# COPPER

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World production of copper from primary and secondary sources was higher than in 1988 and nearly in balance with the record 10.9 million metric tons of copper consumed. Copper consumption grew largely owing to increased consumption by the semifabricating plants of Asia and Europe. Copper demand by U.S. wire and brass mills remained at about the same level. Copper mine supply was constrained by disruptions in Africa, Canada, Mexico, and Papua New Guinea. Most of the production gains reflected continued expansions at mines in Chile and the United States. At yearend, visible refined inventories increased slightly to an estimated 634,000 tons, slightly less than 4 weeks of market economy countries (MEC) consumption.[1] The U.S. producers' delivered price averaged $1.31 per pound, which offered considerable profits for most producers, who were benefiting from cost-cutting of the recent past.

With higher prices and funds available for investment, announcements of new projects and intentions to reopen older mines were commonplace. Exploration expenditures for copper were at the highest level in several decades, particularly in Canada, Chile, and the United States. Rationalization of the industry continued with mines and plants changing owners and companies adapting marketing strategies to the changing international flow of copper.

## LEGISLATION AND GOVERNMENT PROGRAMS

### Copper Study Group

During a negotiation session in Geneva, Switzerland, February 20-24, an agreement was reached on the terms of reference for the formation of an International Copper Study Group. Formation of the study group had been initiated more than 2 years previously by the United States. According to the terms of reference, the organization could come into existence if a sufficient number of countries, accounting for at least 60% of world trade in copper, notified the United Nations Conference on Trade and Development of their intention to join the group by June 30, 1990. However, if the trade represented by those signifying their intent to join fell short of 60%, the interested countries could decide among themselves to inaugurate the study group anyway. The agreement also provided for 3-year temporary or provisional memberships, which allowed interested countries to join without making an initial long-term commitment.

### State Legislation

Following months of debate, Nevada State Legislature approved the first mined lands reclamation laws in the State's history. Assembly Bill 958, passed on June 24, gave enforcement responsibility to the Nevada Div. of Environmental Protection and created several funding mechanisms to support administration of the program. One fund would pay the cost of administering the abandoned mines hazard abatement program, which would be the responsibility of the Nevada Department of Minerals. The bill required that the mining industry pay for all of the State's costs associated with administering and enforcing reclamation laws.[2]

The U.S. Supreme Court upheld a lower court ruling that found a 5% cap on royalties paid by companies in Arizona to mine State trust lands deprives the State of its fair share of minerals value. The ruling was expected to result in Arizona passing new mineral leasing laws that would order higher royalty payments for minerals mined on nearly 10 million acres of land granted to the State by the Arizona Enabling Act of 1910.

Montana State Bill 410 was expected to end the longstanding differences of opinion between mining companies and the State Department of Revenue. The bill proposed to increase the gross proceeds and metal mines license tax. Instead of a sliding-scale based on gross value of metals produced, currently ranging from 0.5% to 1.5%, the tax would be raised to a flat 1.8% rate. Mines would no longer pay a separate fee into the Resource Indemnity Trust (RIT) Fund, but a portion of the flat fee would go into the RIT account. Instead of the General Fund getting two-thirds and the Hardrock Trust getting the remainder, the revenue would go 61.5% to the General Fund, 8% to the Hardrock Mining Impact Trust Account, 15.5% to RIT, and 15% to the area of production. The bill reportedly had broad industry support.[3]

### Trade Legislation and Actions

In an official exchange of letters with the United States, the Commission of the European Community (EC) agreed not to propose renewal of quotas on the export of scrap and waste of copper and copper alloys. As a result, all quotas and systems of licensing associated with scrap exports expired on December 31, 1989. In return, the United States agreed to end a General Agreement on Trade and Tariff (GATT) grievance that had been filed in response to a November 1988 petition by the U.S.

TABLE 1

## SALIENT COPPER STATISTICS

(Metric tons unless otherwise specified)

| | | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|
| United States: | | | | | | |
| Ore produced | thousand metric tons | 165,190 | 172,476 | 202,632 | [r]223,576 | 237,262 |
| Average yield of copper | percent | 0.61 | 0.60 | 0.57 | 0.60 | 0.62 |
| Primary (new) copper produced: | | | | | | |
| From domestic ores, as reported by: | | | | | | |
| Mines | | 1,104,823 | 1,144,213 | [r]1,243,596 | [r]1,416,928 | 1,497,458 |
| Value | millions | $1,631 | $1,666 | $2,262 | [r]$3,764 | $4,323 |
| Smelters | | 939,257 | [1]908,087 | [1]972,141 | [1]1,042,954 | [1]1,120,445 |
| Percent of world total | | 11 | 10 | 11 | 12 | 12 |
| Refineries | | 1,003,713 | [r] [2]1,073,981 | 1,126,908 | [2]1,406,020 | 1,351,748 |
| From foreign ores, matte, etc., as reported by refineries | | 53,528 | W | W | W | 125,085 |
| Total new refined, domestic and foreign | | 1,057,241 | [r]1,073,981 | 1,126,908 | 1,406,020 | 1,476,833 |
| Refined copper from scrap (new and old) | | 371,787 | 405,944 | 414,738 | [r]446,427 | 476,918 |
| Secondary copper recovered from old scrap only | | 503,407 | 477,469 | 497,937 | [r]518,179 | 543,596 |
| Exports: | | | | | | |
| Refined | | 37,937 | 12,452 | 9,197 | 58,325 | 130,189 |
| Unmanufactured[3] | | 435,000 | 442,000 | 387,000 | 557,000 | 721,000 |
| Imports for consumption: | | | | | | |
| Refined | | 377,725 | 501,984 | 469,159 | 331,671 | 300,110 |
| Unmanufactured[3] | | 443,932 | 697,523 | 568,448 | 511,360 | 515,000 |
| Stocks, Dec. 31: Total industry and COMEX: | | | | | | |
| Refined | | 320,000 | [r]224,000 | [r]112,000 | 98,000 | 106,000 |
| Blister and materials in solution | | 146,000 | [r]136,000 | 150,000 | [r]121,000 | 132,000 |
| Consumption: | | | | | | |
| Refined copper (reported) | | 1,976,038 | 2,102,625 | 2,125,699 | [r]2,210,424 | 2,203,143 |
| Apparent consumption, primary and old copper (old scrap only) | | 2,144,436 | [r]2,136,982 | 2,196,807 | [r]2,211,545 | 2,182,349 |
| Price: Weighted average, cathode, cents per pound, producers | | 66.97 | 66.05 | 82.50 | 120.51 | 130.95 |
| World: | | | | | | |
| Production: | | | | | | |
| Mine | thousand metric tons | [r]7,988 | [r]7,993 | 8,306 | [p]8,537 | [e]8,887 |
| Smelter | do. | [r]8,630 | [r]8,816 | 8,923 | [p]9,285 | [e]9,535 |
| Refineries | do. | [r]9,408 | [r]9,602 | 9,833 | [p]10,332 | [e]10,727 |
| Price: London, Grade A, average cents per pound[4] | | 64.27 | 62.28 | 80.88 | 117.92 | 129.15 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Includes production from foreign ores and concentrates.

[2]Includes primary copper produced from foreign ores, matte, etc., to avoid disclosing company proprietary data.

[3]Includes copper content of alloy scrap. Export and 1989 import copper content of alloy scrap were estimated from gross weight.

[4]High-grade prior to 1988.

Copper and Brass Fabricators Council (CBFC). The CBFC charged that the EC scrap quotas were a violation of GATT and were having adverse impacts on domestic producers.

In response to an industry petition by the Non-Ferrous Metals Producers Committee, the U.S. Trade Representative, and the Department of Commerce in a joint decision, determined that both the primary copper and lead industries should be identified under Section 409(b) of the 1988 U.S.-Canadian Free Trade Agreement Act of 1988. In the decision, it was found that these industries may face increased imports of subsidized copper and lead products from Canada once tariffs were lowered according to the Free Trade Agreement, and that deterioration of the competitive position could occur. Based on 409(b) identification, the industry could ask for assistance under the trade laws.

## ISSUES

### Mine and Plant Labor

Productivity at all mines that produced copper as a principal product was 19.6

worker-hours per ton of recoverable copper produced by open pit, underground, and leach methods. Average productivity, including mine, mill, and leach operations was 41 worker-hours per ton for five operating underground mines and 17.7 worker-hours per ton of recoverable copper for 15 open pit mines. Total workers at U.S. mines and mills averaged 12,400 in 1989. Arizona (8,514 workers) led in average number of mine and mill workers, followed by New Mexico (1,487 workers) and Utah (1,084 workers).

The number of union members in the U.S. nonferrous metals industry, including the copper industry, decreased in recent years. The ties of workers to unions were weakened by frequent mine closings, wage concessions, and effects of a poor economy over long periods of time. When mines were acquired by new owners, such as at the Sierrita Mine in Arizona and the Continental East Mine in Montana, new working systems were set up with the workers opting not to reinitiate union rules. Job classifications at both mines were reduced from several hundred to fewer than 15, and workers were offered raises for learning multiple jobs. Small group seminars emphasized healthy working relationships, and at regular meetings, managers sought employee advice. At many mines, management layers were streamlined and managers became multidisciplined, as did workers.[4] At some mines, employees participated in profit-sharing plans, such as at Montana Resources Inc.'s Continental East Mine, where it amounted to 10% of pretax net profits. Otherwise, a unified salary rate of $9.73 per hour (about $20,000 per year) prevailed for the Continental East workers.

In May, workers at the Troy Mine, MT, voted not to accept the United Mine Workers of America (UMWA) as their collective bargaining agent. The UMWA won certification in 1987, but efforts to negotiate a contract with ASARCO Incorporated failed. Late in 1988, an employee group mounted a petition calling for a new election and Asarco withdrew its recognition of the union and stopped contract talks. The National Labor Relations Board ruled against UMWA charges that Asarco unlawfully withdrew union recognition.

Labor contracts with Magma Copper Co. and Asarco were set to expire July 1, 1989, but both were replaced with new agreements that increased base wages and various benefit plans. Asarco and the United Steel Workers union settled on a new 3-year contract covering 1,600 employees that included wage increases of $1.85 per hour over 3 years; an increase in pension payments of $4.00 per month for each year of service; and additional death and dismemberment insurance. Although the wages were slightly higher than before the pay was slashed in 1986, the cost-of-living clause in the contract remained suspended. Magma agreed to increase the weighted average base wage for 3,100 hourly employees by $1.00 per hour in the first year and 25 cents in the second and third years. A premium of 0.6% was to be added to base wages as copper prices varied in 5 cent increments above 95 cents per pound, capping at $1.70 per pound.

Although statistics show that many metal companies were tying employee wages to incentive bonuses as a means of rewarding higher production when profits were high and limiting costs during slow periods, some copper producers reportedly seemed to be reluctant to institute such plans.[5] It was estimated that 75% of all gain-sharing plans in the U.S. mining industry had been installed in the past 5 years. A variety of factors was used to calculate bonuses. Production was most often used in determining bonus size, but safety, ore grade, development advance, cost savings, profits, commodity price, and housekeeping were also used. Penalties were commonly included to encourage safety. Magma arranged to give its employees bonuses linked to copper prices and established production targets; even so, the company eventually found this plan placed Magma in the position of being among the highest cost of U.S. producers.

