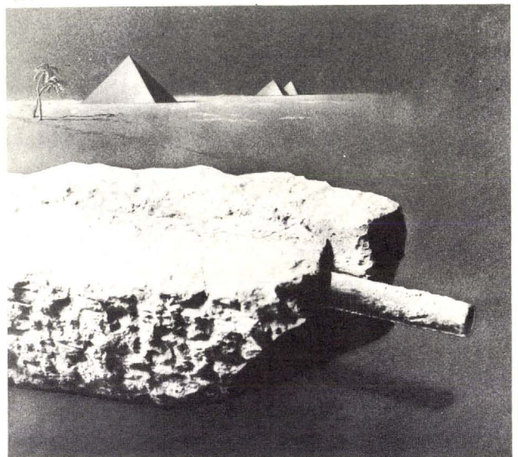
Consequently he discovered the relation of metallic copper to copper-bearing rock and with it the realization that the enduring metal could be obtained in abundance by reducing the ore by heat, the process known today as smelting. This was the birth of metallurgy.

A transitional era, often designated the Cop-

Using crude methods, prehistoric man fashioned a variety of domestic articles and weapons from copper.



Copper pipe that conveyed water to the pyramid of Cheops, Egyptian Pharaoh, 5400 years ago, is still in good condition.



down to ½-inch or smaller rod as previously described. In the succeeding operations a number of machines are employed to draw the rod to the finished wire sizes. Throughout all drawing, annealing and pickling phases the rod is handled in coils, the various machines being equipped with payoff and winding devices.

The primary drawing of hot rolled rod ½-inch and larger in diameter is usually performed on a huge single-draw bull block.[16] The coil is placed on an arbor, the pointed end passed through the die and gripped on the exit side by tongs, then drawn through and fastened on the block. Set in rotation, the block rapidly draws the rod through the die. For further reduction on tandem blocks, several coils are buttwelded to provide sufficient length for continuous drawing through a series of graduated dies. The wire is drawn through the first die and around the second block, and so on, until the stand of blocks is threaded. Set in motion, each successive block rotates at a higher speed than the preceding one to compensate for the elongation.[17] Wire is drawn into special shapes such as half-oval, square and hexagonal, on blocks equipped with special dies. Fine wire is drawn through a series of tungsten carbide and diamond dies on a machine capable of delivering a continuous strand of wire over 150 miles long. Copper alloy wire is similarly formed from extruded rod.

Copper wire (and cable) is generally supplied in one of three tempers: hard drawn, medium hard, or soft annealed. When required for special application, additional tempers are available.

Shapes. Recent developments in extrusion equipment permit the production of a wide variety of special shapes such as machinery components, valve components and structural and hollow sections.[18] Low-copper alloys are commonly used in these fabrications.

Forging. Many copper alloys can be forged. Briefly, the metal is heated and placed between a set of steel dies and subjected to hot pressing operations.[19] The metal flows under compression and fills the contour of the die. Any excess overflowing the die is later trimmed and that present in cavities is pierced out. Refrigeration, automotive, aircraft, and other engineering parts are produced in this manner.

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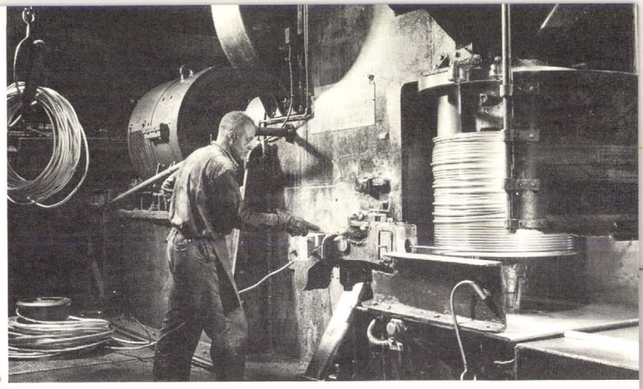

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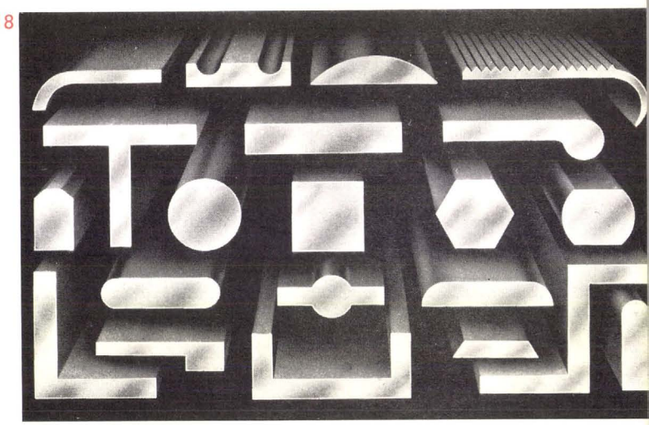

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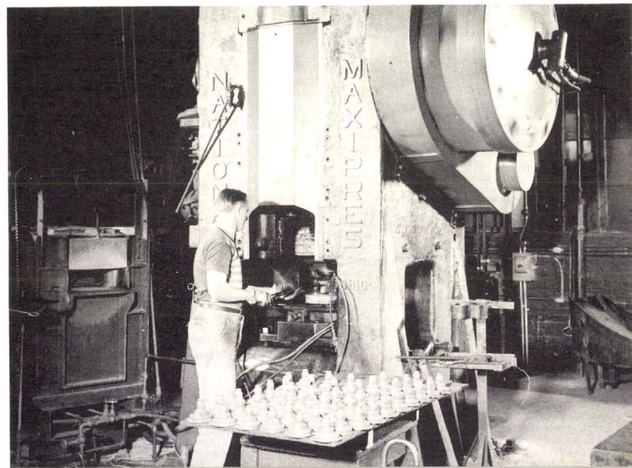

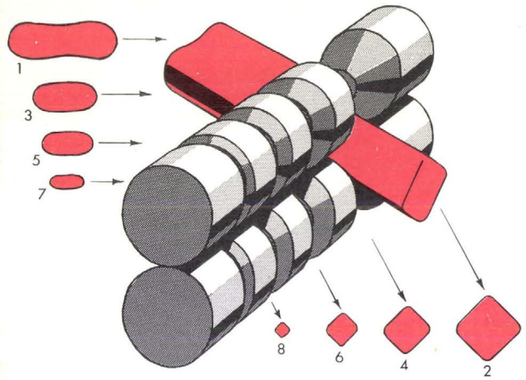

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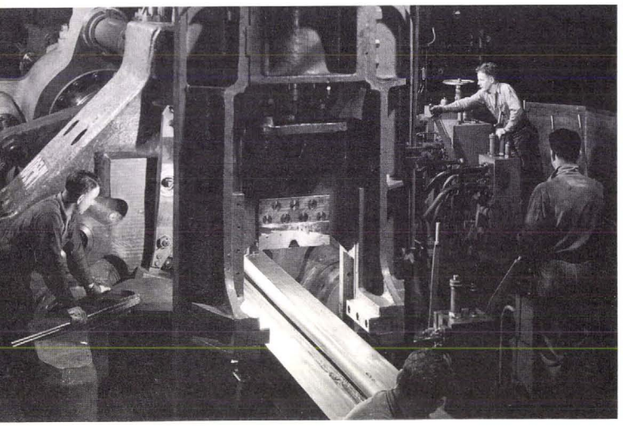

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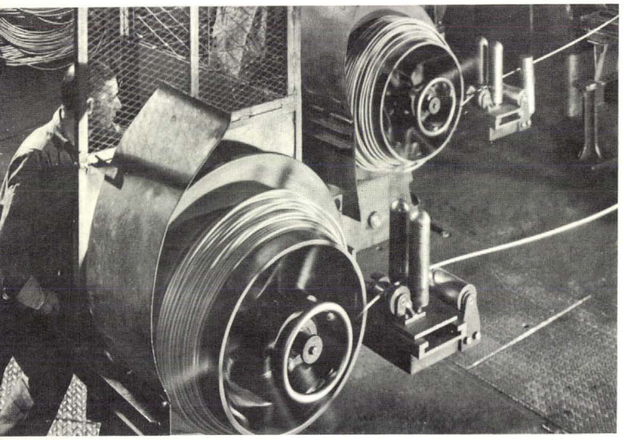

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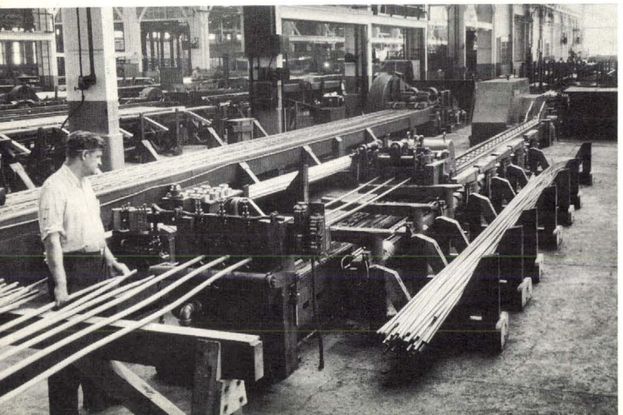

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Rod. Though rod can be cold rolled or cold drawn to small finished size, the major amount is first extruded or hot rolled down to a predetermined size and subsequently cold finished.

In the hot rolling process, a refinery copper wire bar is furnace heated and passed through a special rolling mill containing a series of rolls with graded grooves.[12] The grooves are progressively smaller and alternately square and oval to produce a kneading action which breaks up the cast structure of the rod, replacing it with a superior, uniform fine-grained structure. Emerging from the last grooves, the reduced rod is fed into a revolving coiler rack and cooled by quenching in water. It is then conveyed to a pickling bath to remove scale or oxide. Lastly the rod is washed of excess acid and dipped in hot water to facilitate drying.

Extruded rod is fabricated by a giant extrusion press, capable of exerting up to 2,750 tons of pressure, which literally squeezes hot alloy billets 7 or more inches in diameter into rod as small as ½-inch or smaller in diameter in thirty seconds, the glowing metal riding out of the exit like spaghetti.[13]

Small diameter rod generally is coiled while still hot;[14] larger sizes are held in straight lengths. When necessary, small rod is further reduced in diameter by drawing through successively smaller, integrated dies on inverted draw blocks or by a pass through an automatic rod drawing machine which draws it down to the desired size, straightens, polishes and cuts it to length in a continuous operation. Larger rods are drawn down to finished sizes, three at a time, on a multiple draw bench, straightened on a special machine and cut to length.[15]

Some alloys such as phosphor bronzes, nickel silvers, and beryllium copper are cold worked from original casting to finished rod, interspersed with suitable anneals. Most rod and bar are finished circular in cross-section, but fabrication mills are equipped to produce many shapes: square, octagonal, hexagonal, rectangular, oval, etc.

Wire. Almost two-fifths of the world's consumption of copper is in the form of wire, mainly for the electrical industries. In the initial fabrication stage, copper wire bars are hot rolled

per-Stone Age, followed the discovery of copper. Through this period, knowledge of the reddish metal's ever-lasting qualities gradually spread to areas adjacent to the Tigris-Euphrates section and beyond, reaching Egypt about 5000 B.C. (beginning of the Bronze Age).

Cyprian metal. Cyprus, an island in the eastern end of the Mediterranean, was one of the first great sources of copper. So highly prized were its deposits that war followed war in bloody contest for them. From control by Egypt, the island passed to Assyria, Phoenicia, Greece, Persia to Rome. The word "copper" derives from the name of the island; the Romans called the corrosion resistant metal "aes cyprium" (Cyprium metal) which was corrupted to "cuprum," this became "copper" in English. The first two letters of its latin name constitute the chemical symbol "Cu."

Copper in antiquity. Man's pace upwards through the ages can be measured by the increasing number of applications to which he put copper as the knowledge of its properties increased. Alloys were probably first produced accidentally due to the presence of impurities in the ores. Arsenic predominated in the ores in Egypt, tin in those of Britain, nickel in Germany, and antimony in Hungary.

Copper metallurgical progress spurted under the Egyptians who were the first to learn to deliberately combine tin with copper to create bronze (about 3800 B.C.). Brilliant craftsmen fashioned numerous household articles and art works from copper and bronze. A section of copper water pipe they produced 5400 years ago was still in excellent condition a few years ago. They employed copper nails and copper bands in ship construction; war galleys were equipped with copper rams. Later, the Greeks and Etruscans similarly made liberal use of this metal in their civilizations.

The Roman era. The Bronze Age reached its pinnacle during the growth of the Roman Empire. Thousands of slaves mined and smelted the ore and transported the metal to Rome.

Copper and bronze were used in ever increasing quantities for more and more purposes, including furniture, household utensils, statuary, architecture, arms, coinage, razors, surgical

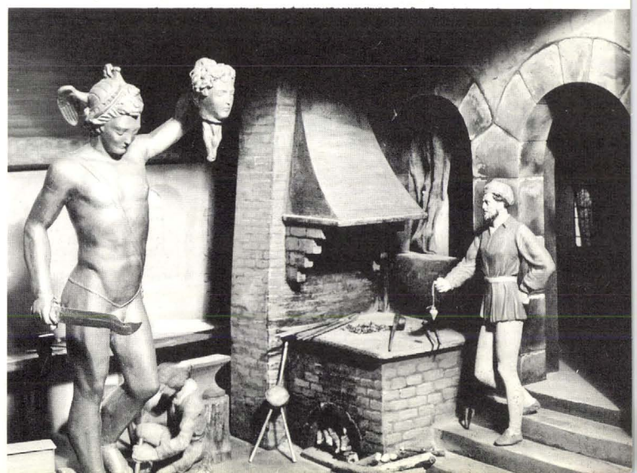
Egyptians casting bronze doors for the great temple of Karnak at Thebes, about 1400 B.C.

instruments, and even artificial limbs.