Magma and labor unions attempted to resolve disputes concerning interpretation of the bonus rules that were part of the 1986 contract. In 1986, the unions had accepted large cuts in wages and benefits in exchange for certain productivity-based bonuses. Although Magma insisted that the production requirement only related to production arising from Magma's own operation, the union contended that ore processed by Magma for Cyprus Minerals Co. should have been included in the calculations for fulfilling production quotas. The bonuses were linked to the copper price and meeting 80% of Magma's production quotas. Magma announced that it would not pay fourth quarter 1988 and second quarter 1989 bonuses to its unionized workers because production and sales quotas under the plan were not met. An independent arbitrator ruled in favor of the company and determined that no bonus was due for the fourth quarter of 1988; arbitration of the 1989 bonus had not been settled.

Bonuses averaging $1,500 per person were paid in December 1989 to about 680 hourly employees at Cyprus Miami Mining Corp.'s copper operations. The bonuses were about equal to those paid in May 1989. The December bonuses were in recognition of achieving a record-breaking year in 1989. Cyprus Minerals announced that as of January 1, 1990, Cyprus Miami employees with at least 20 years of service would receive an additional week of vacation. Cyprus Miami had a total of about 1,020 workers.[6]

## Cost of Production

The weighted-average cash cost, including byproduct credits and taxes but excluding depreciation, of producing refined copper in the United States was estimated to have increased slightly to about 54 cents per pound in 1989, according to Bureau of Mines Minerals Availability System estimates. Including recovery of capital, the average production cost was 60 cents per pound.

Asarco reported that the cost to produce copper was higher in 1989 compared with that of 1988.[7] Startup difficulties with its new milling and concentrating facilities at the Mission complex in Arizona resulted in reduced production and higher costs. Production rates at the Hayden, AZ, smelter also did not meet expectations, thereby increasing costs.

Cyprus Minerals reported that inflation, especially in mining and processing costs, and increased costs and taxes resulting from Federal and State legislation and regulation, were making cost reduction more difficult.[8] The company planned major capital investments for plant and equipment modernization in 1990 to increase operation efficiency. Cyprus' mine production costs, including depreciation, averaged 68 cents per pound for the year, compared with 65 cents in 1988, according to the company annual report. The increase in 1989 was caused partly by price sensitive costs, such as employee incentive compensation plans and service costs associated with acquisitions, and partly by Cyprus' efforts to maximize production during the year. Average mine production costs reached a high of 76 cents per pound during the fourth quarter as a result of reduced recoveries at Twin Buttes Mine. Milling difficulties resulted from blending ores from four pits. Not only did the mill

TABLE 2

## PRODUCTIVITY[1] IN THE U.S. COPPER INDUSTRY, BY ACTIVITY

| | | 1985 | 1986 | 1987[r] | 1988[r] | 1989 |
|---|---|---|---|---|---|---|
| COPPER MINE PRODUCTION | | | | | | |
| Ore concentrated and leached | metric tons | 165,190,000 | 172,476,000 | 202,632,000 | 223,576,000 | 237,262,000 |
| Copper recovered | do. | 1,003,990 | 1,041,520 | 1,154,181 | 1,341,279 | 1,438,267 |
| Average yield of copper | percent | 0.61 | 0.60 | 0.57 | 0.60 | 0.62 |
| Copper from in situ leach | metric tons | 82,948 | 79,031 | 70,136 | 49,299 | 34,485 |
| Total production[2] | do. | 1,086,938 | 1,120,551 | 1,224,317 | 1,390,578 | 1,472,752 |
| MINE AND SX-EW PLANT LABOR | | | | | | |
| Average annual workers[3] | | 9,854 | 10,154 | 11,924 | 11,873 | 12,421 |
| Employee-hours worked | | 18,831,046 | 20,326,091 | 23,197,110 | 25,707,013 | 29,371,885 |
| PRODUCTIVITY AT MINES | | | | | | |
| (hours per ton) | | 17.32 | 18.14 | 18.95 | 18.49 | 19.94 |
| REFINED COPPER PRODUCTION | | | | | | |
| Electrolytic copper | metric tons | 1,231,612 | 1,241,309 | 1,276,933 | 1,525,470 | 1,541,542 |
| PRODUCTIVITY AT PLANTS[4] | | | | | | |
| (hours per ton) | | 9.15 | 10.27 | 9.48 | 8.19 | 8.17 |
| INDUSTRY PRODUCTIVITY | | | | | | |
| (hours per ton) | | 26.47 | 28.41 | 28.43 | 26.68 | 28.11 |

[r]Revised.
[1]Employee hours per metric ton mined and processed.
[2]Production from byproduct mines not included.
[3]Includes mine, mill, SX-EW plant, and administrative workers at copper open pit and underground mines. Construction workers and workers at mines developing, on standby, or care and maintenance are also included. Mines producing copper as a byproduct are not included.
[4]Bureau of Mines estimates based on unpublished Dept. of Labor data.

Sources: U.S. Department of Labor and Mine Safety and Health Administration. Bureau of Mines, production statistics.

recovery fall and costs rise, but more importantly, they were not able to produce copper for sale when prices were high. Recoveries at Miami were reduced because of mining in an area that contained a lower grade of oxide ore.

Cyprus Minerals also faced increased electricity costs at two of its operations. In a hearing held by the Arizona Corporation Commission, Cyprus Sierrita protested the full rate increase that Tucson Electric Power was seeking. The rate increase would cost the company an additional $7 million per year. It took 19 kilowatt hours of electricity to grind 1 ton of ore, and the mine processed about 30 million tons of ore annually. In addition, Cyprus Miami faced increased electricity charges from the Salt River Project with which the company had a long-term contract. The Salt River Project board voted in July to increase Cyprus Miami's fuel cost adjustment factor, causing it to increase by $285,000 per month. The fuel cost adjustment factor rose or fell with the price of fuel. The electrical contract was negotiated before Inspiration built the electric furnace at its smelter to comply with air quality standards.[9]

At Magma, costs were above budget as a result of mining lower grade ore to take advantage of the higher copper prices and an expanded development program. The company restarted limited development of the Kalamazoo ("K") ore body, which would extend the life of the mine, increase extraction tonnage, and improve overall mining costs. The new column cell technology used at the San Manuel concentrator proved cost effective, reducing energy and maintenance costs by 9.5% over the year. Cost efficiency was further improved through complete reinstrumentation of the concentrator for better process control.[10]

Phelps Dodge Corp. completed a $48 million in-pit crushing and conveying project at Morenci, AZ, which significantly reduced haulage costs in the pit. Expansions to the Morenci ($44 million) and Tyrone ($20.5 million) solvent-extraction and electrowinning (SX-EW) plants were also completed during the year. Costs at these plants were reported to be less than 30 cents per pound of copper. The corporation's average production costs for copper in 1989 were reported to be marginally higher than those of 1988 largely because of increased supply costs, total material mined, depreciation, and costs that derived principally from increased capital expenditures.[11]

At the White Pine Mine, MI, gains in efficiency were achieved through a 29% reduction in the work force over that of 1981 levels. As productivity increased, production costs dropped from a 2-year average in the early 1980's of 99 cents per pound, to 62 cents per pound mined and processed, before silver byproduct credits. Meanwhile, the ore grade dropped from 1.46% in 1979 to about 1.1% in 1989. Company efforts focused on modernizing equipment and mining methods. Over the next few years, about $5 million per year was to be provided annually for new underground equipment. New cost targets were set at or below 60 cents per pound.

### Industry Restructuring, Investments, and Earnings

U.S. copper mining companies continued to report record profits during the year. Ownership changes and company restructuring continued. With more money

TABLE 3

## ESTIMATED PRODUCTION COSTS AT PRODUCING COPPER MINES[1]

(January 1989 U.S. dollars per pound of refined copper)

| | Number of mines | Mine operating cost | Mill operating cost[2] | Smelter refinery cost[3] | (Less) byproduct credit | Net operating cost | Taxes[4] | Cash costs | Recovery of capital[5] | Total production cost[4] |
|---|---|---|---|---|---|---|---|---|---|---|
| Production costs:[6] | | | | | | | | | | |
| Australia | 3 | $0.34 | $0.15 | $0.20 | $0.17 | $0.51 | — | $0.51 | $0.09 | $0.60 |
| Canada[7] | 17 | .33 | .30 | .37 | .63 | .36 | — | .37 | .13 | .52 |
| Chile | 7 | .17 | .18 | .09 | .06 | .37 | $0.01 | .38 | .05 | .43 |
| Peru | 5 | .23 | .25 | .25 | .07 | .65 | .02 | .67 | .14 | .81 |
| Philippines | 7 | .32 | .40 | .26 | .42 | .56 | .04 | .60 | .10 | .71 |
| United States | 17 | .17 | .28 | .18 | .11 | .52 | .01 | .54 | .06 | .60 |
| Zaire | 4 | .27 | .14 | .25 | .29 | .37 | .01 | .38 | .03 | .41 |
| Zambia | 9 | .44 | .38 | .31 | .09 | 1.04 | .11 | 1.14 | .07 | 1.22 |
| Other | 40 | .30 | .29 | .30 | .36 | .53 | .01 | .55 | .21 | .76 |
| Total or average | 109 | .25 | .26 | .23 | .23 | .51 | .02 | .53 | .11 | .63 |
| Life-of-the-mine production costs:[8] | | | | | | | | | | |
| Australia | 3 | $0.55 | $0.26 | $0.25 | $0.40 | $0.66 | — | $0.66 | $0.09 | $0.75 |
| Canada[7] | 17 | .30 | .28 | .33 | .51 | .40 | — | .40 | .13 | .53 |
| Chile | 7 | .19 | .24 | .08 | .06 | .46 | $0.01 | .47 | .05 | .52 |
| Peru | 5 | .18 | .26 | .33 | .21 | .56 | .01 | .57 | .14 | .71 |
| Philippines | 7 | .26 | .34 | .26 | .24 | .63 | .03 | .66 | .10 | .77 |
| United States | 17 | .17 | .27 | .18 | .09 | .53 | .01 | .54 | .06 | .60 |
| Zaire | 4 | .27 | .14 | .22 | .22 | .40 | .01 | .41 | .03 | .45 |
| Zambia | 9 | .49 | .37 | .31 | .09 | 1.08 | .11 | 1.18 | .07 | 1.25 |
| Other | 40 | .31 | .38 | .30 | .38 | .60 | .02 | .62 | .20 | .82 |
| Total or average | 109 | .25 | .28 | .20 | .19 | .54 | .02 | .56 | .09 | .65 |

[1]Data may not add to totals shown because of independent rounding.
[2]Includes copper recovery by leaching.
[3]Includes cost of transportation and cost of byproduct and coproduct smelting.
[4]Taxes and production costs are at a zero percent rate of return and do not include State or Federal revenue based taxes.
[5]Average over life-of-the-mine capital cost.
[6]Based on annual production rates and ore grades for 1989.
[7]Includes INCO's and Falconbridge's Sudbury nickel-copper operations.
[8]Based on life-of-the-mine production rates and ore grades. Does not necessarily reflect 1989 operating grade and production.

Source: Bureau of Mines, Minerals Availability System (MAS) cost analysis. Prepared by Kenneth Porter.

available, interests shifted toward reinvestment, expansion, opening of closed mines, and renewed exploration efforts. Phelps Dodge, the largest producer, reported a net income of $267 million, including a write-down in the fourth quarter of certain non-producing assets. The assessed valuation of operating copper mines in Arizona reportedly increased 43% compared with 1988, to more than $860 million.[12]

Asarco reported an operating income of $206 million from the sales of copper. Over the past 4 years, Asarco concentrated on acquisition and ore reserve development to shift from being a custom smelter and refiner for others to being a fully integrated producer. In 1989, the company announced a $270 million project to expand production at Mission and Ray Mines by 40% with financing to come from company funds. Asarco acquired a 49.9% interest in Montana Resources Inc., a partnership that owned and operated the Continental East Mine in Montana, for $100 million and purchased the Pima, AZ, mill for about $6 million. Asarco also acquired a significant share in Mexicana de Cobre S.A. through its 34% share of Mexico Desarrollo Industrial Minero S.A. de C.V. (MEDIMSA). MEDIMSA acquired Mexicana de Cobre for $1.36 billion.

In May, Metall Mining Corp. of Toronto purchased the Copper Range Co. for $83 million. Each of the 1,000 workers received about $65,000 for their shares in the company. In addition, each employee will gain an additional $18 per share if the mine meets the 5-year production and efficiency goals set by Metall. It was announced that the Copper Range name, which originated in 1899, would be retained to preserve the historical significance of the company. Copper Range became the first wholly owned mining operation of Metall, which also held minority interests in several Canadian and Papua New Guinea operations. Metall Mining's parent company, Metallgesellschaft AG, based in the Federal Republic of Germany, retained a 62% interest in the Toronto company.

Cyprus Mineral's record earnings of $250 million after taxes was more than the combined earnings of the past 3 years, largely as a result of increased copper production and higher prices. Since the July 1985 spinoff from Amoco Minerals Co., Cyprus had made more than 20 acquisitions, including coal, copper, lithium, molybdenum, talc, and silver mines. Early in 1989, Cyprus acquired the Warrenton Refining Co., a Missouri producer of copper ingot and wirebar from scrap. By yearend, Cyprus had made arrangements to purchase MCR Product Co.'s copper rod mill in Chicago, IL.

Rio Tinto Zinc (RTZ) Corp. completed its acquisition of British Petroleum PLC's (BP) minerals group for $3.6 billion on June 30, 1989. The name Kennecott Corp. was restored as the official title of the properties. The primary asset of Kennecott was its Utah Copper Corp. Bingham Canyon Copper mine, smelter, and refinery in Utah. In 1989, Kennecott's expenditures were $200 million, of which $76 million was spent at Utah Copper. Plans for a second $227 million construction project at Bingham Canyon were announced. Construction was to begin in June 1990, with completion scheduled for the last half of 1992.

Magma had a record net income of $58.5 million. Earnings were stronger because of lower labor costs and higher copper prices. Magma's earnings included a $3.5 million pretax write-down of assets in the fourth quarter, related to the closure of the company's MCR Products' rod casting facility in Chicago, IL. A change in sales strategy toward increased cathode sales resulted in just 53% of Magma's 1989 production being sold as rod, compared with 93% in 1988. Of equal importance was the change in arrangements for procuring smelter feedstock, which now would include increased toll and purchased concentrates. The company was restructured into four operating divisions: the San Manuel Mining Div., Pinto Valley Mining Div., Superior Mining Div., and the Smelting and Refining Div.

Plexus Resource Corp., in a property exchange with Cyprus Minerals acquired the rights to the Bornite Project, a copper-gold-silver property about 45 miles east of Salem, OR. Cyprus acquired the rights to develop the Lyon property in Nevada, as well as a 2% share of the net proceeds from Bornite. Rio Gold Mining Ltd., a Canadian company, acquired the Hillsboro-Copper Flat Mine in New Mexico from Inspiration Development Co., the owner, and from Cobb Resources Inc., the lessee.

### Mine Environmental Issues

Several sites in Montana continued to be the focus of environmental concern during the year. The Montana Water Quality Bureau received a report about high concentrations of metals in water from seepage at a tailings impoundment site at Asarco's mine near Troy. A local environmental group reported an average of 0.0036% copper in water at several sites.[13] Atlantic Richfield Co. (ARCO) filed a motion in the U.S. District Court protesting the limitless cost responsibility for cleaning mine and smelter wastes located between Butte and Milltown Dam, just east of Missoula. ARCO wanted the court to dismiss a Federal lawsuit filed last June by the Environmental Protection Agency (EPA) to recover $6.3 million spent replacing the arsenic-polluted water supply at Milltown, relocating families at Mill Creek, and demolishing the Anaconda Smelter. ARCO reportedly had spent about $20 million in reclamation costs in Montana, mostly in the Butte area. The 6-year, $25 million cleanup of the site, which stretched from Silver Bow Creek in Butte to Milltown Reservoir near Missoula, was considered to be the country's largest and among the most controversial of the Superfund cleanup efforts.

Late in the year, Cyprus protested the proposed inclusion of two tracts, the Upper and Lower Burro Creek, into the Arizona wilderness system. Withdrawal of these two areas from development would have a significant impact on its $24 million expansion project and drastically reduce the Bagdad Mine's projected 30-year life. The New Mexico State Environmental Improvement Div. approved the Cyprus plan, estimated to cost $1 million, for revamping and reopening the Deming concentrator. Originally built as a custom concentrator for small regional mines, the plant also treated lead-zinc ores from the old Groundhog Mine. The plant was to be used for processing Pinos Altos ores.[14] According to the company annual report, Cyprus spent more than $28 million on environmental protection measures in 1989.

The U.S. Forest Service awarded a $3.1 million contract to a Port Angeles, WA, firm for cleanup of 8 million tons of tailings at Holden, WA. The tailings covered a large part of the valley near Holden Village, about 12 miles above Lake Chelan. The Holden Mine, the only major copper producer in Washington at the time, closed in late 1956 because of poor markets.

### Smelter Environmental Issues

According to the company annual report, Asarco received notice from EPA that it and numerous other parties were responsible, under CERCLA, for correction of hazardous substance releases at the following locations on the dates indicated: The Commencement Bay area in Tacoma, WA (1982); Pitcher Mining Field in Oklahoma (1982); YAK drainage tunnel in Leadville, CO (1983); the Tacoma Smelter site (1984); southeastern Cherokee Co. in Kansas (1985); the East Helena Smelter (1987); and the Ruston, WA, area (1988). In 1987, part of an Asarco subsidiary's (Federated Metals Co.) former scrap processing plant in Houston was listed on the Texas Superfund Registry. Asarco was also involved in litigation under CERCLA and State law involving alleged hazardous substance releases at the company's former Perth Amboy, NJ, smelter site and at its Globe Plant in Denver, CO. Asarco had established financial reserves for these programs, spending $13.4 million in 1989, $13.7 million in 1988, and $19.2 million in 1987 on environmental compliance. Asarco had spent more than $12 million to clean up the Tacoma, WA, smelter since it closed in 1985. The demolition of the 565-foot-tall stack was expected to cost about $3 million. Because of the contaminants, EPA had declared the smelter site a Federal Superfund Site for cleanup, one of 36 in the Pacific Northwest.

## PRODUCTION

### Mine Production and Reserves

Copper was mined in 13 States during 1989, with Arizona maintaining its lead with 60% of the total, followed by New Mexico and Utah. There were 68 copper-producing mines, up from 65 mines in 1988. Of these, 22 were copper mines, and 46 were mines from which copper was produced as a byproduct or coproduct of gold, lead, silver, or zinc. Total U.S. operating mine capacity, in terms of recoverable copper per year, was estimated to be 1.79 million tons in 1989, compared with 1.62 million tons in 1988. The increase was largely the result of improvements at operating mines, although some new mines were brought on-stream during the year. Annual SX-EW capacity was expanded by about 50,000 tons to 358,000 tons and by 1992 was expected to reach 434,000 tons. Some companies' reserves were reevaluated in light of higher copper prices, and the mill-head grade decreased at some mines as lower graded ore became economic to mine.

As a result of sustained higher copper prices, interest was being shown in reopening several long-closed U.S. copper mines. Among those planned for production were the Centennial No. 6 Mine near Kearsarge, MI; the Continental and Copper Flat Mines in New Mexico; an SX-EW project at the Yerrington Mine in Nevada; several small mines near Butte, MT; and the Superior Mine, the Oracle Ridge copper-silver property, the Johnson Camp Mine, and the Emerald Isle Project, all in Arizona. A tentative agreement was reached for the restart of the Arbiter electrowinning plant in Montana. Anaconda Enviro-Refining Co. planned to convert copper and other metal concentrates into finished metals at the Arbiter plant.

Cyprus signed a letter of intent with Sharon Steel Corp. in August to consider a joint venture at the Continental Mine in New Mexico after it had completed evaluating the geology, assets, and accounts. Production would be limited to the open pit mine at first, which had a 4,500-ton-per-day concentrator. The underground mine and its 2,700-ton-per-day concentrator would not be operated. In addition, the nearby Hanover Mountain deposit was reported to have reserves of 9 million tons of mixed oxide and sulfide mineralization that averaged 0.63% copper. Portions of this property reportedly could be used for leaching and SX-EW recovery.[15]

Magma approved a plan for the rehabilitation of the Superior Mine, AZ, which closed in 1982 because of low copper prices. Expenditures for this project were expected to be $12 million, with production at the rate of 12,700 tons per year scheduled for late 1990. The mine life was estimated to be about 8 years. The mine was about 1 mile deep and had been flooded to about 3,000 feet. In addition, two promising vein structures to the south of the present workings were being explored. The new project would require a new shaft and concentrator. In 1989, Magma resumed development of a small part of the Kalamazoo ore body, which had been suspended during the fourth quarter of 1988. The company planned to mine at the 2,950-foot level using high-performance work teams for cost reduction. Ore production from this section of the mine was expected to begin in the third quarter of 1990.

Rio Gold Mining Ltd., a new company from British Columbia with headquarters in Denver, CO, announced intention of reopening the Copper Flat Mine, NM, which closed in 1982; and the mill was dismantled and sold. Once financing of the $37 million project was secured, the mine was expected to be commissioned within 1 year. Production was expected to be about 18,000 tons of copper, 12,000 ounces of gold, 300,000 ounces of silver, and 386 tons of molybdenum per year. At a cutoff grade of 0.25% copper, a minable reserve of 48 million tons averaging 0.45% copper was reported.