Decline and rise. The chaotic social conditions prevailing after the collapse of the Roman Empire; the universal brigandage in Europe during the Dark Ages, combined to disrupt industry and trade, and metallurgy fell into a period of decline. By the ninth century, however, bronze church bells were being produced. By the fourteenth century churches were being roofed with copper, a practice which has become standard for edifices designed to withstand the assault of time. During the Renaissance in Italy, skilled artisans revived the art of bronze working, and this metal resumed its traditional role of permanently recording man's cultural progress.

War and trade. From time immemorial, copper has been the strategic metal in warfare, and need for it multiplied after the invention of gunpowder; the brass and bronze cannon manufactured during the fourteenth century, for example, weighed up to eighteen tons. A new area of demand occurred when increased trade and

Perseus holding the head of Medusa, a famous bronze statue executed by Cellini, noted Italian Renaissance sculptor.



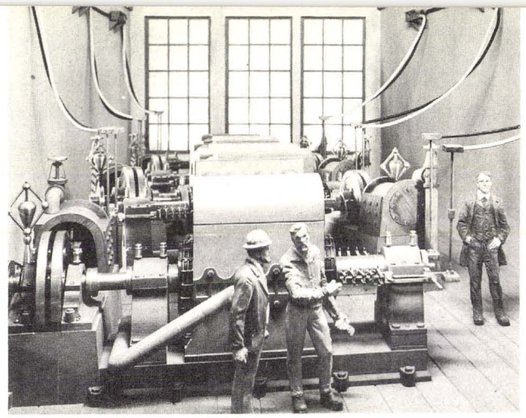
manufacture necessitated expanding ship building programs from the fifteenth century on. Copper sheathing protected wooden hulls from the damaging effects of sea life, and copper lightning conductors protected the ship's masts from angry heavens.

America. Pioneer efforts to found the American copper industry were initiated by John Winthrop's foundry, established in 1664 at Lynn, Mass. Copper and brass kettles were handmade in Philadelphia in 1725, and by 1759 a factory in Waterbury, Conn., was producing knee and shoe buckles. The site of the first brass sheet rolling mill, in 1802, was also in this town. Paul Revere erected the first mill to roll copper at Canton, Mass., in 1801.

Old ship sheathings, stills, copper kettles, warming pans, candlesticks and similar items were the main sources of copper supply for the young industry. Small amounts were also directly received from England. The first copper mine was worked at Simsbury, Conn., in 1705. Additional mines were subsequently opened in New Jersey and Pennsylvania, but total production was of little commercial value.

In its early growing years the industry relied on heavy imports from Chile until native copper ores from the Lake Superior region became available to the east coast mills. In 1844, the Cliff Mine in this area was opened and the United States embarked on a copper producing program that was ultimately to make it one of the principal producers in the world. This is the only district in North America where commercial native copper ore is found.

The Industrial Revolution. The technical developments of the Industrial Revolution led copper to assume an increasingly important role. The stepping stones of great inventions, one following upon the other at an ever swifter pace,

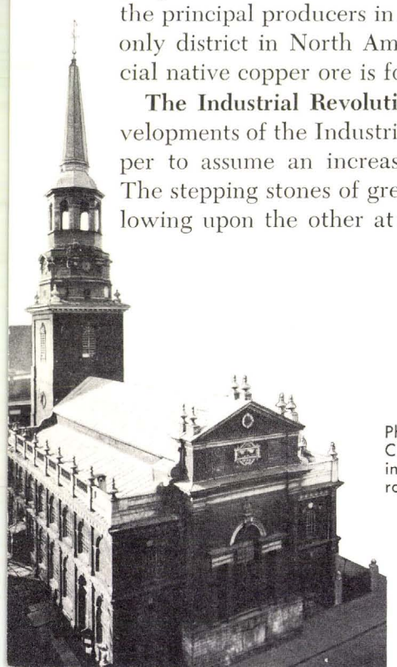


Thomas Edison's Pearl Street Station, pioneer power station for the generation of electricity, New York City, 1882.

culminating in the miracles of our own day, were all dependent in some degree on versatile copper.

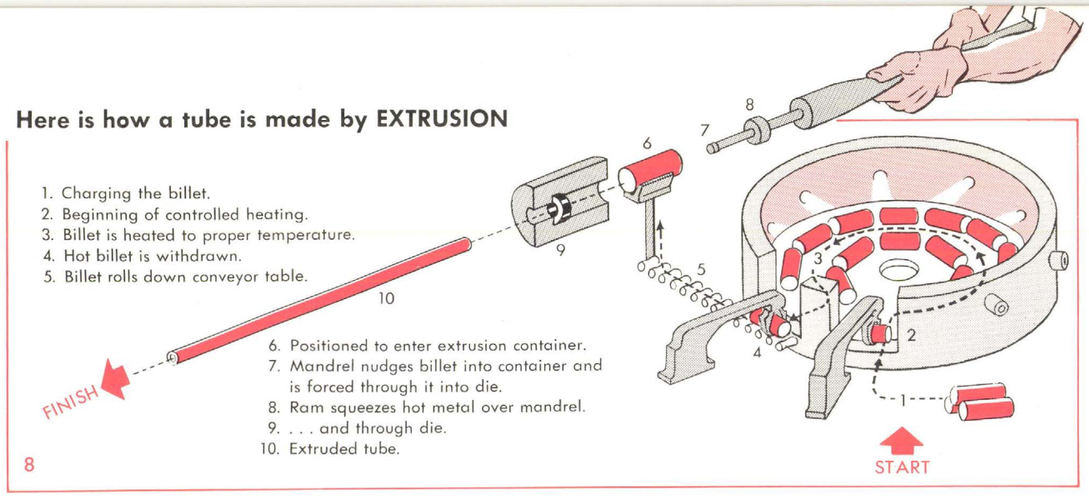
Power and communications. On a stormy day in 1752, Benjamin Franklin unlocked the door to the extraordinary era of electricity, using a brass key in the famous kite-flying experiment that proved that lightning and electrical discharges were one and the same. Volta took a giant step forward when he built the first electric battery in 1779, employing copper as the active element. Copper, from this date, played a stellar role in the harnessing of electric power. In 1831, Michael Faraday built the first magneto-electric machine, the principal part being a copper disc twelve inches in diameter. This machine was the forerunner of the modern dynamos and generators, which require many tons of copper in construction. Samuel Morse, in 1832, relayed the first electric signals over 1700 feet of copper wire, the first telegraph line. Today there are 7,000,000 miles of telegraph wire in the world, one third of it in the United States. In 1876, Alexander Graham Bell put the human voice on copper wire. Today in United States alone there are 56,000,000 telephones connected by enough copper wire to encircle the world 5,000 times. Thomas Edison produced the first incandescent lamp in 1878 and ushered in the great age of electricity. From the first, copper was recognized as the most efficient and practical conductor of electricity.

Copper's future. It is impossible to predict what new marvels the coming atomic age will produce, but it is certain that copper, the metal of invention, will share in their development.



Philadelphia's historic Christ Church, which was completed in 1732, has oldest copper roof in the United States.

Here is how a tube is made by EXTRUSION

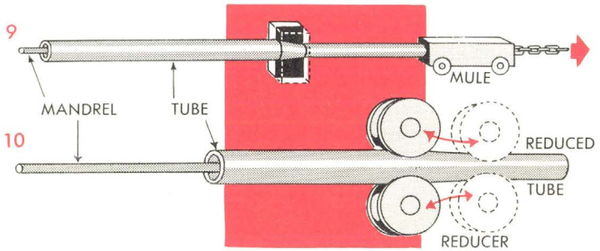


alloys are supplied in various degrees of hardness according to the rolling it has received subsequent to the last annealing. The customary temper designations are quarter-hard, half-hard, hard, extra-hard, spring and extra-spring.

Seamless tube and pipe. Copper, brass and other alloy tube and pipe are fabricated by one of several different processes.

Hot Extruding: A billet is heated to plastic temperature (which varies with different alloys) and inserted in a giant hydraulic press. Under tremendous pressure, the metal is forced to flow outward between a die and a plug on the end of a mandrel, the die determining the outer diameter, and the plug the inner one.[8] One end of the hot-formed tube or pipe shell is then pointed in a hydraulic squeeze machine. A mandrel terminating in a plug is inserted in the open end of the shell; the pointed end is inserted into a die, and the entire tube drawn through. Employing progressively smaller dies, the tube is cold drawn down to size.[9] In another method the shells are swaged over a tapered mandrel between two roller dies. The rolls move back and forth and the tapered grooves squeeze the metal against the mandrel reducing wall thickness and diameter.[10]

Hot Piercing: A billet is heated and inserted in a piercing mill. Rolls grip the red-hot billet and rotate it forward against a piercing mandrel with sufficient force to induce the plastic metal to flow over it, thus forming it into a shell.[11] The latter is reduced to size by one of the two methods previously described.



Shell casting: A tubular shell is sand cast, the exterior rough surface, which often accompanies such casting is removed, and the shell drawn and redrawn until the desired tube size is obtained.

Cup drawing: A flat slab or cake of metal is rolled to about ½-inch thickness, surface imperfections are removed by machining, and discs blanked from the rolled metal. Each disc is cupped, the closed end cut off, and the remaining shell drawn to size.

Depending on the copper or alloy and the size of the tube, a number of annealings are required in these various tube fabrication methods.

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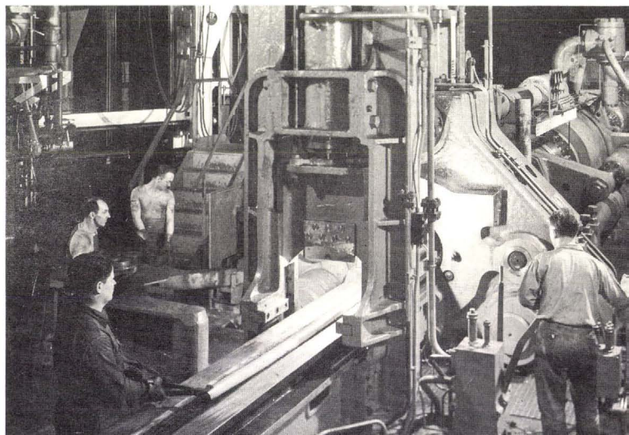

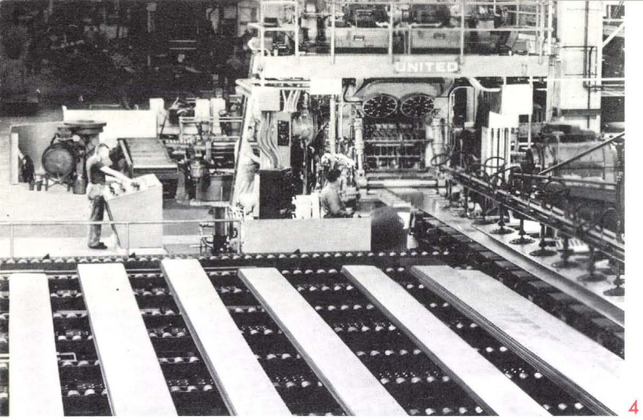

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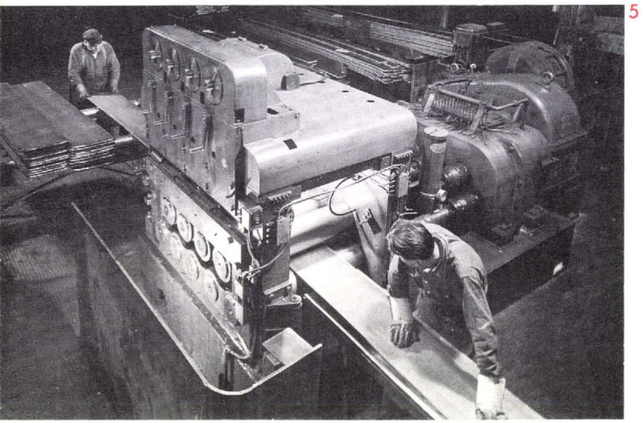

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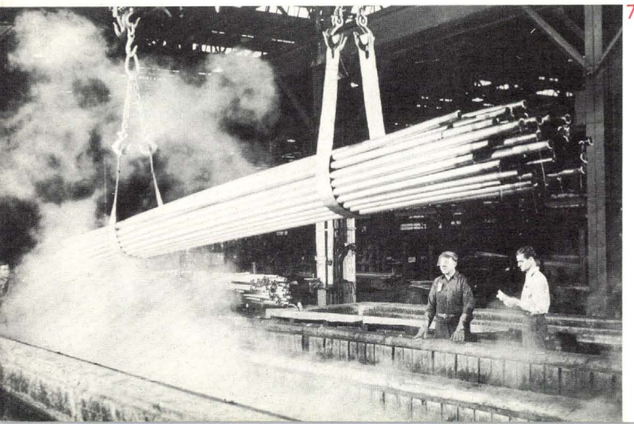

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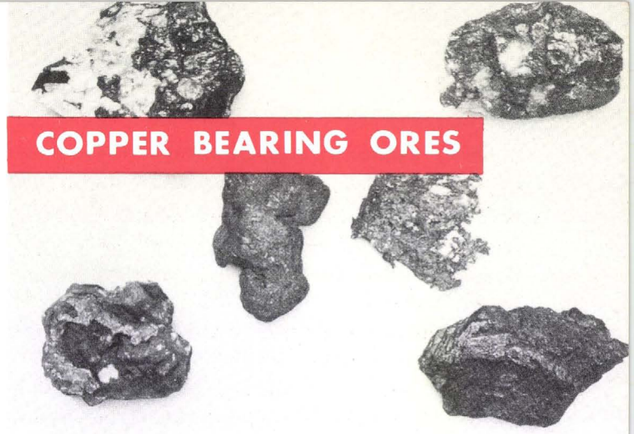
employ casting machines capable of casting billets or bars at a continuous rate. The largest of these, a giant, four-story affair, can operate months on end, never stopping, producing billets or bars at the rate of millions of pounds a week. Many brass mills cast intermittently, using simple "book molds," "cannon molds," and "water-jacketed molds." Regardless of how produced, the alloyed-metal bars are fabricated into sheet and strip, and the billets into tube, rod, and wire.