An $8 million loan with Chemical Bank of New York was approved for Michcan to reopen the Centennial No. 6 Mine in Michigan. Michcan, a group of investors that included Peninsula Copper Industries (PCI) of Hubbell, MI, also received a $350,000 loan to assist in dewatering the 5,000-foot mine shaft. PCI produced copper oxide, which was used in wood preservatives and automobile safety airbag propellants. The 4,000 tons per year production from the Centennial Mine would be used for copper oxide production. Copper oxide production was to be expanded from 8 to 11.5 million pounds annually. PCI held 29.5% of Michcan, with American Chemet Inc. and a New York investment group holding the rest.

In addition to reopening older mines, increased interest also was shown in exploration for and development of new projects. Exploration expenditures were increased by Phelps Dodge, which reported spending $50 million on exploration, advanced mine evaluations, research, and development. Nearly 80% of the 1989 exploration expenditures were in the United States with emphasis on copper, mixed base metal sulfides, and precious metals. In addition to its acquisitions program, Cyprus also expanded its exploration efforts in 1989 to include copper with funds increased to $15.2 million, up $7 million over that of 1987. Exploration efforts were conducted in Australia, Canada, Chile, Mexico, New Zealand, and the United States. Cyprus Northshore Mining Corp. was exploring the former Minnamax copper-nickel property adjacent to its Babbit taconite mine. The property was partially developed in the 1970's by Amax Inc. with shaft sinking and underground work.

Chevron Minerals Co. was reported to have sold the Bald Mountain Mine in Maine to Boliden International Mining. Ore reserves at Bald Mountain were sufficient to support a 15-year mining operation. Two mining companies, Crown Butte Mines Inc. and Noranda Minerals Corp. reportedly were considering the development of a copper and gold mine located 2 miles north of Yellowstone Park. Sunshine Mining and Noranda sought $150 million to further finance exploration and development of the Montanore, MT, property, which was expected to be in production by 1992. Western World Mining Co. had petitioned the planning commission of Yuba County, CA, for a permit to operate a copper mine in Big Oak Valley. Mine plans called for the open pit removal of 1.4 million tons of copper-zinc ore, averaging 2% copper, over a 6-year period. However, local public opposition prevented the permit from being granted. The project had been started in 1971 by Superior Oil Co. Plexus Resource Corp. planned to expedite development of the Bornite Project, OR. The deposit was estimated to contain 2.54 million tons of ore grading 2.49% copper in a bornite-rich breccia pipe, extending to a depth of 800 feet.

RTZ indicated that development of Kennecott's North Ore Shoot Extension in Utah could begin in 1990. The deposit contained a minable reserve of 11.2 million tons of ore grading 2.9% copper within a resource of 118.5 million tons of ore. Production at the annual rate of 25,000 tons of copper and 31,000 ounces of gold could begin as early as 1993. The company's Flambeau deposit in Wisconsin was scheduled to commence production in 1992.

Expansions at established operating mines also continued during the year. Asarco announced a 3-year expansion program to improve its mining, milling, and smelting capacity. At the Ray Mine, about $130 million would be spent to install an in-pit crusher and new mill and concentrator. An 18-mile pipeline was to be built to pump slurry from the new mill to tailings ponds. Asarco estimated that output at Ray would be boosted by about 20,000 tons of ore per day. The entire plan would boost Ray Mine output by 37,000 tons of copper per year. The Pima mill and concentrator would be reopened and refurbished for about $94 million.

Cyprus reported total copper production of about 270,000 tons in 1989.[16] With a $21 million expansion at the Bagdad Mine, the company production target was 295,000 tons in 1990. Bagdad was to be expanded by 10% to 104,000 tons of copper in concentrate per year by adding a fifth grinding line. Cyprus' ore reserves (table 4) were based on a long-term copper price projection of 75 cents per pound and reevaluation of Bagdad ores. This was offset in part by the reclassification of Twin Butte's reserves from copper to cooper-molybdenum reserves, according to the company annual report.

TABLE 4

## MAJOR U.S. COPPER-PRODUCING COMPANY RESERVES IN 1989

| Company and deposit | Percent company ownership | 1989 Ore (thousand metric tons) | 1989 Percent copper | 1989 Copper content (thousand metric tons) | Company share, thousand tons copper | Deposit and company percent of grand total |
|---|---|---|---|---|---|---|
| Cyprus Minerals Co.[1] | | | | | | |
| Copper deposits | 100.0 | 891,853 | 0.44 | 3,924 | 3,924 | 11.0 |
| Copper-molybdenum deposits | 100.0 | 504,123 | .34 | 1,714 | 1,714 | 4.8 |
| Total reserves | | 1,395,976 | .40 | 5,638 | 5,638 | 15.8 |
| ASARCO Incorporated[2] | | | | | | |
| Copper deposits: | | | | | | |
| Mission Complex, AZ | 100.0 | 302,060 | .67 | 2,024 | 2,024 | 5.7 |
| Ray, AZ | 100.0 | 582,458 | .69 | 4,019 | 4,019 | 11.3 |
| Silver Bell, AZ | 100.0 | 91,938 | .47 | 432 | 432 | 1.2 |
| Continental, MT | 49.9 | 380,972 | .28 | 1,067 | 532 | 1.5 |
| Total copper deposits | | 1,357,428 | .56 | 7,542 | 7,007 | 19.6 |
| Byproduct deposits: | | | | | | |
| Coeur, ID | 50.0 | 339 | .83 | 3 | 2 | (3) |
| Galena, ID | 37.5 | 1,067 | .54 | 6 | 2 | (3) |
| Troy, MT | 75.0 | 21,334 | .70 | 149 | 112 | 0.3 |
| Leadville, CO | 50.0 | 709 | .18 | 1 | 1 | (3) |
| West Fork, MO | 100.0 | 8,303 | .04 | 3 | 3 | (3) |
| Total byproduct deposits | | 31,752 | .51 | 162 | 119 | .3 |
| Total reserves | | 1,389,180 | .55 | 7,704 | 7,126 | 19.9 |
| Phelps Dodge Corp.[4] | | | | | | |
| Morenci, AZ | 85.0 | 641,540 | .79 | 5,068 | 4,308 | 12.1 |
| Chino, NM | 66.7 | 294,011 | .70 | 2,058 | 1,372 | 3.8 |
| Tyrone, NM | 100.0 | 49,804 | .73 | 364 | 364 | 1.0 |
| Burro Chief, NM, leach[e] | 100.0 | 217,724 | .35 | 762 | 762 | 2.1 |
| Total reserves | | 1,203,079 | .75 | 8,252 | 6,806 | 19.0 |
| Copper Range Co.[5] | | | | | | |
| White Pine, MI | 100.0 | 162,982 | 1.08 | 1,760 | 1,760 | 4.7 |
| Contiguous leased | 100.0 | 17,670 | 1.44 | 254 | 254 | .7 |
| Total reserves | | 180,652 | 1.12 | 2,014 | 2,014 | 5.4 |
| Kennecott Corp.[6] | | | | | | |
| Bingham Canyon | 100.0 | 650,452 | .70 | 4,579 | 4,579 | 12.2 |
| Magma Copper Co.[7] | | | | | | |
| Magma Superior | 100.0 | 3,991 | 5.70 | 228 | 228 | .6 |
| San Manuel: | | | | | | |
| Oxide pit | 100.0 | 38,288 | .42 | 160 | 160 | .5 |
| Oxide pit[8] | 100.0 | 9,524 | .89 | 85 | 85 | .2 |
| In situ leach ores | 100.0 | 234,601 | .35 | 828 | 828 | 2.3 |
| Underground sulfide | 100.0 | 88,555 | .72 | 641 | 641 | 1.8 |
| Underground sulfide[8] | 100.0 | 128,530 | .64 | 824 | 824 | 2.3 |
| Kalamazoo underground: | | | | | | |
| Sulfide reserves | 100.0 | 10,207 | .72 | 73 | 73 | .2 |
| Deep sulfide[8] | 100.0 | 280,903 | .73 | 2,056 | 2,056 | 5.8 |

TABLE 4—Continued

## MAJOR U.S. COPPER-PRODUCING COMPANY RESERVES IN 1989

| Company and deposit | Percent company ownership | 1989 Ore (thousand metric tons) | 1989 Percent copper | 1989 Copper content (thousand metric tons) | Company share, thousand tons copper | Deposit and company percent of grand total |
|---|---|---|---|---|---|---|
| Pinto Valley: | | | | | | |
| Dump leach (sulfide) | 100.0 | 353,839 | .12 | 414 | 414 | 1.2 |
| Miami tailings leach | 100.0 | 30,557 | .33 | 101 | 101 | .3 |
| Open pit sulfide | 100.0 | 342,719 | .39 | 1,340 | 1,340 | 3.8 |
| Undeveloped sulfide[8] | 100.0 | 287,685 | .39 | 1,134 | 1,134 | 3 |
| Total reserves | | 1,809,399 | .44 | 7,884 | 7,884 | 22.1 |
| Grand total, major companies | XX | 6,628,738 | .55 | 36,071 | 34,047 | 94.4 |

XX Not applicable.
[1]Source: Cyprus Minerals Co. 1989 Annual Report, p. 44.
[2]Source: ASARCO Incorporated 1989 Annual Report, pp. 7, 17.
[3]Less than 1/2.
[4]Source: Phelps Dodge Corp. 1989 Annual Report, p. 11.
[5]Source: Metal Mining Corp. Annual Report 1989, p. 8.
[6]Source: RTZ Corp. Acquisition of BP Minerals Issue, 1989.
[7]Source: Magma Copper Co. 1989 10K Report, pp. 17, 18.
[8]Additional reserves in and around shaft pillars and in lowest mine levels, not included in stated mine plan in 1989. Active reserves based on 70 cents per pound. Pinto Valley undeveloped reserves are peripheral to the current reserves and in the mine plan for beyond 2006 when current reserves are depleted.

Copper Range expected to spend about $30 million on larger scale replacement equipment that would boost the copper production to about 60,000 tons per year over the next 3 to 4 years. In addition to improvements underground, the mill was to be expanded.

Kennecott redefined the Bingham Canyon reserves to incorporate lower grade material and announced plans to increase production by about 32,000 tons of ore per day. The new project included an expansion of the coarse ore stockpile facility, addition of a fourth grinding line, a new flotation circuit with 21 3,000-cubic-foot flotation cells, expansion of the molybdenum plant at the Copperton concentrator, and installation of a fourth filter press at the smelter. As a result, mill capacity would increase from 70,000 tons to 102,000 tons of ore per day, in addition to the ore that continued to be processed through the older Bonneville and Magna concentrators. Total copper production would be about 245,000 tons per year.

Magma completed its expansion of Pinto Valley Division's Miami Unit SX-EW plant. Production began during the year from the tailings leach project associated with the plant expansion. According to the company annual report, Pinto Valley's total production included 260,000 tons of concentrate and 9,500 tons of electrowon copper cathode.