Sheet and Strip. The flat cast bar is delivered from the foundry to a powerful cold-breakdown or hot-breakdown rolling mill. Passed repeatedly through the rolls of the cold mill, the bar becomes thinner and longer with each successive pass.[4] Cold working the metal in this manner hardens it and creates internal stress. To restore ductility it is necessary to correlate the rolling operation with periodic annealing. Continuous annealing furnaces of the roller hearth type heat the bars to the temperature at which recrystallization occurs and the material is restored to a soft condition.

Before further rolling, all imperfections are removed from the top and bottom surfaces of the bars by special milling machines. They are then delivered to a four-high rundown mill and rolled to about 5/16-inch thickness, emerging at the rate of about 1000 feet per minute as cold rolled sheet.[5] Final rolling down to specified gages is performed by four-high finishing mills. Slitting machines stationed at cut-off points along the route traveled by the coils during the finishing operations trim uneven edges and slit the sheet into predetermined widths. Annealing during these operations is performed in furnaces designed to accommodate 10 to 20 tons of coil per hour, each coil remaining in the furnace five or six hours.[6] Heating causes some oxidation (discoloration), necessitating a cleaning operation known as "pickling" (a bath in dilute sulfuric acid solution);[7] the metal is then thoroughly rinsed in hot water.

Copper plate and sheet are similarly fabricated, with the exception that the flat copper cake from the refinery is heated before entering the hot breakdown mill.

Plate, sheet and strip of copper or copper-base



COPPER BEARING ORES

THE METALLIC ELEMENT COPPER is globally distributed and is present in a variety of unusual and unrelated substances. It occurs in either a natural state or combined with additional elements in many rocks and soils, river silts and oceanic clays, the ashes of seaweed and other plants, in numerous anthropoda and mollusca such as spiders and snails, and even in the human liver.

Commercial sources of the metal are confined to a variety of copper ores. These ores are natural alliances of copper-bearing minerals (chemical compounds, crystalline in structure) and other minerals, and they contain sufficient copper to make practical and economic the mining and extraction of the metal. Though there are 165 known copper-containing minerals, few are commonly found in ores. Generally distinguished as either sulfide or oxide types, the ores differ in the quantity of copper present, varying from "low grade" to "high grade"; the amount and type of associated metal (gold, silver, iron, etc.); the nature of the accompanying "gangue" minerals, either valueless or of secondary importance; and the hardness and texture of the ore.

These factors, plus the type of host rock and the location of the ore bodies in the earth's crust, determine the selection of the method by which the ore is mined and the manner in which it is reduced to copper metal.

Origin. Eons ago, the ores, like many metals, probably were molten solutions, lodged in the fiery interior of the earth. During a period when the earth heaved, buckled and rumbled under the tremendous impact of volcanic and other igneous disturbances, immense cracks appeared in its crust. Continued twisting and bending pressures acted upon the ore solutions, forcing them upwards. Flowing through the natural routes provided by the cracks, the boiling liquids and gases ascended to the surface layer and gradually cooled, solidifying into copper ore vein systems. In some instances, the ore solutions penetrated the tiny pores in adjoining rocks, or replaced other minerals in the rocks in the form of almost microscopic grains and became "disseminated" ore bodies.

These original ores (sulfides) are primary ores. Deposits in this group lying near the earth's surface were altered by weathering processes to produce secondary ores. In some instances the sulfides were converted into copper oxides by erosion. In others, surface water seeping down through the earth leached the copper from its original ore and deposited it near ground water level where it replaced or enriched primary sulfides formed earlier.

Sulfide Ores. These ores are composed of copper-bearing sulfide minerals and gangue. The latter may be composed simply of the minerals making up the host rock, or it may consist of various other minerals, or it may be formed in a combination of these two groups. The most important minerals in this category are bornite, chalcopyrite, enargite, tetrahedrite, tennantite, chalcocite, and covellite. It is believed that about half the world's copper resources are in the form of chalcopyrite (34.5 percent copper by weight) or "yellow ore," which is composed of sulfur, iron and copper. The old Roman mines of Rio Tinto in the Spanish peninsula, in operation for more than 2000 years, contain considerable chalcopyrite. The richest ore, with the exception of native copper, is chalcocite (79.8 percent copper, 20.2 percent sulfur) or "copper glance."

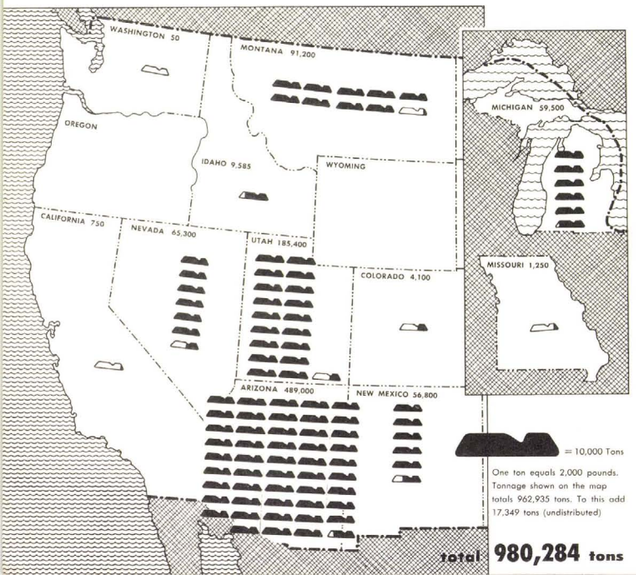
Oxidized ores. In this group the ores are similarly natural mixtures of gangue and copper minerals, but the latter have been altered by oxidation or weathering processes. Cuprite, tenorite, malachite, azurite, antlerite, brochantite and atacamite are representative oxide minerals. The most common minerals are malachite (57.3 percent copper), azurite (55.1 percent) and native copper ores.

Other values in copper ores. The kind and amount of other metals (and non-metallic elements) associated with copper add to the value of an ore. Gold, silver, nickel, molybdenum, etc., may be present in varying ores to the extent that their recovery is economically feasible. In some few instances, copper occurs in co-ordinate importance with other valuable metals to form what is termed a "complex ore." Famatinite (43.3-47.9 percent copper) is in this category.

Low and high grade. Low grade ores containing approximately two percent or less copper by weight account for about four-fifths of the world's yearly production of copper metal. Considerable amounts of gangue or waste material are always present and must be eliminated before the smelting operation. High grade ores usually carry from about three to ten percent copper, though in certain instances they may be higher, and are sometimes smelted directly without preliminary separation of undesirable waste materials. The major amount of copper metal produced in this country is produced from low grade ores mainly in the sulfide forms, with an average grade of 0.85 percent copper.

Deposits. Ore bodies may range in size from several thousand tons to hundreds of millions of tons. Further, the deposits may lie close to the earth's surface in wide horizontal areas in which the minerals are fairly evenly disseminated in fine grains throughout the ore, or they may plunge deep into the earth in vein form.

COPPER PRODUCTION BY STATES...1958



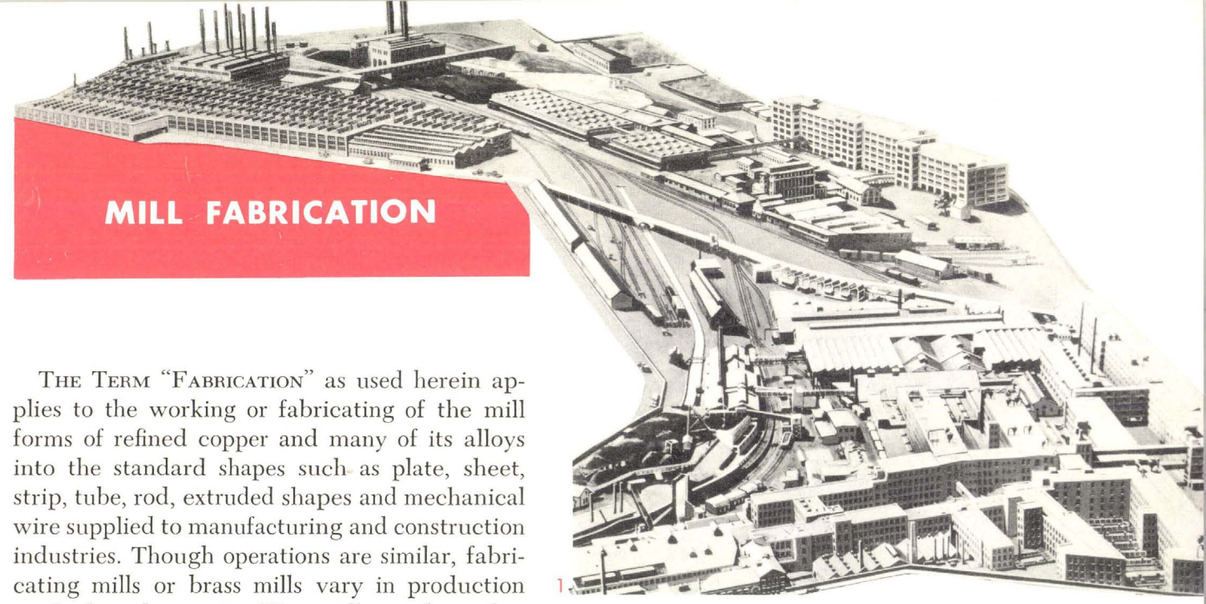
The famous mines in the Lake Superior region are composed primarily of native copper. Some of this copper needs only melting to produce the renowned "Lake" copper which was the standard of copper purity for almost 50 years. There are several other native copper districts in the world, but their contribution to total production is negligible today. Today copper ores are being mined in this region.

World copper producing areas. Productive copper ore deposits are presently in every continent, but 90 percent of the world's known reserve is located in five general areas. In order of their importance, these copper producing regions are: (1) Rocky Mountain and Great Basin area of the United States; (2) the Andes in Peru and Chile; (3) the central plateau of Africa in the Belgian Congo and Northern Rhodesia; (4) the Precambrian area of central Canada and its extension into northern Michigan; (5) the Urals in the U.S.S.R.; Turkestan and Siberia. Add to these, widely distributed localized rich deposits of smaller size exploited throughout the world.

In this country, though commercial deposits exist in 28 of the 48 states, about 95 percent of the deposits are concentrated in six states: Arizona (with largest deposits), Utah, Montana, Nevada, New Mexico and Michigan. These states account for about 97 percent of the total annual production of the United States. Smaller deposits exist throughout the western states, Missouri, Tennessee, Pennsylvania and Vermont.

Porphyry deposits. These deposits represent the major source of the world's copper metal tonnage. The copper minerals are more or less uniformly scattered (disseminated) throughout the host rock, which may be porphyry, schist or other types. The typical porphyry deposit lies near the surface, is much larger in breadth than depth, and contains a low grade ore amenable to mass extraction and treatment techniques.

Porphyry ore regions are located in nine sections in the southwestern and western United States, one in Mexico, three in South America, one in Canada, and probably several in Asiatic Russia. Additional areas in South America and this country are in the process of exploration.



MILL FABRICATION

THE TERM "FABRICATION" as used herein applies to the working or fabricating of the mill forms of refined copper and many of its alloys into the standard shapes such as plate, sheet, strip, tube, rod, extruded shapes and mechanical wire supplied to manufacturing and construction industries. Though operations are similar, fabricating mills or brass mills vary in production methods and capacity. Wire mills are those that primarily produce wire and cable for electrical conductivity purposes.

A typical, modern high-capacity "primary" brass mill is an immense affair. The main plant may be nearly a mile long and perhaps half that wide.[1] It contains a foundry with its furnaces and casting equipment, milling machines, and several miles of inter-connecting railroad track. Operations demand huge amounts of water and electric power. Roller conveyors, mechanical handling devices, small trucks and mobile cranes move materials uninterruptedly through the various production phases. Thousands of tons of raw material and finished product are annually hauled to and from the mills by an almost endless chain of freight trains and trucks.

Melting and casting. Refined copper and alloying metals such as zinc, tin, lead, nickel, and aluminum, and new scrap, the mill's raw materials, are first sampled and analyzed in the laboratory before use.[2] In lots of as much as 5000 pounds, the components of a designated alloy are assembled in the proper proportion and periodically charged into a battery of electric furnaces, or otherwise melted. Some of the furnaces supply bar or cake castings; the remainder, billet castings. Each furnace is tapped at suitable intervals, and the molten metal is transported in huge ladles by an overhead crane and charged into holding furnaces mounted on top of the casting equipment.[3]

To facilitate volume production, some mills

Nickel Silver brings glistening beauty to costume jewelry, hollow ware and hundreds of additional articles.

The Cupro Nickels, alloys nominally composed only of copper and nickel, with other metals sometimes present in small quantities, used primarily in heat exchangers, condensers, and piping where corrosion is severe.

Bronzes. Strictly speaking, the word "bronze" denotes a copper/tin combination, but the word also is used commercially to signify a number of copper-base alloys, some of which contain no tin at all, but have bronze-like characteristics, especially the typical bronze color such as *Architectural Bronze* and *Commercial Bronze*. Other bronzes have, through the development of modern metallurgy, substituted other elements for the tin as, for example, *Aluminum Bronze* and *Cadmium Bronze*.

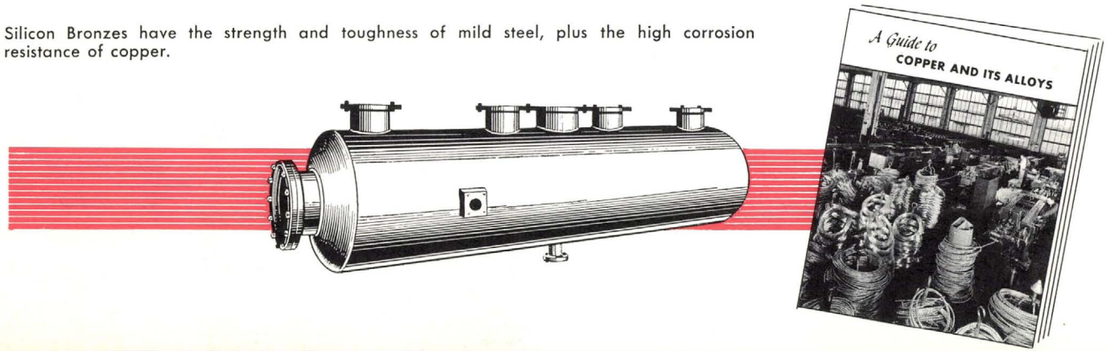
Lineal descendants of the ancient bronzes are the modern *Phosphor Bronzes*. True bronzes into which minute amounts of phosphorus have been introduced, they are alloys with great resiliency, fatigue endurance, and hardness which, allied with superior corrosion resistance, endow them with a special distinctiveness. Some typical uses include expansion and bridge bearing plates, springs, shafting, diaphragms and hardware. *Phosphor Bronze*, 5% (95% copper/5%tin/0.35% max. phosphorus) is the most common of these bronzes.

Silicon bronzes. Modern metallurgy has developed a line of copper/silicon alloys with high strength and excellent corrosion resistance. Not true bronzes, their compositions consist of a copper/silicon base to which are added from one to a half dozen other elements, depending upon the particular silicon bronze alloy desired. Elements commonly added include manganese, zinc, iron, tin, nickel, and lead. These alloys have established reputations for versatility and are applied in practically every field of engineering and manufacture.

Some special alloys. In addition to the alloys mentioned, there are several others that merit some attention. *Beryllium Copper*, a remarkable alloy composed of copper and about 2 percent beryllium, is widely used where very high strength is required and for spark-resistant tools wherever fire or explosion is a hazard. It is one of the few copper-base alloys that are commercially heat treatable. *Cadmium Bronze*, an alloy of copper and a small amount of cadmium, principally applied in the electrical field for purposes requiring a combination of high strength and high electrical conductivity. *Tellurium-Nickel-Copper*, another excellent alloy used principally for forgings and screw machine parts requiring high strength, hardenability, extensive machining and corrosive resistance.

This discussion of alloys has been necessarily brief, and the listing of special alloys is far from complete. For more detailed information on the subject, write to the Copper & Brass Research Association, 420 Lexington Avenue, New York 17, New York, for a copy of "A Guide to Copper and its Alloys."

Silicon Bronzes have the strength and toughness of mild steel, plus the high corrosion resistance of copper.



MINING COPPER is accomplished by either of two established methods : (1) open-pit mining, employed to remove ore from porphyry and other deposits; (2) underground mining, employed to remove ore occurring in veins and other ore bodies.

Open-pit mining. This type mining procedure is a massive operation involving a tremendous quantity of heavy-duty earth and rock moving machinery and miles of railroad track and truck roads (constantly being moved to meet new operating needs). To uncover the ore body, huge quantities of over-burden must be removed to provide a working surface termed a "bench." By continual excavation, a series of benches are formed, like giant steps, leading deeper into the pit. In time, a large mine assumes the proportions of a great amphitheater. Heavy explosive charges blast the ore free, specially designed electric shovels scoop it up, dump it into ore cars or powerful diesel trucks and haul it to the concentrating mills. Blasting is also used to free large amounts of waste rock which must be removed from the mine pit and disposed of elsewhere.

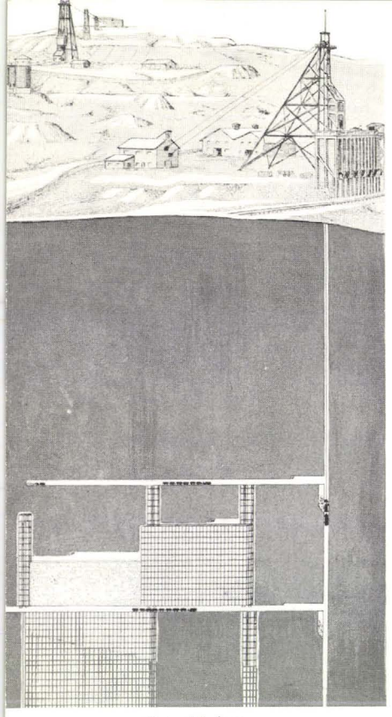
Underground mining. This method is costlier and usually demands a higher grade of ore to make it economically profitable. Whereas the mass production open-pit technique exploits ores yielding as little as 0.40 percent copper, underground mining requires a grade with a minimum range of from 0.70 to 6 percent.

An underground mine is a complex structure containing miles of electric railway track, and extensive hoisting facilities, ventilating, lighting, inter-communication, safety, fire-fighting and fire-protection systems. Its activities revolve around a series of shafts sunk deep into the earth. Where veins occur, horizontal passages are run out from a shaft and connected by cross-cuts. The ore veins are mined in sections, the workings extending vertically, stepwise on an incline, or roomwise horizontally.

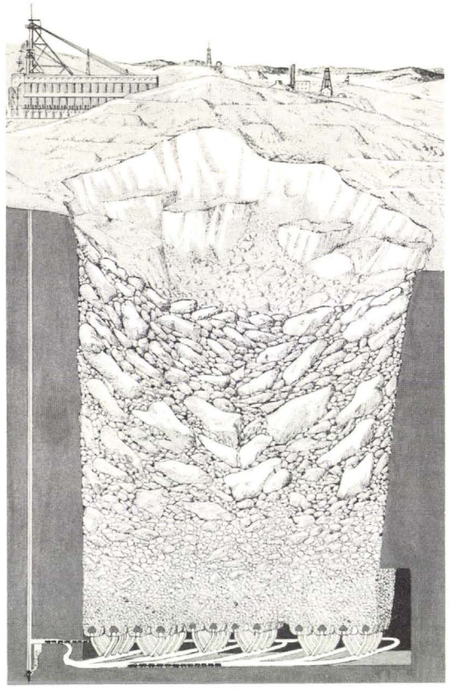
As the mine grows, the mine shafts are extended and the horizontal drifts are driven out at approximately every 100 to 150 feet of depth, depending on the ore body.

Compressed air drills are used to drill the rock for blasting. The shattered ore may be loaded directly into ore cars, or, if the "diggings" are some distance from the tracks, it is "chuted" down to a level maintaining one, hauled to a

Tiers of benches formed in a giant open pit mine of the Kennecott Copper Corporation, Bingham Canyon, Utah.

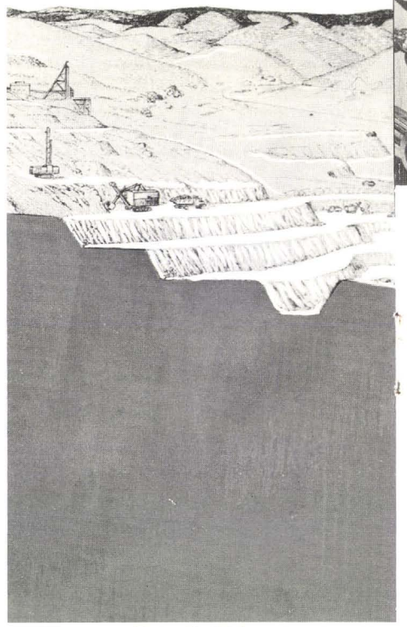


Vein Mining



Block Caving

Courtesy of The Anaconda Company



Open Pit Mining

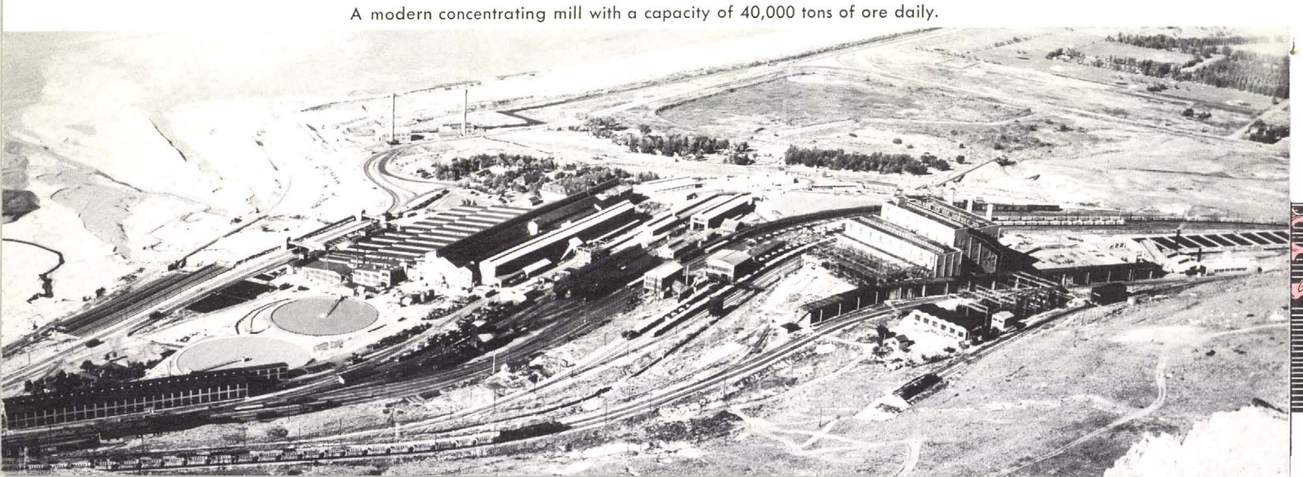
shaft, transferred to skip cars and hoisted to the surface. The ore is then transferred to the concentrating mill. Other methods are also used.

Block caving. This is another form of underground mining. A large scale, low cost operation, it is extraordinarily successful when the ore appears in a multitude of "horse tail" veins and veinlets with intervening rock containing disseminated copper ores. An entire underground block of ore is removed without leaving supporting pillars. The block "caves" and the material flows by gravity through raises to cars or to slusher drifts and then to cars on the haulage horizon. The earth above settles to fill the resulting void. Block caving together with new smelting methods make available tremendous tonnages of ore which previously were regarded as uneconomical to handle.

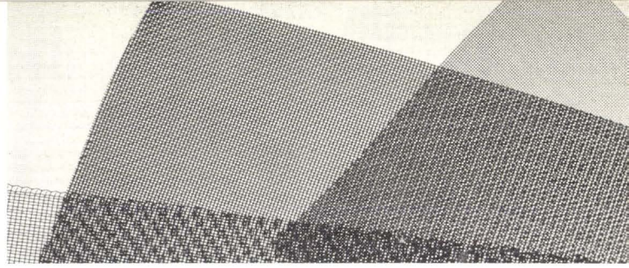
Extraction. Copper extraction from ores is mainly accomplished by either of two methods: (1) heat (concentration, smelting and refining) and (2) wet-extraction (flotation and leaching). Where the ore is of low grade or poor composition, economy usually dictates the use of a wet-extraction process. Oxidized, mixed oxide-sulfide, and low grade native copper ores are more commonly treated by this method. A heat process applied to these ores often would be too costly, or the over-all recovery of copper would be too small.

In instances where the ore is of a very high grade it is smelted direct, without concentration.

A modern concentrating mill with a capacity of 40,000 tons of ore daily.



Red Brass formed this fine jewelry.



Commercial Bronze wire screens are weather-resistant.

ing properties). When the zinc content exceeds 37 percent, a second phase, known as "beta" appears (with remarkable hot working properties). The *Low-Zinc Brasses* contain from 5 to 20 percent zinc; in this group are alloys especially suited for the manufacture of water pipe, rotating bands for artillery shells, medallions, costume jewelry, compacts, lipstick cases and related items. One of the outstanding alloys in this category is *Red Brass*, 85% (85% copper/15% zinc). *High-Zinc Brasses* containing from 30 to 40 percent zinc, are widely specified for the production of cartridge cases, musical instruments, lamps, automobile radiator tanks and cores, building hardware, condenser tubes and plates, valve stems, and many additional applications. *Cartridge Brass* (70% copper/30% zinc) is the most important alloy in this division.

Additional brass alloys. Small quantities of one or more other elements added to the plain brasses led to a series of so-called "Special Brasses." The *Tin Brasses* are among these alloys. Composed of copper, zinc, varying amounts of tin, and in some instances additional elements, the tin brasses are particularly suited for certain applications where corrosion resistance is a paramount factor. *Inhibited Admiralty* (71% copper/28% zinc/1% tin) used for condenser, evaporator, and heat exchanger tubes, and *Naval Brass* (60% copper/39.25% zinc/0.75% tin), used for valve stems, propeller shafting and marine hardware, are popular alloys in this group.

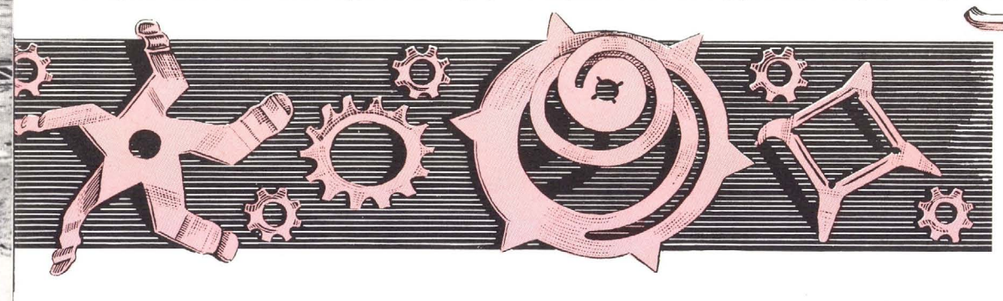
The admixture of lead in the plain brasses produces the widely used *Leaded Brasses*. These brasses, copper/zinc blends to which has been added one-half to three percent lead, are in constant demand for their superior machinability.