New Butte Mining PLC conducted limited underground mining near the Missoula Horsetails, which were relatively untouched parts of the heavily mined main Lexington vein in Butte, MT. New Butte was operating under a small-miners exclusion that permitted only a limited (about 32,600 tons) amount of ore to be mined each year. Once the Montana Department of State Lands approved its mining permit, the company planned to expand production. After the Missoula Horsetails and Chief Joseph vein systems, the Gray Rock area was to be the next production site.

In 1989, Phelps Dodge invested $217.4 million in copper mining expansion and improvement projects. About $112 million was allocated to the expansion of the Morenci, AZ, SX-EW operations. New capacity of 63,500 tons per year was to come on-stream in mid-1991. The expansion also involved development of the Northwest Extension adjacent to the Morenci Mine. A $48 million, in-pit crushing and conveying project was completed during the year. According to the company annual report, Phelps Dodge had a record production of 534,967 tons of copper from its Morenci, AZ, and Chino and Tyrone, NM, operations, including 106,322 tons from electrowinning.

### Smelter Production

Total U.S. smelting capacity was 1.8 million tons, a slight increase compared with 1988. Cyprus Lakeshore, AZ, roaster was included. At Lakeshore, concentrates from other mines were roasted before treatment in a vat-leach, SX-EW system. Nine primary plants, including the Lakeshore roast-leach plant, operated during the year with a total capacity of 1.35 million tons of copper. Five secondary smelters operated with a combined capacity of 416,000 tons of copper anode.

Asarco announced plans to retrofit its El Paso reverberatory furnaces with Contop flash smelting units at a cost of $30 million. The retrofit was expected to improve sulfur capture, improve quality of sulfuric acid recovered, and reduce production costs by about 17%. At its Hayden, AZ, plant, Asarco installed a new electric slag cleaning furnace in the third quarter.

A flashback at Cyprus' Miami, AZ, smelter occurred in September, closing the smelter for 2 weeks and injuring one worker. Cyprus settled a concentrate contract dispute with Magma and entered into a new smelting and refining agreement. The Magma smelter, Cyprus' Miami smelter, and the Casa Grande roast-leach plant were anticipated to meet Cyprus' current smelting needs. In 1989, Cyprus sold 78,000 tons of concentrates overseas, according to the company annual report. Copper concentrates from Cyprus' newly refurbished Deming mill were to go to the Asarco El Paso smelter for toll smelting. Sales of siliceous flux products from the Pinos Altos Mine to copper smelters in the region would not continue because the flux ore body at Pinos Altos was depleted during the year.[17]

According to the company annual report, Magma's smelter treated 853,000 tons of concentrate. In 1989, Magma significantly increased the amount of purchased concentrates. The smelter was able to achieve its installed capacity of about 1 million tons of concentrate per year. In addition to the new Cyprus concentrate contract of about 272,000 tons per year, Magma also secured a 140,000-ton-per-year, multiyear concentrate purchase contract with Compania Minera de Cananea S.A. of Mexico.[18]

Texas Copper Corp., a consortium of Mitsubishi Metal Corp. (51%) and four other Japanese companies, announced that the design capacity of its intended Texas City smelter would be 182,000 tons per year of copper. The smelter was expected to operate on a toll basis with each shareholder providing concentrates according to their percentage of ownership. The majority of concentrates was expected to come from South America. About 12,000 tons of total copper production was expected to be from scrap. The proximity to the Florida sulfuric acid market and ease of concentrates transport were important factors in selecting a gulf coast location. Construction of the $200 million smelter could begin in 1991, depending on the progress of environmental permitting.

### Refinery Production

Ten electrolytic, six fire refineries, and twelve SX-EW plants were operating at yearend. Increased refinery production resulted from the continued expansion at electrowinning plants, startup of the Lakeshore roast-leach process, and electrolytic refinery expansion at Magma and Kennecott facilities. Two secondary plants also expanded capacity during the year. Total U.S. refinery capacity at primary and secondary plants was 2.42 million tons, up by nearly 10% over that of 1988. Of the total, 636,000 tons of capacity was at secondary electrolytic and fire-refining plants.

At the end of October, the American Telephone and Telegraph Co. (AT&T) announced that its Nassau Metals Corp. operations, including its electrolytic copper refinery and wirerod plant, were for sale. Nassau's facility, one of the largest secondary copper processing plants in the United States, was constructed in 1978 and provided Western Electric with between 40% and 45% of its copper.

According to the company annual report, Magma had a record electrolytic cathode production of 243,000 tons, including 66,200 tons refined for others. Production from the company's SX-EW plants accounted for 22% of refined cathode produced, with the San Manuel Div. producing 77.4% of the SX-EW production. Magma operated three SX-EW plants with the following capacities: San Manuel oxide plant, 68,000 tons per year; Pinto Valley waste leach, 7,260 tons per year; and the Miami in situ leach plant, 9,000 tons per year. Four new sections were added to the San Manuel electrolytic refinery during the year that will enable the plant to produce more than 272,000 tons of cathode per year.

Magma announced the closure of its MCR Products Co. (Chicago) rod mill as of January 1, 1990. The move reflected basic changes in Magma's marketing plans. Magma was to continue to supply rod from its San Manuel rod plant, which had a capacity of 164,000 tons of rod per year. MCR had a capacity of 127,000 tons per year of rod.

This was the first full year of operation for Phelps Dodge's 40,000-ton-per year SX-EW plant at the Chino Mine, NM. In December, a 100% expansion of the Morenci, AZ, SX-EW plant was completed, raising the capacity to about 91,000 tons of cathode per year. The company's Tyrone plant had a capacity of 50,000 tons per year. The company was anticipating SX-EW production to comprise about 50% of its total production over the long run. Phelps Dodge reported that it was the world's largest producer of copper rod. Its U.S. facilities, located at Norwich, CT, and El Paso, TX, were capable of producing about 380,000 tons per year of rod. The El Paso refinery also initiated a $9 million modernization program that was to improve production costs.

### Copper Sulfate Production

Copper sulfate was produced from copper scrap, blister copper, copper precipitates, electrolytic refinery solutions, and spent electroplating solutions. U.S. production of copper sulfate was a little lower than in 1988, while imports increased significantly. In October, Kocide Chemical Corp. discontinued production of copper precipitates from in situ leaching at the Van Dyke property, AZ. Closure reportedly was the result of technical problems, including a buildup of soluble iron and diminished flow rates. Precipitates had been used for production of copper sulfate at the company's Casa Grande Plant. Data supplied by domestic producers for 1989 indicated that 64% of their shipments were for agricultural uses, 24% for industrial uses such as wood preservatives, and 12% for water treatment. In agriculture, copper sulfate was used principally as a fungicide for treatment of citrus and vegetable crops.

### Copper Powder Production

Copper powder production and consumption were at about the same level as in 1988, which was about one-half that of 1979. Copper powder consumption was highly dependent on the automobile industry, which comprised the largest single end-use market. Copper powder used to manufacture self-lubricating bearings accounted for about 70% of the granular powder used. Pure copper powder was also used in the electrical and electronic industries. Copper flakes were used for antifouling paints, decorative and protective coatings, and printing inks. Nonstructural applications included brazing, cold-soldering, mechanical planting, metals and medallions, metal-plastic decorative products such as floor tile and epoxy resins, and various chemical and medical applications. American Metal Market commercial-grade copper powder prices ranged from $1.64 to $1.80 per pound, reflecting the higher refined copper prices.

TABLE 5

**COPPER SULFATE PRODUCERS IN THE UNITED STATES IN 1989**

| Company | Plant location |
|---|---|
| CP Chemicals Inc. | Sewaren, NJ, and Sumpter, SC. |
| Kocide Chemical Corp. | Casa Grande, AZ. |
| Madison Industries Inc. | Old Bridge, NJ. |
| Phelps Dodge Corp. | El Paso, TX. |
| Southern California Chemical Co. | Santa Fe Springs, CA, Union, IL, Garland, TX. |
| Tennessee Chemical Co. | Copperhill, TN. |

Granular copper powder can be produced by a number of methods, including atomization, electrolysis, hydrometallurgy, and solid-state reduction.

### Sulfuric Acid Production

Sulfuric acid was produced as a byproduct of copper smelting. Seven copper smelters produced a total of 3.1 million tons of sulfuric acid; in addition, some sulfuric acid was produced at Cyprus' Lakeshore concentrate roaster. Copper Range does not produce sulfuric acid at its smelter. According to the company annual report, Magma's new smelter produced 744,250 tons of sulfuric acid and was largely responsible for the significant increase in acid production over that of 1988. About 280,000 tons was used in Magma's leach operations and 464,000 tons was sold. Magma reported that the smelter captures greater than 97% of the input sulfur.

## CONSUMPTION

U.S. apparent and reported demand for copper, which trended upward since 1983, were essentially unchanged in 1989. However, the trend for an increasing domestic self-sufficiency for copper continued. Domestic production of primary refined copper and copper recovered from old scrap accounted for about 93% of domestic demand. Imports of brass mill products, as reported by the CBFC, declined by 7%.

Refined copper or directly melted scrap was consumed at about 20 wire-rod mills, 40 brass mills, and more than 1,000 foundries, chemical plants, and miscellaneous manufacturers. According to Bureau of Mines estimates, 72% of the copper, as a percentage of apparent consumption, was consumed in electrical applications; 15% in construction; 6% in machinery; 3% each in transportation and miscellaneous uses; and 1% in ordnance. Copper used in electrical wiring and devices in all end uses, except ordnance, was included under electrical applications.

Although demand for unwrought copper (refined plus direct-melt scrap) was stagnant, demand for copper semifabricates declined. According to Copper Development Association estimates, mill shipments to domestic markets declined by about 3%. Much of the decline in total shipments was accounted for by a decline in imports of brass mill products. Shipments to the building construction, industrial machinery and equipment, and transportation equipment sectors declined by about 2%, 6%, and 7%, respectively. According to Copper Development Association, building construction was the largest end use sector, accounting for 41% of shipments, followed by electrical and electronic products, 24%; industrial machinery and equipment, 13.5%; transportation equipment, 11.5%; and consumer and general products, 10%.

While demand in most industry sectors was weak, the brass tubing market was undergoing restructuring, and several new plants were announced. Water tubing demand was negatively impacted by the housing slump, but demand for thin-walled and inner-grooved copper tubing used in air-conditioning and refrigeration was strong and supply was tight. At least two major domestic air-conditioning manufacturers who switched to aluminum reversed their position and returned to copper tubing. A decline in imported air-conditioning units and a decline in imported tube boosted demand for domestically produced air-conditioning tube. Domestic mills announced a series of expansions to boost their production of air-conditioning and refrigeration tube. Kobe Copper Products Inc. announced plans to boost air-conditioning and refrigeration tube capacity from 400 tons per month to 1,000 tons per month at its Pine Hall, NC, plant. The plant, adjacent to Halstead Industries' tube mill, was a joint venture among Kobe Steel, Halstead, and three other Japanese companies. American Brass increased capacity at its Franklin, KY, plant to 30,000 tons per year, and Wolverine Tube was constructing a new redraw mill at Booneville, MO. Cerro Copper Products, which completed a second expansion of its redraw capacity in Selbina, MO, announced plans to build a new fully integrated tube plant.