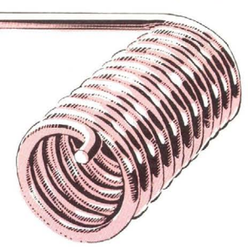
The lead addition does not modify the other properties of the brass, except to reduce somewhat its malleability and ductility. It does not enter into chemical combination with the brass, but is disseminated in small particles throughout the alloy. When the metal is machined, these particles cause the metal being pared off to form into small chips rather than long spirals, thus freeing themselves quickly from the tool. This action prevents fouling and dulling of the tools.

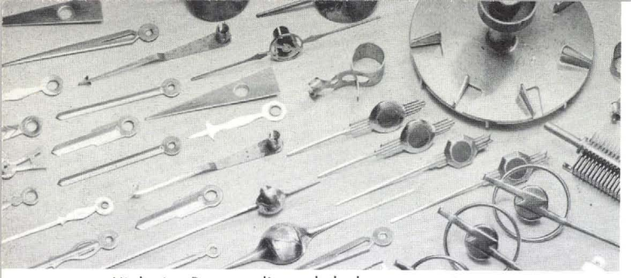
Leaded brasses are utilized in the production of clock and watch parts, plumbers' brass goods, engraving plates, architectural trim, to identify a few. From the standpoint of tool wear, cutting speeds, feeds and resultant finish, *Free-Cutting Brass* (61.5% copper/35.5% zinc/3% lead) is considered to be the most economical and practical leaded brass for drilling, forming, knurling, milling, reaming, tapping, threading and turning. It is the raw material for gears, pinions, and a multitude of automatic high-speed screw machine parts too numerous to mention.

Nickel Silvers. These handsome alloys are mixtures of varying proportions of copper, zinc and nickel. Actually, they are brasses in which the nickel is substituted for part of the zinc. A prominent characteristic common to them is a natural, silvery-white color similar to that of genuine silver. They especially comply to the exacting requirements of the etching, enameling, silver-plating and chromium-plating industries. Typical applications include plated silverware, hollow ware, optical goods, jewelry, and so on.

Phosphor Bronzes have infinite application ranging from expansion and bearing plates for bridges, through hardware, to a variety of springs.







High-zinc Brass radio and clock components.

Low-zinc Brass was used to produce these medals.

COMMERCIALLY PURE COPPER

A level "set" on the surface of refinery castings can be obtained with *electrolytic tough-pitch* copper by adjusting the oxygen content to approximately 0.04 percent. The minute quantity of oxygen present affects the mechanical properties to some degree, but it is entirely satisfactory for most general purposes. This copper (99.90 percent minimum copper) is more economical to produce, and is produced in larger quantities than other types. Wire, rod, plate, sheet, and strip are formed from it.

Fabrication is possible by most of the usual processes. Aside from far-ranging electrical application, it is used in the manufacture of automobile radiators, sheet metal for buildings, screens, printing rolls, and many other items.

Deoxidized copper. A copper produced by introducing sufficient phosphorus or other material as a deoxidizing agent, to assure the removal of all the oxygen. It is prime material for uses requiring hot working, annealing, brazing or welding. Consequently it is of major importance in the production of tubes. It is used in such applications as gas and oil lines, pulp and paper lines, refrigeration and air conditioning, plumbing pipe and tube, and brewery and distilling tubes. The minimum copper content is 99.90 percent; phosphorus is a nominal 0.02 percent.

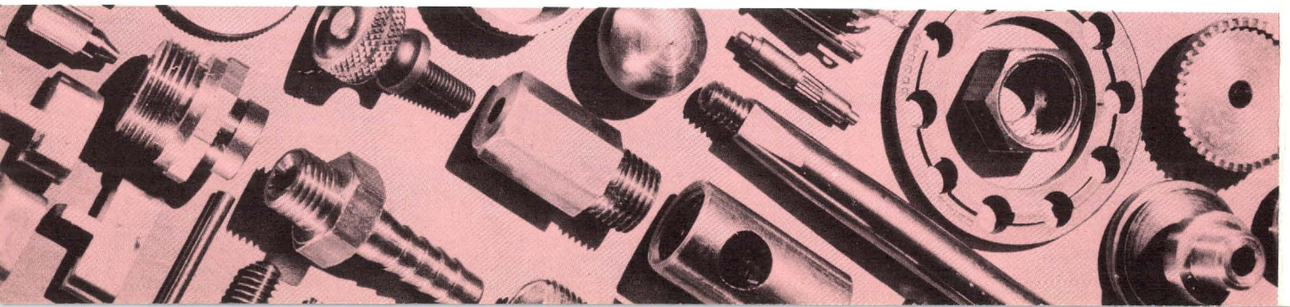
Oxygen-free copper. Production of this type either involves melting and pouring the copper in the presence of carbon or carbonaceous gases, so that no oxygen can be absorbed, or uniting specially prepared and treated cathodes under heat and pressure. The metal resulting from both methods is well suited for situations where a high conductivity copper must withstand hydrogen atmospheres, where high residual ductility is required in hard temper material; and for impact extrusion or other processes that require severe cold work. The metal produced by the first method is particularly well suited for metal-to-glass seals such as in the electronic industry. The metal produced by the second method also is used for the manufacture of conductors in the form of wire, flat wire, bar and strip. Minimum purity is 99.92 percent.

COPPER-BASE ALLOYS

Copper possesses a natural ability to combine with many other metals to create numerous alloys which offer additional important characteristics such as high fatigue resistance, wear resistance, high tensile strength, susceptibility to heat treatment and special fabrication capacities. There are several hundred wrought copper alloys available commercially, and metallurgical advances are constantly producing new ones. Marked by distinctive, pleasing hues ranging from red to bronze to gold to yellow to silver, they are non-magnetic (except for alloys containing small amounts of iron), can be soldered, brazed and otherwise readily joined, and can be effectively finished by plating and lacquering.

The Brasses. Chief among the copper-base alloys are the *Brasses,* copper/zinc compositions. Alloys in this group containing about 37 percent zinc and less are single-phase alloys termed "alpha" brasses (they have excellent cold work-

Leaded Brasses are employed when a high degree of machinability is desired.



MILLING

CONCENTRATION is a general designation embracing the various mechanical milling methods employed to eliminate systematically unwanted waste materials from the copper minerals in the ore preparatory to smelting. Actually, an initial concentration occurs in the mining operation when ore-bearing rocks are separated from non-ore-bearing or waste rocks.

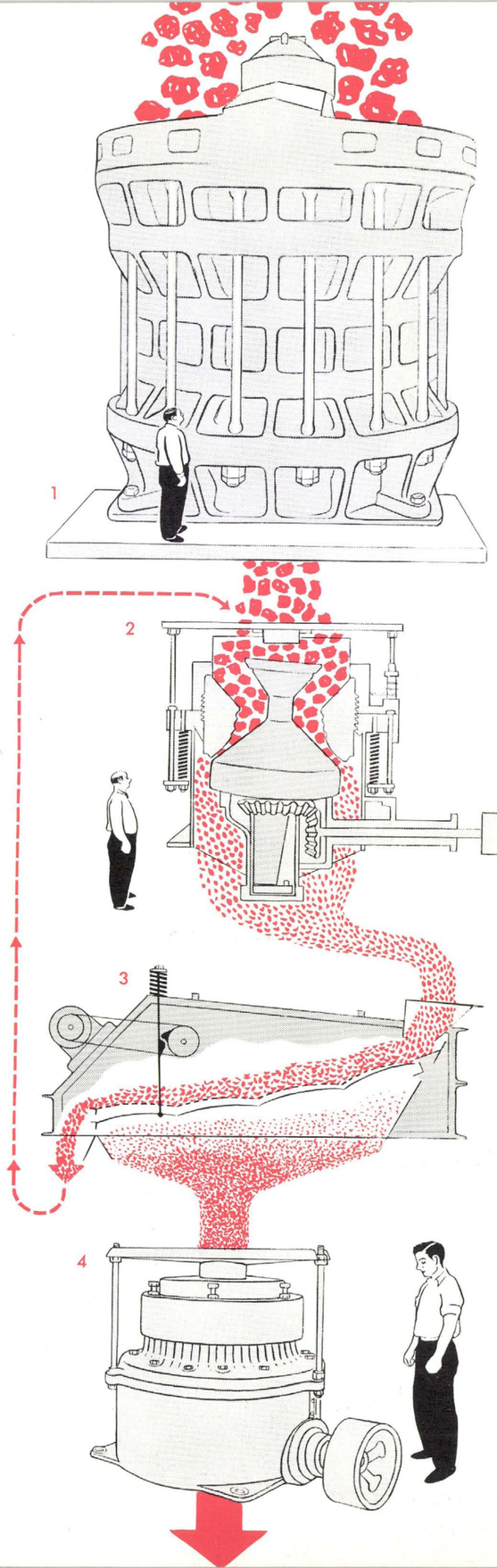
To liberate the mineral particles it is necessary to break down the rock containing them to fine sand capable of passing through a fine mesh screen. The whole procedure is very extensive and often requires a huge complex plant. The various transfers of ores from one operation to another are accomplished by gravity flow or, when the point of delivery is to a higher elevation, by inclined belt conveyors.

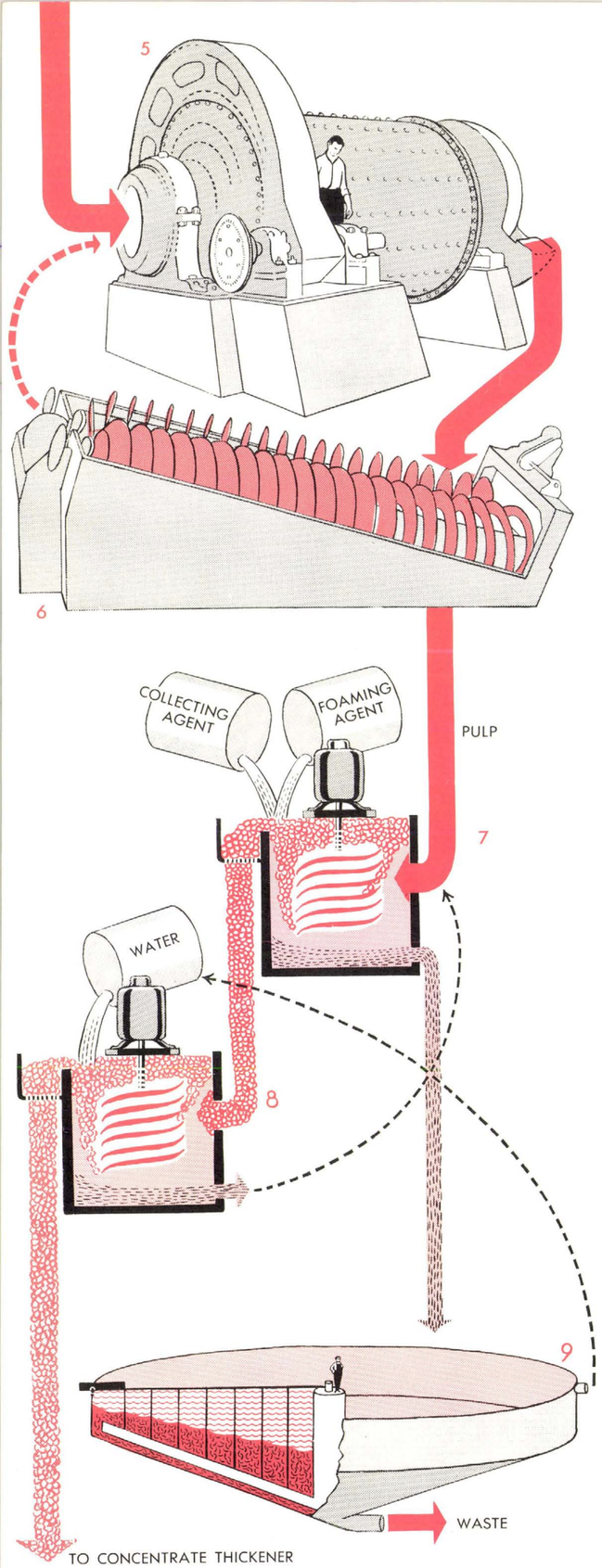
Coarse crushing. In the first step of the liberation or concentration process, large chunks of ore from the mine are dumped into massive jaw or gyratory-type crushing machines and broken into small pieces roughly 6 to 9 inches in diameter.[1] The crushed ore is further reduced in smaller, secondary cone-type crushers, the individual pieces emerging ½ to 1 inch maximum size,[2] larger pieces may be recirculated.

Screening. In this operation, impact or vibrating double-deck screens receive the ore and screen out all pieces fine enough (about minus ⅝-inch) for wet-grinding.[3] The remaining oversize ore is fed into a third crusher, a high-speed modified gyratory type, for further reduction or returned to the secondary crusher.[4] Broken ore from the crusher is recirculated over the screens. The process is continued until all pieces are of the size necessary for wet-grinding.

Wet-grinding. The big ore chunks have now been smashed to fragments; but even these bits of ore are too large. Because of the tiny size of the copper mineral particles, further reduction must be made before economic separation of the minerals by flotation can occur. To achieve this end, the ore removed by the screens is transferred to the wet-grinding machines.

There are several variations of these machines, but the most common in operation today are the ball and rod mills of the cylindrical or





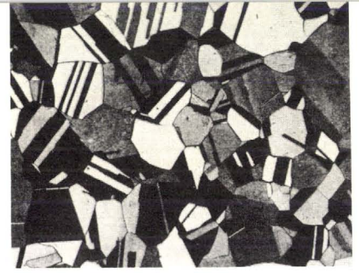
cylindro-conical type.[5] Roughly, a ball mill of this type is a rotating horizontal steel cylinder loaded with tons of manganese steel balls of varying diameter, none larger than 4 inches.

A prescribed combination of ore and water is fed into one end of the mill and passed rapidly through the powerful grinding action of the tumbling balls which literally powder the ore. The resultant product is automatically discharged from the opposite end of the mill into the "pool" of a mechanical classifier.

Classification. The water contents or pool of the classifier—which may be a shallow steel tank with a sloping bottom—is kept in a constant state of agitation by mechanical means.[6] The oversized particles of ore settle to the bottom and are conveyed up the slope of the tank through the action of submerged spiral or reciprocating rakes, drained of water, and passed into the feed box of the same or another ball mill to repeat the wet-grinding process. The remaining fine particles overflow into a weir located along the opposite side or lower end of the tank.

Rougher flotation. The fine particles, mixed with water—referred to as "pulp"— are transported to a battery of flotation machines. This operation is termed "rougher flotation," and is the process which first separates the copper minerals from the water and gangue minerals. Each machine is actually a tank or cell provided with an agitating and aeration mechanism.[7] To effect maximum recovery, the pulp passes successively from the first tank through the remaining tanks. Small, carefully controlled amounts of at least two chemical reagents are added to the pulp. One of these reagents assists in promoting the creation of a froth in the watery mixture; the other coats the copper minerals, making them water-repellent and giving them an affinity for the bubbles of the froth. The mineral particles attach themselves to the bubbles, rise to the surface, and float over the sides of the tanks into overflow weirs.

Cleaner flotation. The mineralized froth, of "rougher" concentrate, from the rougher flotation tanks passes next to the "cleaner flotation" tanks, and in turn concentrate from these tanks is conveyed to the "recleaner flotation" tanks.[8] In these processes water is added to dilute the


Original grain structure.

After cold working.

After annealing.

Free Copper are terms related to the characteristics obtained by the casting or processing method (regardless of how refined).

Additional terms identify copper according to specific kind. *High Conductivity Copper,* for example, is a copper which, in the annealed condition, has an electrical conductivity of 100 percent I.A.C.S. (International Annealed Copper Standard) minimum. A copper deoxidized with phosphorus is termed a *Phosphorized Copper. Leaded Copper, Tellurium Copper, Arsenical Copper, Chromium Copper, Silver-Bearing Copper* and *Cadmium Copper* are coppers containing less than 1.0 percent of the designated element. Each element is added to improve a specific mechanical or physical characteristic.

The inclusion of small amounts of lead in copper increases its machinability rating without appreciably lowering its electrical conductivity. The presence of tellurium in copper makes it easy to machine, maintain high conductivity and hot workability. Silver has practically no effect on conductivity, and cadmium and chromium have "moderate" effect on electrical or thermal conductivity, but improve or modify other physical and mechanical properties. Arsenic in copper considerably reduces its electrical conductivity, but slightly increases its tensile strength and the ability to resist certain types of corrosion.

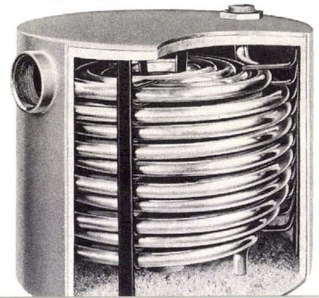
Basis for selection. Rarely does a single factor govern the selection of a copper or one of its alloys for a particular product application. Rather it is a combination of physical and mechanical properties, some of primary, some of secondary consideration, that determine the type to be utilized.

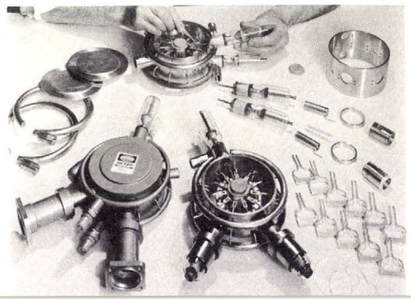
In one instance, for example, color will be of prime importance; in another, it will be thermal or electrical conductivity. If exposure to corrosion by sea water, atmospheric conditions, chemicals, etc. must be considered, alloys especially suited to resist these types of corrosion are recommended. This selection will demand further decisions: the fabrication qualities of the recommended alloys may vary to a large degree; therefore, the choice of the proper one will be influenced by the type of work operations to which the metal will be subjected. If forging is required, the alloy must have good hot working characteristics; if it is to be turned on a high-speed lathe, a high rate of machinability; if deep drawn, a low rate of work hardening.

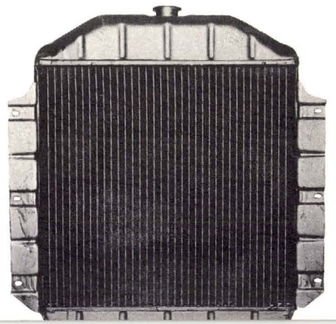
Forms and tempers may also contribute to the selection. Copper and its alloys are available in many forms (sheet, rod, tube, etc.), and for each of these there is a variety of tempers. It is not always possible to produce each alloy in all forms. For instance, an alloy may be malleable enough to roll into thin sheets or strips, and yet it may lack ductility and therefore cannot be readily drawn into wire. Sometimes an alloy can be rolled when hot, but not when cold, while other alloys are more readily rolled cold than hot. Some alloys cannot be hot-rolled at all.

Similarly, strength, joining qualities, or additional factors may also enter into the ultimate selection of a copper or an alloy.

Copper application is wide and varied: water heater, radar parts, auto radiator.







PROPERTIES OF COPPER AND ITS ALLOYS

THOUGH COPPER CAN BE BLENDED with many other metals to make available to industry a broad range of useful alloys, it is one of the few common metals also widely employed in the commercially pure form. This is due to innate properties that enable this metal to conform easily to the complex demands of modern industry.

Chemical properties. In the periodic classification of the elements, copper lies between nickel and zinc, and is in sub-group I (copper, silver, gold). Its atomic number is 29 and its atomic weight is 63.57. Of the ten transition elements, it is number nine, falling between calcium and gallium. In the electromotive series, copper lies below hydrogen, and thus does not displace this element from solution. It lies below iron, zinc and lead, and these metals will displace copper from solutions of its salts.

Copper is readily soluble in oxidizing acids, or in acids in the presence of other oxidizing agents (example: nitric acid or sulfuric acid and ferric sulfate), but it is not soluble in acids with the evolution of hydrogen. It possesses very high resistance to the action of sea water and the atmosphere. When it is exposed to the atmosphere for long periods, a thin coating of basic copper-sulfate or carbonate is formed. This coating, which beautifies copper roofs and statuary, is called patina, and is an attractive green color.

Physical and Mechanical properties. Though not exceptionally strong or hard, copper can be strengthened and hardened by cold working. For example, soft copper varies in tensile strength from about 30,000 to 36,000 pounds per square inch. Severe cold working will increase this figure to a maximum of 70,000 pounds. Ductility (copper is one of the most ductile of metals) is reduced by cold working, but annealing will restore it. In the annealing process, a group of equiaxed crystals are formed in place of the elongated crystals produced by cold rolling or drawing.

Because it has no allotropic forms, copper has no critical temperature at which changes occur in its crystalline grain structure. Copper may be formed or hot rolled at any temperature above the recrystallization temperature and below the melting point without hardening.

Among its more important properties are high electrical and thermal conductivity, excellent corrosion resistance, ease of fabrication, reasonable tensile strength, high ductility, controllable annealing qualities, good soldering and joining characteristics, and suitability for electroplating, finishing and polishing.

Copper classification. A number of terms are used to identify this reddish, non-magnetic metal. *Electrolytic Copper* and *Fire-Refined Copper* refer to the refining method.

The former is refined by electrolytic deposition, the latter by furnace process only. *Tough Pitch Copper, Deoxidized Copper* and *Oxygen-*

froth, permitting waste material to drop out into the "cleaner tailings." The latter is pumped back into the rougher flotation tanks to capture any unclaimed copper minerals. Waste tailings from the rougher flotation tanks are passed into a tailings thickener[9] where some of the water is removed for reuse, and the thickened waste is mechanically discharged and flows to dumps.

Concentrate thickening. Product from the cleaner tanks is enriched copper concentrate containing considerable water. To reduce the water content, the concentrate is fed into a similar mechanical thickener.[10] The solids of the concentrate settle to the bottom, forming a heavy sludge. A slowly revolving submerged rake moves the sludge to a center cone.

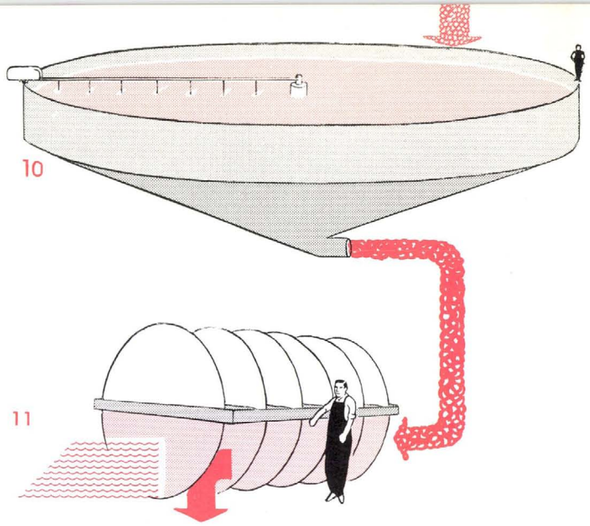
Filtering. The sludge is then automatically removed and delivered to a vacuum filter.[11] All but about 10 percent of the remaining water is removed by the filter, the remaining concentrate —a filter cake—is discharged and conveyed to storage beds to await smelting.

Remarks. All concentration operations do not necessarily duplicate the procedure described here. Because of technological and economic considerations there are many variations. In some mills dry or wet crushing rolls are substituted for the third grinding stage. In others, flotation is inserted between the primary and secondary grinding stages, with the classification, regrinding and flotation tailings. Or, in some instances, the final copper concentrates are reground and passed through selective flotation to recover molybdenum. And so on.

SMELTING

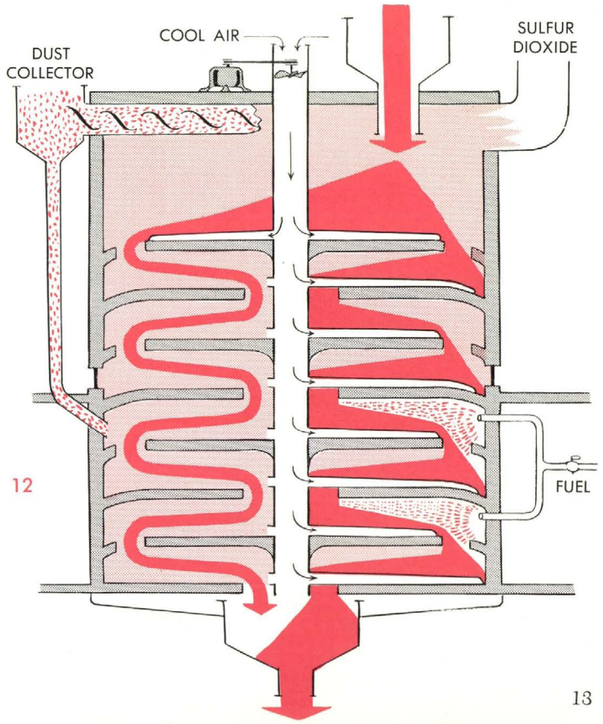
MANY IMPURITIES, including precious metals, bismuth, antimony, zinc, arsenic, and mineral pyrite FeS_2, are often present in sulfide ores in company with an excess of sulfur. Before smelting, some of the volatile impurities are removed, and the sulfur-copper ratio adjusted by roasting. Primary purpose of roasting is to eliminate part of the sulfur and to preheat the concentrates for smelting.

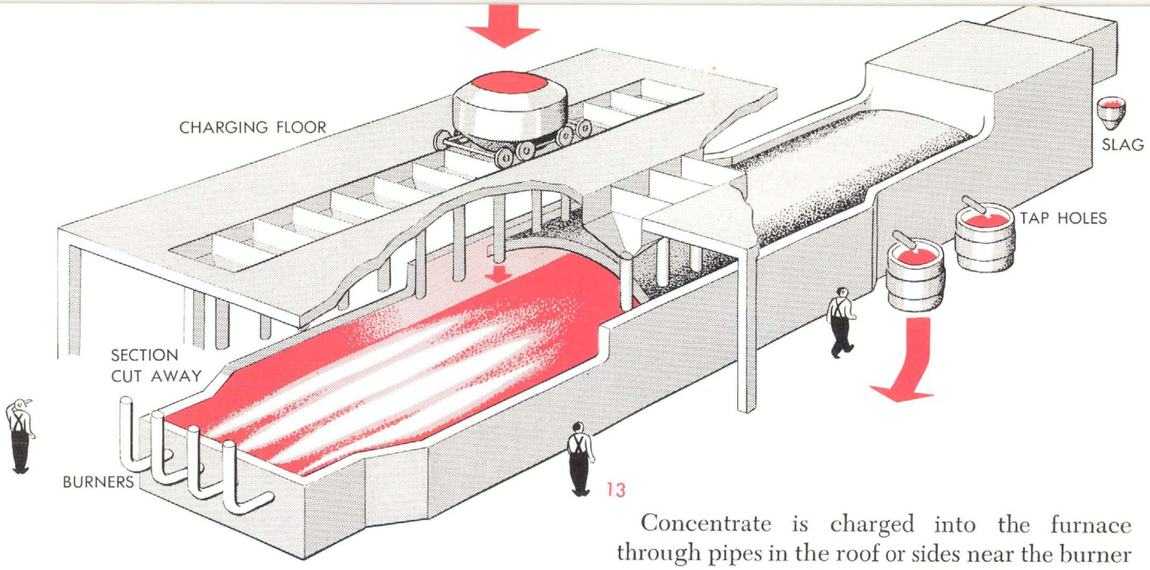
Roasting. The roasting process is performed in multiple-hearth furnaces at temperatures ranging from 1200-1380°F, high enough to par-



tially volatilize such impurities as antimony and arsenic and to oxidize the desired amount of sulfur.[12] These materials are removed from the solid charges as gases. The quantity of sulfur released is controlled by adjusting the temperature and the amount of air admitted.