Several other expansions or new plants were announced during the year. PMX Industries, a subsidiary of Poongsan Corp. of the Republic of Korea, announced plans to open an 80,000-ton-per-year sheet mill in Cedar Rapids, IA. Some of the plant equipment was to be purchased from Canada's Arrowhead Metals, which closed its brass mill during the year. Other announced plant expansions included Plume and Atwood's Connecticut mill and MRM Industries, who relocated expanded facilities from Connecticut to Sikeston, MO. North Coast Brass and Copper, formerly Chase Brass and Copper Co., announced its intent to close its 60,000-ton-per-year sheet mill in Ohio.

## PRICES

The average annual price for copper was at a record-high level in 1989. Industry stocks remained near the low level established during the second half of 1988. At the prevailing rates of consumption, stocks represented only about an 18-day supply. With stocks at such a low level by historical measure, prices were volatile and sensitive to real or perceived changes in supply availability. The Commodity Exchange of New York (COMEX) spot price fell by almost 10 cents per pound over a 2-day period in March. The decline coincided with economic indicators showing a potential softness in the market, a rise in exchange stocks, and cancellation of a planned 3-day strike in Peru. On average, prices declined throughout the first 7 months of the year, having reached record levels in December 1988.

Copper prices rose during the third quarter. The COMEX spot price peaked at $1.42 per pound in mid-September. The price rise coincided with strong industry demand, a decline in COMEX stocks, and the announcement of an additional production setback in Chile. To insure an orderly expiration of its September copper contracts, COMEX raised its margin requirement for all September contracts to 100% of their value. A slight increase in refined copper inventories, uncertainties about sustaining the strong demand for copper, and the prospect for increased primary production in 1990 contributed to a fourth quarter decline in prices. Yearend prices were at the lowest point of the year.

December 27 was the last trading day for the standard-grade copper contract on the COMEX. Beginning January 1990, only the high-grade contract, first introduced in July 1988, was traded. COMEX delisted the remaining inventory of standard-grade copper, causing reported stocks between the end of December and the beginning of January to decline by 7,000 tons. Standard-grade stocks were expected to be withdrawn from warehouses by contract holders during the first half of 1990. Prices on COMEX remained in backwardation during most of the year with forward contracts trading at a discount to spot purchases. A normal or contango market, where forward contracts sell at a premium to spot purchases, briefly returned in July and August for 3-month forward contracts. Copper prices were at the low point for the year. However, 12-month forward contracts remained in backwardation throughout the year. The market backwardation was attributed to industry expectation that new primary copper production would lead to supply surplus and lower prices.

Producer prices for refined copper closely tracked that of COMEX prices, because domestic producers had adopted a COMEX-based pricing system. Producer premiums to COMEX ranged between 4 and 5 cents per pound throughout the year, but generally declined slightly with lower prices. Though copper scrap prices generally tracked refined copper prices up and down, the spread in price between refined prices and scrap prices was more of an inverse relationship. High prices for refined copper generally attracted more scrap to the marketplace, depressing its price relative to refined prices. For example, during the September price surge, the spread between the price refineries paid for No. 1 copper scrap and the producer price for refined copper was more than 20 cents per pound. This narrowed to only about 13 cents at yearend. Thus, when prices rose, processing margins increased for secondary smelters and for brass mills, who adjusted product prices to reflect the refined value of contained copper.

Though the average annual delivered producer price for copper cathode, as reported by Metals Week, was $1.31 per pound, the price realized by producers varied depending on their pricing, delivery charges, and sales policies. The average price realized by Asarco for the year was $1.28 per pound, compared with $1.17 in 1988, according to the company annual report. Magma, on the other hand, reported average sales prices of $1.22 and $1.14 for 1989 and 1988, respectively, in its annual report. Some of the realized price difference between the two companies was ascribed to guaranteed forward sales contracts made the previous year by Magma in anticipation of lower copper prices. Cyprus, which reported a 1989 realized price of $1.27 per pound, implemented price protection strategies in 1989 in the advent of a decline in copper prices. About 30% of Cyprus' anticipated 1990 production was reportedly sold forward at prices ranging from $0.80 to $1.00 per pound. Magma entered into contracts to supply cathode to fabricators in Asia, selling forward about one-third of the company's anticipated production at prices that averaged $1.02 per pound over 1990 and 1991. Similarly, Copper Range sold forward contracts covering 45,000 tons of copper at a minimum average price of $1.00 per pound for 1990 and $0.98 per pound for 1991, according to Metall Mining's annual report.

## WORLD REVIEW

Despite an increase in world refined production, the close balance between the supply and demand for refined copper that prevailed during 1988 continued throughout 1989. World consumption kept pace with the growth in production, and total stocks of refined copper changed only slightly throughout the year. However, with stocks representing only 4 to 5 weeks of supply, extremely low by historical standards, the price of refined copper was sensitive to even small changes in availability. Though total estimated world stocks remained unchanged during the first quarter, commodity exchange stocks rose by more than 50%. Coincidentally, copper prices declined steadily during the first half of 1989. Prices had risen to historic high levels in December 1988. In addition, several disruptions to the production of primary copper, which had threatened availability during the traditional yearend 1988 buying season, were resolved during the first quarter of 1989. A renewed price rise during the third quarter of 1989 coincided with strong industry demand and additional disruptions to supply. Prices declined to the lowest levels of the year when both exchange and industry inventories rose slightly and some supply disruptions were settled.

### Industry Structure

***Consumption.***—While total world consumption of refined copper rose, consumption in the United States remained at about the same level. Weak demand in Canada from the depressed U.S. automobile market and the closure of a major Canadian brass mill was balanced by increased Mexican demand. The increase in Mexican demand was ascribed to an overall economic recovery. Demand for refined copper in Europe, according to the World Bureau of Metal Statistics, rose by about 4%, buoyed by strong demand in France, the Federal Republic of Germany, Italy, and Spain. The growth in the Federal Republic of Germany was attributed to strong domestic and export demand for sheet products; in France to strong domestic and export demand for wire mill products; and in Italy and Spain to a boom in construction demand for wire, tube, and sheeting. In Asia, an overall demand increase of about 10% was fueled by strong demand in Japan and Taiwan. In Japan, increased consumption resulted from a boom in construction and domestic automotive and consumer electronic consumption. Demand in Taiwan increased along with increased exports.

***Supply Disruptions.***—Though world mine and refined production increased, an anticipated copper surplus failed to materialize owing to sustained strong demand and significant disruptions to production. In January, an explosion at Corporacion Nacional del Cobre de Chile's (CODELCO-Chile) new flash smelter at Chuquicamata, resulted in an estimated 20,000 tons of lost production. In September, CODELCO-Chile suffered a month-long setback at its El Teniente underground mine, where a landslide cut production by about 25%. Repeated acts of sabotage throughout the first half of the year led to production curtailments at the 170,000-ton-per-year Bougainville mine in Papua New Guinea. Bougainville Copper imposed a force majeure on June shipments of concentrates following closure of the mine in mid-May. At yearend, the mine remained shuttered and near-term prospects for reopening the mine were poor. In June, a 3-week strike at the Metallurgie Hoboken-Overpelt S.A. (MHO) Olen refinery in Belgium led both MHO and La Générale des Carrières et des Mines du Zaire (Gécamines) to declare a force majeure on shipments. Gécamines had a toll refining agreement with MHO. A 107-day strike at Highland Valley, Canada's largest copper producer, began in July and also led to declaration of a force majeure. The strike resulted in the loss of about 56,000 tons of copper in concentrate compared with 1988 production.

The Government of Mexico, failing in its attempt to sell its interest in Cia Minera de Cananea S.A. to private investors, declared Cananea to be bankrupt and, on August 20, shut down the mine and dismissed the workers. It was not until the end of October that an agreement was reached with the unions to allow the reopening of the mine. The agreement called for a 25% reduction in the work force and a 33% increase in wages for remaining employees. Though less severe than the previous year, strikes continued to impact Peruvian production. Production by Centromin in Peru was affected by strikes in February and sabotage in July. A nationwide strike by the National Federation of Mining Unions closed Southern Peru Copper Company's (SPCC) Toquepala and Cuajone Mines in August, as well as Minero Perú's Ilo refinery and Cerro Verde Mine.

In the Philippines, mine production fell by more than 13% compared with 1988. Atlas Consolidated Mining and Development reported significant losses because of heavy rains in January, February, and June; typhoons in August; labor problems in the second half of the year; and disruption of its new underground conveyor system by a landslide. Water saturation of the mine and a 26-day shutdown of the mill reduced output by Philex Mining Corp. Production by Lepanto Consolidated Mines fell by 50% during the first half of the year owing to closure of its roasting plant. Benguet Corp.'s Dizon Mines also reported lower output for 1989.

***Mine Expansions.***—Despite setbacks, mine production in Chile increased significantly. CODELCO-Chile invested $410 million dollars in capital projects, resulting in production increasing by 111,000 tons to 1,218,000 tons of copper.[19] The largest gain was at the Chuquicamata Div. where a 51,000-ton-ore-per-day concentrator expansion was completed in March. Production at Chuquicamata rose to 660,000 tons of copper in 1989. Expansions of smelting, refining, and sulfuric acid plants were also underway. Production at the Salvador Div., which began processing relatively high-grade slag from the Chuquicamata smelter, rose by about 50% to 130,000 tons of copper. In addition, production from the Quebrada "M" open pit, which began during the second half of the year, and an expansion of the Porterillos smelter was partially completed. The above gains in production more than offset production declines of 7,000 and 26,000 tons at the Andina and El Teniente Mines, respectively. Andina and El Teniente suffered from declining ore grades, and El Teniente also suffered severe mine stability problems.

In Canada, eight copper and copper coproduct mines with a combined annual capacity of about 75,000 tons of copper started production during the year. Minnova Inc. began production from its Ansil copper-zinc mine in Quebec and the Samatosum silver-zinc-copper mine in British Columbia. Noranda reopened the Gaspé Mine, closed in 1987 owing to a major underground fire. Other reopened mines included the Mobrun Mine, the Shebandowan nickel-copper mine, the Heath Steele and adjacent Stratmat zinc-lead-copper mines, and the Callinan zinc-copper mine at Flin Flon. In addition to the above new or reopened projects, steps were taken to extend mine life at the Gibralter Mine, the Similkameen Mine, and BHP-Utah Mines Ltd. open pit on Vancouver Island. With the relocation of the former Highmont mill to the Lornex millsite, Highland Valley Copper increased its mill capacity by about 10,000 tons per day.[20]

Samincor's Neves Corvo Mine in Portugal was brought into production early in the year, and by yearend, was operating at or near its projected annual capacity of 120,000 tons of copper in concentrate. Ore grades at the underground massive-sulfide mine were reported to average between 8% and 11% copper. In Australia, production rose significantly owing to expanded production from the large Olympic Dam copper-uranium-gold project, the Selwyn Mine, and the Horseshoe Lights Mine, all of which began production in 1988. Production also increased from the Gecko copper-gold mine, which reopened in 1988.