There are several variations of multiple-hearth furnaces. A basic design consists of a refractory-lined vertical shell with a central shaft. The furnace is divided into from 8 to 12 hearths. Concentrate is fed to the top hearth, and a system of arms and rakes attached to the central revolving shaft slowly moves the material across the hearth from the center to the outside where it is discharged through the openings to the hearth





below. This is a continuous operation, the material passing from hearth to hearth until the final product is ejected into a hopper beneath the furnace. Once the furnace has been brought to the roasting temperature, the burning sulfur will maintain the temperature without the aid of additional fuel.

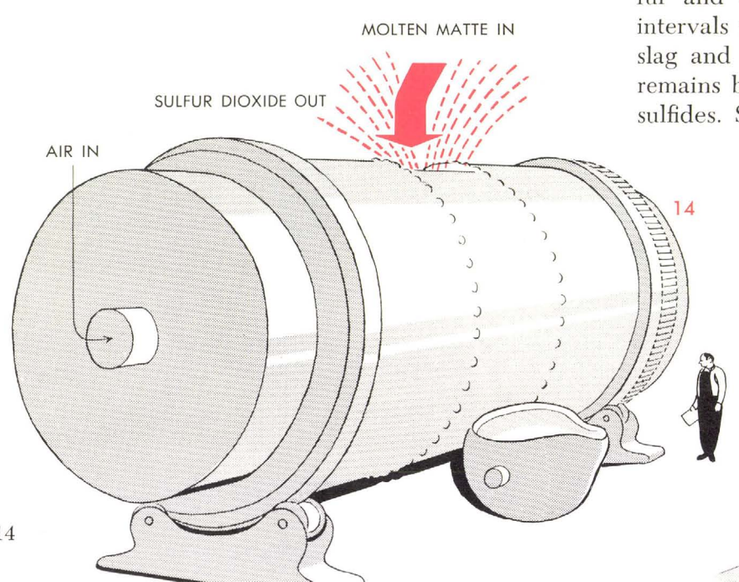
Smelting. Reverberatory furnaces are almost universally employed in the smelting operation. Long, low, massive structures, they are ordinarily constructed with reinforced silica brick walls and silica or magnesite brick roofs either of a suspended arch or sprung-arch type.[13] Furnace-firing is accomplished by oil, gas or pulverized coal blown directly into one end of the chamber with an air blast. The flame burns fiercely and it can be controlled to maintain the proper temperature of 2500-2700°F. The arch of the reverberatory furnace at the stack end reflects heat back into the chamber.

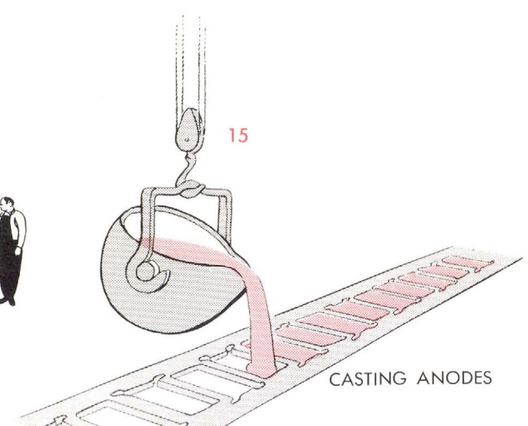
Concentrate is charged into the furnace through pipes in the roof or sides near the burner end, where it melts, and collects in a molten pool. Chemical reactions induced by fluxes (most common are limestone and silica), occur in the mass with the result that a fluid waste material, termed "slag," forms and rises to the top.

Slag is periodically drawn off and is usually discarded. The heavier iron and copper sulfides settle to the bottom in an impure mixture called "matte." Matte is tapped from the furnace as it is needed for subsequent operations.

Converting. This is a term applied to the final step of reducing the original ore to metallic copper. Huge overhead cranes transport molten matte to a converter—a large, refractory-lined, horizontal cylinder—where it is charged through a top opening.[14]

Slag-forming material (silica) is added, and air is blown through the mass by means of a series of tubes (tuyeres) in the side of the converter (furnace), burning off any remaining sulfur and oxidizing and slagging the iron. At intervals the converter is revolved to draw off slag and add more matte. Ultimately nothing remains but molten copper with some residual sulfides. Slagging is stopped, but the injection





ingot makers.

Ingot makers. The principal scrap product is alloyed ingot metal. Because of the diversity of sizes, shapes, and consistencies of the aggregate making up a furnace charge, the smelting procedure is complicated. However, scientific techniques have been developed to assure a high degree of purification without loss of alloying elements during refining. Aside from these factors, the procedure is roughly similar to that described in the section dealing with primary copper production.

In the first operation of the presmelting stage, skilled workmen sort the scrap, piece by piece, in lots in accordance with the forty-one copper and brass scrap classifications employed by the industry. Some classification is also performed by a magnetic separator. Separations are made on the basis of color, hardness, magnetic properties, etc. A representative sample of each lot is then melted and assayed to determine the chemical composition. A metallurgist then prepares a furnace charge in such proportions of the various grades of material to assure the required chemical, physical and mechanical properties in the particular alloy desired.

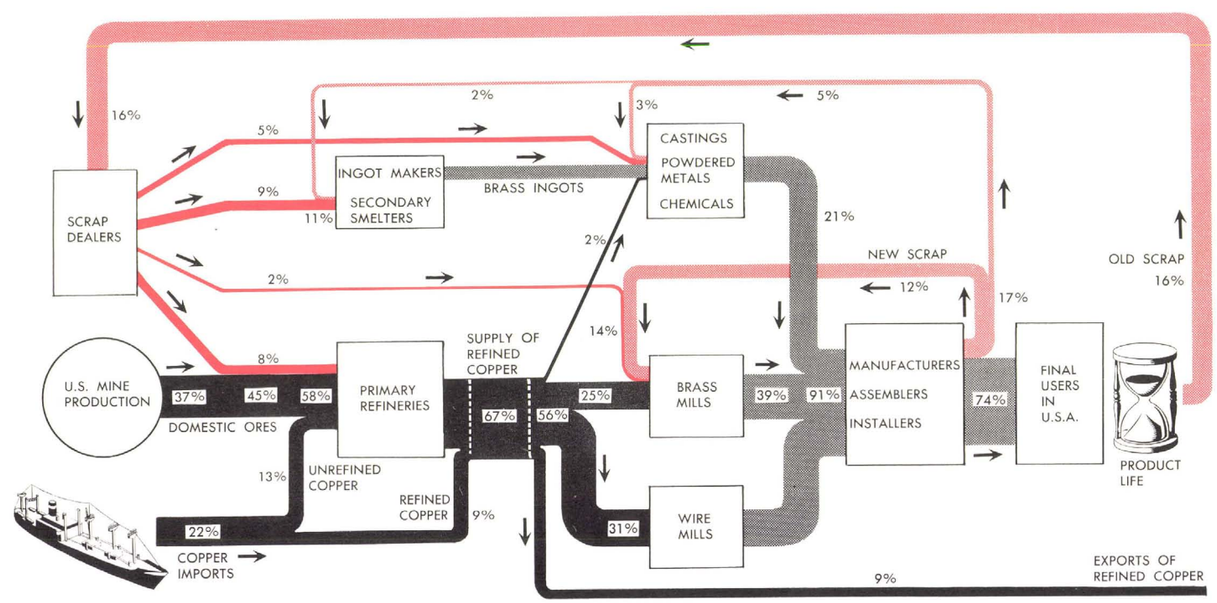
The various bronzes and brasses produced are usually cast into ingots for shipment to foundries where bronze and brass castings are made. In some instances, ingot makers cast special shapes such as billets for brass mills.

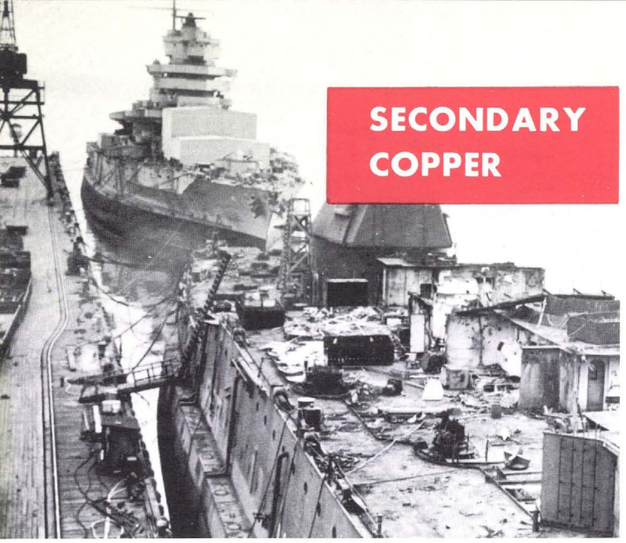
Secondary copper is vital. Since the First World War, the contribution of the secondary and copperbase alloy industry to the whole of non-ferrous metal production has grown enormously. This growth is a consequence of improved methods of copper recovery plus more rapid obsolescence of installations involving copper in this fast-changing era.

In 1925, the total production of secondary copper amounted to 420,000 short tons, roughly 50 percent of the new primary copper mined that year. During World War II, total secondary production averaged 940,000 short tons per year, equalling mine production in the top year of 1943, when the output of new copper climbed to 1,086,000 tons.

Domestic consumption of primary copper for the five-year period 1952-56 averaged 1,442,000 short tons annually. In the same period, total secondary copper recovered averaged 847,000 tons annually. With regard to conservation of mine resources the latter figure is significant; it represents the extra quantity of primary copper that it would have been necessary to supply if no recovery from scrap metal had been made.

The sources of distribution of secondary (red) and primary (black) copper. This chart was prepared on the basis of figures in the 1959 Copper Industry Report #3 of the U. S. Department of Commerce, Business and Defense Services Administration. The percentages are derived from an average of the years 1948 to 1958 inclusive. The diagram has been simplified by the elimination of many small lines. Of the *refined* copper consumed in this country, the Brass Mills use 44 percent, the Wire Mills 53 percent, and Foundries and Others 3 percent (averaged over the 1948-1958 period inclusive).





SECONDARY COPPER

Obsolete naval vessels are valuable sources of scrap copper.

Copper Is Virtually Indestructible. Except when put to such applications as fungicides and salts, or when located in soils of high acid content, it has a high reclamation value. Thousands of products made from it or its alloys eventually become obsolete or unserviceable and are reduced to scrap, but the metal values can be recovered again and again. The copper content of the reclaimed metal is termed "secondary copper."

A given mass of copper may have traveled through a cycle of scrap dealer—smelter—foundry—consumer many times, yet, through modern handling techniques, segregation, scientifically controlled smelting and refining, the same metal reappears in usable form without suffering chemical and physical deterioration. Approximately 60 percent of the copper entering our economy is ultimately recovered in this manner. The cycle of copper usefulness, from consumer to scrap pile, it has been estimated, averages 35 years.

Divisions and sources of scrap. Secondary copper is recovered from two classes of raw material: (1) new scrap from the many industries that fabricate brass and wire mill products, and (2) old scrap from discarded copper and copper alloy products.

New scrap. In mills and shops where primary copper and its alloys are fabricated into finished products, scrap accumulates in the refuse bins in many forms and shapes—defective castings, punchings, boring, clippings and turnings.

Old scrap. Obsolescence, wear and damage annually consign to the scrap metal heap thousands of objects—automobile radiators, worn out kitchen utensils, old pipe, wire, cable, fired cartridge cases, printing plates, and so on, from which secondary copper is obtained. Large tonnages of scrap metal are recovered during the demolition of industrial plants, factories, and other commercial and private structures, and the dismantling of obsolete naval vessels and ocean liners.

Ratio of old scrap and new. Prior to World War II, old scrap constituted anywhere from two-thirds to three-quarters of the total supply of scrap. This figure changed during the war when the heavy consumption of primary copper resulted in greatly increased tonnages of new scrap to the extent that in the years of top consumption more new scrap than old was generated. In the reconversion and accelerated production years following the war, however, old scrap assumed a slight lead as source, a position which it still maintains.

Strictly speaking, the metal reclaimed from new scrap does not actually increase the domestic supply for it has already been accounted for as a primary material before becoming scrap. It recirculates to brass mills, secondary refineries, ingot makers and other processors. Old scrap, on the other hand, having been subtracted from the available supply when first manufactured, constitutes an additional source when it appears for reprocessing after having served a useful purpose.

Scrap application. Commercial grades of scrap come in many sizes, shapes, and consistencies, running the gamut from turnings and borings to industrial castings. The bulk of new scrap is forwarded to brass mills for reprocessing; the remainder goes to foundries, ingot makers and secondary refineries. The latter two operations, especially the ingot makers, also consume the major portion of old scrap. Primary refineries, brass mills and foundries account for the rest.

Refined high grade unalloyed copper (which enters the flow of refined copper) is produced by the secondary refineries; alloyed ingots by the

of air is not interrupted, the oxidation continuing until most of the sulfur has been removed and molten copper, 98 percent pure, remains.

It is then immediately conveyed to a refining furnace for further elimination of impurities, particularly sulfur, or, if the refinery is at a distance, it may be cast into solid cakes called "blister" copper, for shipment. The converter slag contains a residual amount of copper and is retreated in a reverberatory furnace. However, most smelters cast anodes for refinery shipment.[15]

REFINING

To Meet the Demand of modern fabrication mills and the electrical industry, copper containing less than 0.01 percent metallic impurities is produced by electrolytic refining.