***New Mine Projects and Investments.***—The sustained high price for copper projected declines in ore grades and reserves, and a long-term outlook for a copper supply deficit stimulated investments in new copper production and in expansions of existing facilities. In Chile, development of the Sur open pit at Andina began during 1989, and partial production was expected to begin in 1990. At El Teniente, development of the Mina Sur and Mina Norte extensions continued. A 2-stage, 24,000-ton-ore-per-day expansion of the Colon concentrator was planned for completion in 1991. While production from the State-controlled Empresa Nacional de Minería (ENAMI) and the private sector only rose by a combined 20,000 tons in 1989, numerous expansions and new mine developments were underway, which could boost non-CODELCO capacity by as much as 750,000 tons of copper by 1992. Most notable was La Escondida Mine, where development was running ahead of schedule and under budget. Production startup was now projected for yearend 1990. The long-term production rate was expected to be 320,000 tons of copper per year in concentrates. Exxon Minerals International Inc. signed an investment agreement with the Chilean Government that included $400 million for expansion of its Los Bronces Mine from 49,000 tons of copper per year to 130,000 tons per year by 1992. Other smaller projects that were underway included the joint development of the 40,000-ton-per-year Quebrada Blanca sulfide and oxide leach project by Cominco Resources and ENAMI; the 20,000-ton-per-year Los Pelambres underground sulfide flotation project owned in part by the Midland Bank and Anaconda Chile SA; the 40,000-ton-per-year Cerro Zaldivar sulfide flotation project, acquired by Outokumpu Resources in 1989; and numerous smaller oxide leaching projects with a combined capacity in excess of 60,000 tons of copper per year.

In Indonesia, expansion of Freeport-McMoRan Copper Co.'s mine and concentrator from 20,000 tons of ore per day to 32,000 tons was initiated early in the year. In August, further expansion of the facilities to 52,000 tons of ore per day was approved. The expansions were to accommodate production from the Grasberg copper-gold deposit discovered in 1988, about 2.5 kilometers from their existing Ertsberg operation. Production from Grasberg was to begin in 1990.

In Canada, Geddes Resources Ltd. continued exploratory drilling and was proposing to develop a 120,000-ton-per-year copper mine on its Windy Craggy property in the northwestern corner of British Columbia. The company reported proven and probable reserves of 114 million tons of ore grading 1.9% copper. The company was proceeding with the environmental permitting process. Numerous other Canadian deposits, including the Louvicourt Township property and the Estrades property in Quebec, the Duck Pond property in Newfoundland, the Hanson Lake property in Saskatchewan, and the Mount Milligan property in British Columbia were being considered for development.[21] Other new projects included a 20,000-ton-per-year mine in Burma, mill expansions at RTB Bor's mines in Yugoslavia scheduled for completion by 1992, and modernization and expansion of the Erdinet Mine in Mongolia.

***Smelting and Refining Production.***—World smelter and refinery production during 1989 rose with increased availability of copper concentrates. Refined copper production from scrap, which had increased markedly in response to higher prices during 1988, remained high in 1989 at about 2 million tons and comprised about 22% of refined copper production. Production increases of secondary refined copper in the United States were tempered by the static secondary recovery in Europe, the largest producer of refined copper from scrap. According to Bureau of Mines estimates, the Western European countries produced about 710,000 tons of refined copper from scrap, compared with only 540,000 tons for the North American countries. The increase in smelter production lagged behind that of both mine and refinery production. The expansion of world SX-EW production, which bypasses the smelting step, helped to boost primary refined production.

Increased concentrate production, smelter setbacks, and a decision by Japanese smelters to maintain their relatively low operating rate led to a surplus of copper concentrates. Consequently, treatment and refining charges rose significantly during the first quarter of the year. A tight supply of concentrates, which had prevailed over the past several years, had led to low treatment and refining charges. According to Commodity Research Unit Ltd. of London, United Kingdom, combined spot treatment and refining charges rose by 45% during the first half of the year to about 29 cents per pound of copper. However, by yearend, charges had returned to 1988 levels. Disruptions to mine production and increased smelter utilization rates again led to a tight supply in the custom concentrate market. However, refined copper production was not affected by the return of tight supply. Stocks of concentrate, accrued by smelters earlier in the year, were able to supplement new production.

Limited surplus primary smelter capacity and expanding mine production served to stimulate numerous smelter expansion plans. In Chile, several smelter projects were being considered at yearend. In addition to the ongoing expansion of the Ventanas smelter and refinery, expansion of the Paipote smelter was planned, and construction of two new ENAMI smelters was being considered. In the Philippines, the Philippine Associated Smelting and Refining Co. (PASAR) announced plans to expand its smelter by 34,000 tons per year to 172,000 tons per year, and in Thailand, Padaeng Industry Co. planned construction of a 100,000-ton-per-year smelter by 1995. In addition to the new smelter planned in the United States, Mitsubishi announced plans to retrofit its Naoshima smelter with a new smelter, equal in capacity to its existing two smelting furnaces. In Mexico, startup of the Santa Rosalia smelter was delayed until 1990 owing to delays in refurbishing the shuttered smelter. In June, Finland's Outokumpu Oy and a consortium of Portuguese companies initiated a feasibility study on constructing a major smelter in Portugal. Other potential sites for new smelters included Brazil and Indonesia.

### Capacity

Compared with that of 1988, world mine capacity increased by 6%, smelter capacity by 3.3%, and refinery capacity by 1.5%. Copper mine, smelter, and refinery capacity for 1989 is shown in table 6. World capacity utilization (82%) at mines continued to be low in 1989 owing to the extensive disruptions at mines, discussed in the previous section. Since 1974, average annual world mine production has ranged between 79% and 85% of available capacity, being highest during periods of peak demand and low available capacity, such as existed in 1987, a year of high-capacity (85%) utilization.

The data in table 6 are rated annual production capacity for mines, smelters, and refineries as of December 31, 1989. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

Capacity at mines represents the potential copper production contained in concentrates for many producers, but for some major producers—such as Chile, the United States, and Zambia—it represents copper recoverable at the smelter level, based on known recovery factors. SX-EW capacity is counted as smelter-level capacity only when the material must be further refined. It is otherwise counted as mine and refinery capacity, bypassing the smelter level. Past and present production potential are taken into consideration when rating a mine, especially where an engineering estimation is not available or seems inappropriate in the case of decreased ore grades. Generally, the rated capacity is based on 360 days per year and two to three shifts per day. For new facilities, capacity is prorated for the year in which it started, but the full capacity is used for the year in which a facility closes. Mines and plants generally are not counted if they are not operating at any time during the year, except where it may be reasonably expected that a shutdown may be temporary, i.e., usually less than 2 years.

## OUTLOOK

### Trends in Consumption

U.S. demand for refined copper from 1950 to 1989 rose an average of 1.3% per year and was anticipated to remain less than 2.3 million tons per year through 1991. World demand increased at about 3.6% per year over the same period. Demand rates for select periods within the 1950-2000 time span have varied significantly, as shown in table 7 and in figures 1 and 2. Particularly noticeable in the United States are the lower growth rates that have existed since 1980. Growth in other countries during this same period was more robust, accounting for the higher 1963-89 average growth rate of 2.5% per year for market economy countries (MEC).

In general, copper demand is largely dependent on economic growth. High demand for copper products is associated with a high standard of living and increased electrical uses. The growth of plastics, fiber-optic cable, and aluminum as competing materials continued to impact several copper markets, but the outlook remains positive for growth in copper consumption, which has related historically to industrial growth. In the United States, a high degree of correlation since 1960 ($R^2$ value of 0.90) between the Gross Private Domestic Investment (GPDI) and the demand for copper in electrical uses indicates the strong tie between copper demand and economic growth.

Copper consumption has been increasing in the electrical sector as a share of end-use markets since 1960, so that in 1989 this sector comprised more than 70% of U.S. copper demand. Statistical projections provided by the Bureau of Mines Branch of Economic Analysis indicated that, by using an independent forecast for the GPDI as a comparative basis, copper consumption

TABLE 6

## WORLD MINE, SMELTER, AND REFINERY CAPACITIES IN 1989

(Thousand metric tons, primary and secondary copper)

| Continent and country | Rated capacity | | |
|---|---|---|---|
| | Mine | Smelter | Refinery |
| North America: | | | |
| Canada | 953 | 629 | 610 |
| Mexico | 354 | 285 | 190 |
| United States | 1,790 | 1,807 | 2,446 |
| Total | 3,097 | 2,721 | 3,246 |
| Central and South America: | | | |
| Brazil | 58 | 160 | 194 |
| Chile | 1,752 | 1,454 | 1,208 |
| Peru | 443 | 362 | 272 |
| Other[2] | 5 | 7 | 6 |
| Total | 2,258 | 1,983 | 1,680 |
| Europe: | | | |
| Albania | 19 | 15 | 14 |
| Austria | — | 45 | 45 |
| Belgium | — | 172 | 495 |
| Bulgaria | 103 | 140 | 140 |
| Czechoslovakia | 11 | 25 | 26 |
| Denmark | — | 5 | 5 |
| Finland | 19 | 100 | 70 |
| France | — | 17 | 47 |
| German Democratic Republic | 12 | 45 | 105 |
| Germany, Federal Republic of | — | 389 | 362 |
| Hungary | — | 4 | 14 |
| Italy | — | 72 | 104 |
| Netherlands | — | 8 | — |
| Norway | 22 | 35 | 40 |
| Poland | 465 | 395 | 432 |
| Portugal | 110 | 10 | 10 |
| Romania | 45 | 60 | 50 |
| Spain | 40 | 196 | 252 |
| Sweden | 84 | 110 | 107 |
| Turkey | 72 | 81 | 123 |
| U.S.S.R. | 680 | 1,053 | 1,070 |
| United Kingdom | — | 75 | 155 |
| Yugoslavia | 142 | 180 | 165 |
| Other | 3 | — | — |
| Total | 1,827 | 3,232 | 3,831 |
| Of which: | | | |
| Centrally planned economies | 1,335 | 1,737 | 1,837 |
| Market economy countries | 492 | 1,495 | 1,994 |
| Africa: | | | |
| Botswana | 26 | 25 | — |
| Morocco | 27 | — | — |
| Namibia | 45 | 60 | — |
| Zaire | 779 | 525 | 250 |
| Zambia | 627 | 464 | 625 |
| Zimbabwe | 19 | 34 | 33 |
| Other[1] | 3 | 2 | 3 |
| Total | 1,747 | 1,366 | 1,074 |
| Asia: | | | |
| Burma | 18 | — | — |
| China | 400 | 585 | 475 |
| India | 75 | 65 | 47 |
| Iran | 97 | 70 | 145 |
| Japan | 22 | 1,212 | 1,196 |
| Korea, North | 15 | — | 25 |
| Korea, Republic of | 2 | 185 | 175 |
| Malaysia | 30 | — | — |
| Mongolia | 180 | — | — |
| Oman | 20 | 22 | 20 |
| Philippines | 244 | 138 | 138 |
| Taiwan | — | 60 | 62 |
| Other | 2 | — | — |
| Total | 1,105 | 2,337 | 2,283 |
| Of which: | | | |
| Centrally planned economies | 595 | 585 | 500 |
| Market economy countries | 510 | 1,752 | 1,783 |
| Oceania: | | | |
| Australia | 372 | 295 | 287 |
| Indonesia | 150 | — | — |
| Papua New Guinea | 344 | — | — |
| Total | 866 | 295 | 287 |
| Total world | 10,900 | 11,934 | 12,401 |
| Of which: | | | |
| Centrally planned economies | 1,936 | 2,322 | 2,337 |
| Market economy countries | 8,964 | 9,612 | 10,064 |

[1]Includes mine capacity of 1,000 tons for Republic of Congo (Brazzaville), a centrally planned economy.