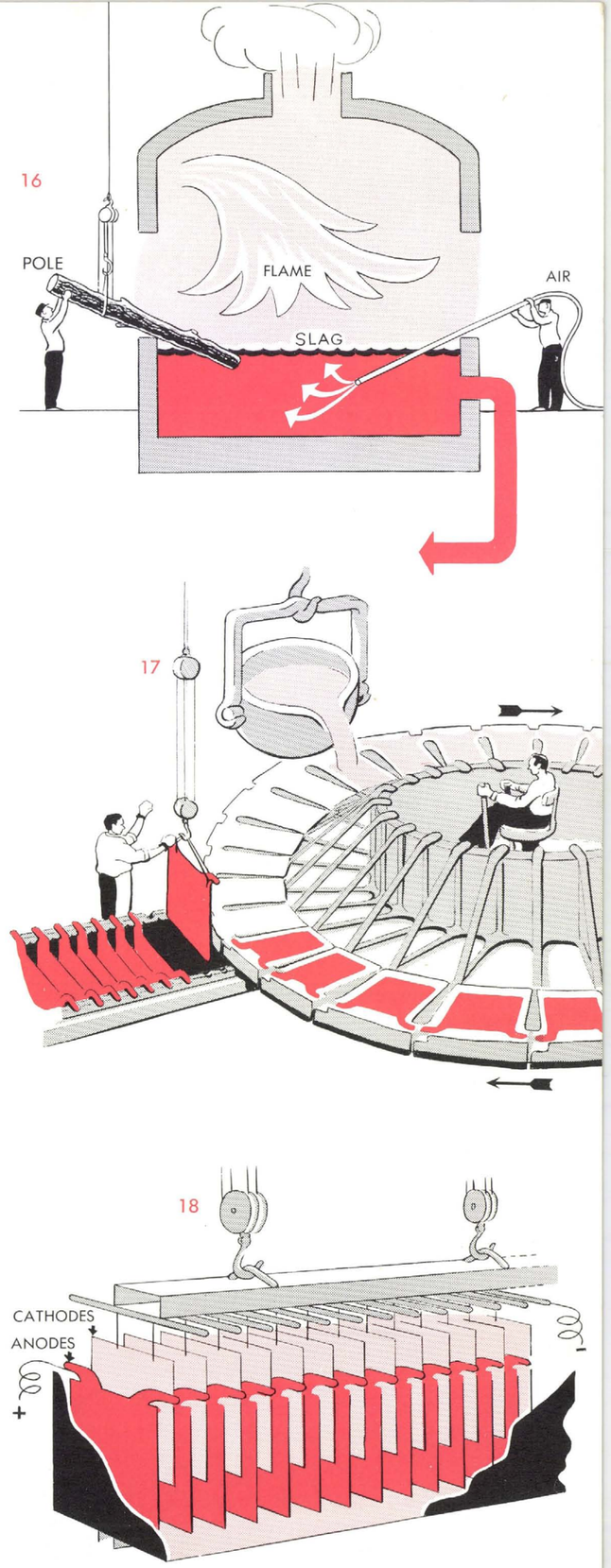
Blister copper, in addition to copper oxide and residual sulfur, contains minute amounts of foreign substances. In preparation for electrolytic refining, it is further purified in either of two types of fuel-fired anode furnaces: (1) a reverberatory type for refining solid blister, (2) a cylindrical type for molten blister.[16] With the exception of charging and melting steps, the refining process of both types are similar.

Compressed air is forced through the pool of molten blister in the furnace via iron pipes. Impurities are oxidized and are either eliminated as gases or are collected in a slag, and then skimmed off. The blowing also oxidizes a certain amount of the copper. Deoxidation is accomplished through an operation known as "poling."

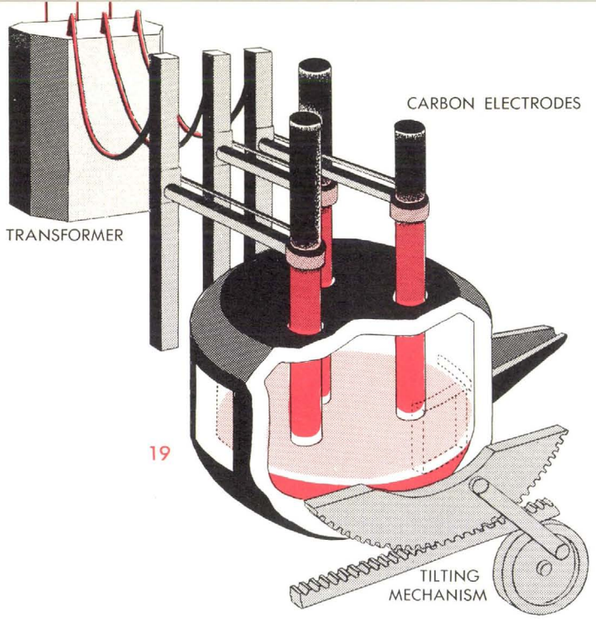
Coke is strewn over the surface of the molten pool and the heavy ends of green logs are thrust into it. The combined reducing action of the wood coke removes most of the oxygen from the metal.

The resulting metal is impure "tough pitch" copper. Cast into shapes called "anodes," it is shipped to an electrolytic refinery for the final purification.[17]

Electrolytic refining. The impure copper anodes are suspended between "starting sheets" —thin plates of pure copper—called cathodes, and immersed in long tanks containing a solution of copper sulfate and sulfuric acid—an electrolytic bath.[18] Under the action of an electrical



ELECTROLYTIC REFINING TANK



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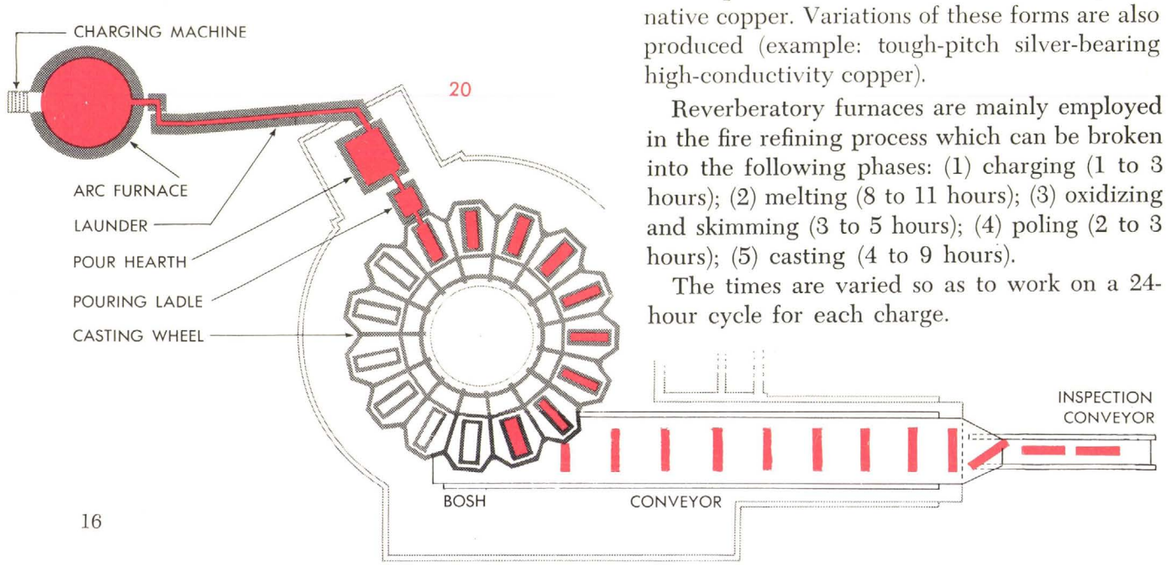
current passed through the bath, copper dissolves from each anode, or positive plate, passes into the solution where it separates from the impurities, and is deposited on a cathode, or negative plate. Usually, 28 days are required to consume an anode and 14 days to produce a finished cathode. Copper ore commonly contains small amounts of gold, silver and other precious metals and by-products which are picked up by the copper during smelting. Their recovery from the anode slime at the bottom of the tank constitutes a profitable sideline of the electrolytic process.

The cathodes with their deposits of almost pure copper are melted either in electric arc furnaces[19] or in fuel fired furnaces (the latter process is similar to the one described under "Fire Refining").



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In charging an empty electric furnace, an initial bath is formed by the transfer of molten metal to the furnace. If no such metal is available, sheetscrap is melted down and used.

An example of a wire bar casting operation in conjunction with an electric furnace is illustrated in fig. 20. Selected cathodes are mechanically charged at calculated intervals according to the desired melting rate. From the furnace, the molten metal is channeled through the enclosed preheated launder – which contains a trough covered with fireclay brick and asbestos sheet–into the pour hearth, a holding vessel. Then it is poured into the ladle and subsequently into a series of vertical water-cooled molds in the casting wheel. Lastly, the wire bar castings are turned out in the cooling bosh conveyor and carried to the inspection conveyor.

The refineries cast all the various shapes necessary to meet the needs of the fabricating or wire mills.[21] Through special treatment during the melting process, oxygen-free copper may also be produced.

About 85 percent of all copper is electrolitically refined. From ore to cathode, conditions being normal, the process takes about three months, and requires the utilization of equipment and transportation facilities costing millions of dollars.

Fire refining. In addition to the blister copper refined and cast into anodes in preparation for electrolytic refining, a small percentage of it is fire-refined to produce two forms of marketable copper: (1) tough-pitch of normal purity; (2) tough-pitch of high conductivity from selected qualities of blister or from Lake Superior native copper. Variations of these forms are also produced (example: tough-pitch silver-bearing high-conductivity copper).

Reverberatory furnaces are mainly employed in the fire refining process which can be broken into the following phases: (1) charging (1 to 3 hours); (2) melting (8 to 11 hours); (3) oxidizing and skimming (3 to 5 hours); (4) poling (2 to 3 hours); (5) casting (4 to 9 hours).

The times are varied so as to work on a 24-hour cycle for each charge.

Some impurities are passed into the slag by oxidization or removed by volatilization; subsequently, the excess oxygen is eliminated and the gas contents controlled. Though many impurities are removed, gold, silver, and other traces remain.

Refinery shapes. The various coppers produced by refineries are cast into standard shapes for shipment to the fabrication mills.[21]

Wire bars: In cross-section, they are about 3½ x 5 inches, up to 54 inches in length, and normally weigh from 175 to 420 pounds. For fabricating into rod, and subsequently wire, both ends are tapered or pointed.

Cakes: Cast either continuously in water-cooled vertical molds or horizontally in open tray molds, they are rectangular or square in shape, and are used for rolling into plate, sheet, strip or other forms. Weight ranges from 140 to 4000 pounds.

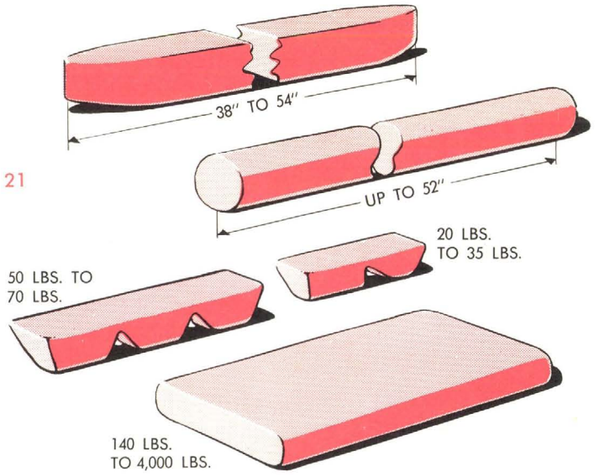
Billets: Circular in cross-section, with diameters usually ranging from 3 to 10 inches, and varying lengths up to 52 inches, they are used for the manufacture of tubes by either piercing or extrusion. Weight ranges from 100 to 1500 pounds.

Ingots and ingot bars: These castings are not used for direct fabrication, but are remelted to produce copper and copper-alloy castings. Cast in open horizontal molds, the ingot bars weigh 50 to 70 pounds, and ingots 20 to 35 pounds.

° ° ° °

Leaching. A smaller percentage of the world's copper is extracted by leaching. Briefly, this process consists of treating the ore with a suitable solvent (water, water-acid, sulfuric acid, are typical leach solutions) which will take the copper into solution and leave a good share of the undesired material unaltered. Subsequently, fairly pure copper is recovered from the leach solution by either chemical or electrolytic precipitation, or by smelting.

Of the several leaching methods, percolation is by far the most widely applied. The process is diagrammed in fig. 22. Represented is a cross-section of one of a battery of concrete, lead-lined leaching tanks. Reduced to essentials, the percolation method is as follows: The tanks are filled with ore (previously crushed) via an overhead ore car. A leaching solution is pumped into



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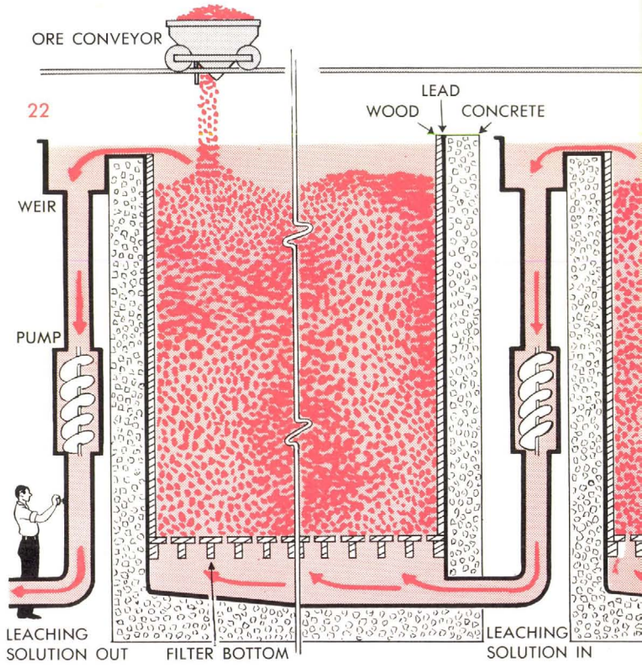
the first tank. It flows down to the bottom, and then moves up through the filter, percolating through the ore. At the top of the tank it overflows into a weir. Subsequently it is drained and pumped into the bottom of the next tank and the process is repeated. The tanks receive successive applications of the solution until the copper separation has been completed.

The solution is treated for removal of all impurities and the copper recovered by either chemical or electrolytic precipitation. Dissolved copper remaining in the residual material in the tanks is removed by a series of wash solutions and chemically recovered. Lastly, the tanks are emptied of the residual material.



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