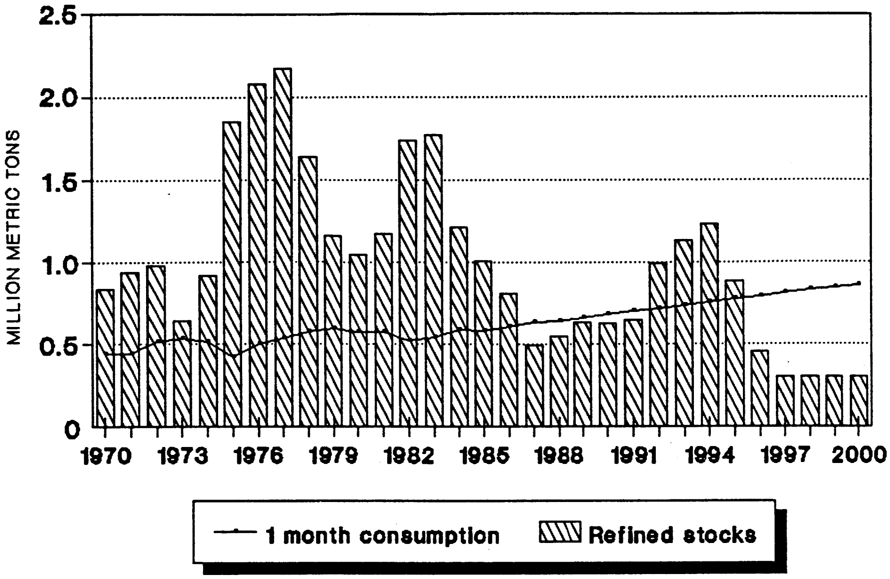
[2]Includes mine capacity of 5,000 tons for Cuba, a centrally planned economy.

in electrical uses alone could reach 2.29 million tons by the year 2000 in the United States.

Although the correlation is high between total U.S. copper consumption and the GPDI, it is not as high as for electrical uses. The GPDI correlates very poorly with copper consumed for other end-use sectors. One explanation has been the increased U.S. consumption of imported manufactured goods containing copper, which were not reflected in the measure of copper consumed at U.S. semifabricating plants, but which were included in the dollar-valued GPDI. Another reason is that the impact of substitution has been higher in other sectors. Shearson Lehman Hutton also found a high historical correlation with

FIGURE 1

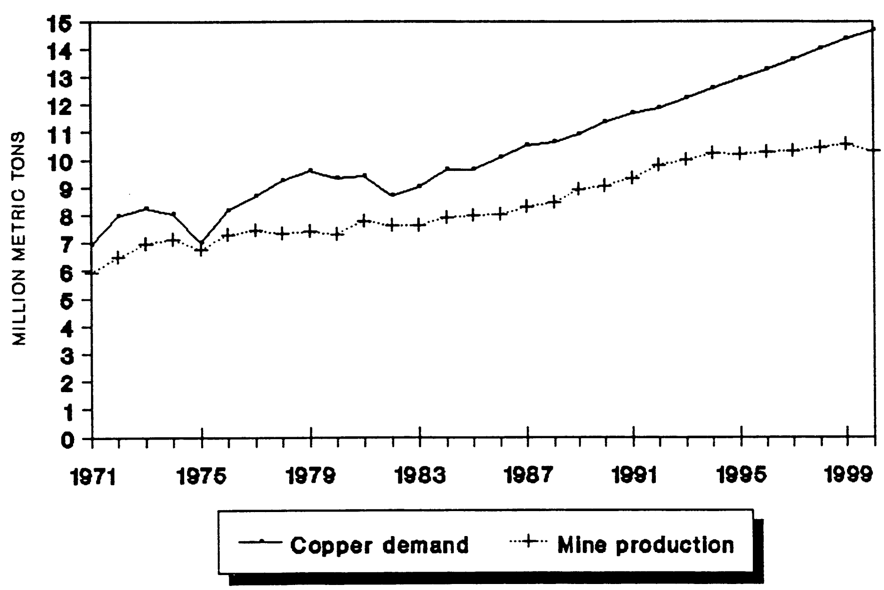
## MARKET ECONOMY COUNTRIES' REFINED INVENTORIES AND AVERAGE MONTHS' CONSUMPTION




*Source: Bureau of Mines; Aug. 1990*

FIGURE 2

## WORLD CONSUMPTION AND PRIMARY (MINE) SUPPLY




*Source: Bureau of Mines; Aug. 1990.*

Organization for Economic Cooperation and Development (OECD) Countries' industrial activity and the level of total OECD copper consumption.[22]

### Trends in Supply

World mine production has grown steadily since World War II, interrupted only by short periods of severe depression or long-term labor strikes. Financial investment in expanding capacity at new and existing mines has exceeded $10 billion since 1987. Much of the new capacity developed in the 1980's and 1990's stems from a more intensive prospecting and reserve development period that took place during the 1950's and 1960's. The long period of poor profits for the copper industry through much of the 1970's and 1980's lent credence to a perception that exploration in nonferrous metals was a poor investment. In addition, although many large deposits already had been discovered, the large sums of money required for further development were not available. The location of some of the largest deposits further increased financial risks. Political and economic stability was poor in some nations with large copper resources. In other countries, such as the United States, environmental and other licensing procedures made new mine development costs prohibitive in some areas. Although new arrangements for investment sharing and methods of financing are possible among mining companies, banks, and Governments, sufficient capital to develop some of these deposits may be a future problem.

The direction of mine supply growth, forecasted from 1989 to the year 2000, is shown in table 8. Also shown is the amount of capacity still in exploration stages that has been incorporated in the country forecasts for the latter part of the 1990's. Although speculated for possible initiation during the latter half of this period, no firm development plans had been made for these projects, and their implementation, therefore, was speculative.

Copper and copper alloy scrap is also a major source of copper. Although the potential supply of world scrap is significant, the rate of old scrap recovery is limited by copper's long life in its essential uses. The historical recovery of old scrap has averaged an estimated 18% of world copper consumption. Although old scrap recovery has been higher in the United States, it seldom has exceeded 22% of world consumption.

TABLE 7

**COPPER CONSUMPTION TRENDS**

| Period | United States | Market economy countries | World total |
|---|---|---|---|
| | | Copper consumed (thousand metric tons) | |
| 1950 | 1,337 | 2,502 | 2,774 |
| 1963 | 1,712 | 4,489 | 5,531 |
| 1983 | 2,013 | 7,079 | 8,963 |
| 1989 | 2,181 | 8,587 | 10,962 |
| 2000 (forecast) | 2,700 | 11,100 | 14,680 |
| | | Annual growth rates (percent) | |
| 1950-63 | 1.27 | 3.20 | 3.62 |
| 1963-89 | 1.00 | 2.50 | 2.67 |
| 1983-2000 (forecast)[1] | 1.90 | 2.60 | 2.90 |
| 1989-2000 (forecast) | 1.95 | 2.43 | 2.70 |

[1]Forecast 1983-2000 adapted from Mineral Facts and Problems, Bulletin 675, 1985 Edition, Bureau of Mines.

Source: Bureau of Mines.

### Forecast Supply and Demand Trends

Copper demand is forecast to grow at a 1.9% rate in the United States and at a 2.7% rate in the world between 1989 and the year 2000. While consumption in the United States, Europe, and Japan was expected to increase at a relatively lower rate, other countries were expected to surpass these rates as their economies develop. Significant increases in world copper demand could be driven by economic recovery in the centrally planned economy (CPE) countries and by increased domestic consumption in the less developed countries (LDC) and newly industrialized countries. Rejuvenation and building of new plants, equipment, and infrastructure in these countries could consume major amounts of copper. However, the problems of some African, Southeast Asian, and South American countries could continue or could deteriorate further. Consumption in these countries, therefore, was expected to exhibit minimal growth.

The projected balance between supply and demand forecasts is shown in figures 1 and 2. Estimated MEC refined inventories are compared with projected average monthly MEC consumption in figure 1, and world consumption is compared with primary (mine) supply in figure 2. Both illustrations indicate the potential for tight copper supply in the latter part of the 1990's. Historically, when inventories were less than 1 month's supply at prevailing rates of consumption, price pressures became significant. Supplies are anticipated to be impacted negatively during 1990 and 1991 by the continued shutdown of the Bougainville Mine, Papua New Guinea. A significantly positive supply influence will result from the anticipated early 1991 startup of the large Escondida Mine in Chile. Although some inventory surpluses are anticipated through 1993, it is not anticipated that the depressed market conditions of the middle 1970's and early 1980's will reoccur, causing inventories to accumulate to 4 months or more of supply.

## BACKGROUND

### Definition, Grades, and Specifications

Copper is traded in many forms that relate to different stages of processing. For example, at the mine copper may be sold as ore, concentrate, or precipitate. Copper ore may contain as little as 0.40% copper or more than 10% copper, depending on its source. Copper concentrates are produced by milling and concentrating copper ore and may contain between 18% and 40% copper. Copper precipitate or cement copper is recovered from leach solutions by chemical precipitation with scrap iron and may contain as much as 90% copper.

Smelter products include copper matte, blister, slag, and anode. Slag is the waste formed in smelting through the combination of a flux, such as limestone and silica, with the gangue or waste portion of the ore and, although it may contain small amounts of copper, is high in silicon and iron. Copper matte contains between 15% and 65% copper, together with much of the sulfur and other nonferrous and precious metals. The newer flash smelting technologies result in a much lower sulfur content in the matte than was possible in the reverberatory furnaces. Copper matte is transferred to a converting furnace where the sulfur is oxidized and removed as sulfur dioxide, and the enriched copper melt is poured as blister copper. Blister contains 97% to 98.5% copper. The blister is then fire refined by oxidizing the impurities in a reverberatory furnace, followed by removal of the excess oxygen by a process called poling. Poling may be done by insertion of green logs or a reducing gas into the melt. The blister is then cast into anode shape and further treated in an electrolyte bath to form refined copper cathode through electrolysis, transferring the copper ions of the anode by electrical current to the negatively charged cathode. Impurities in the copper anode such as gold, selenium, and silver are collected at the bottom of the electrolytic tank for recovery in a later process. Cathode copper may also be obtained from an electrowinning process. In this process, cathode copper is plated directly from copper-bearing solutions obtained from leaching copper-bearing ore, matte, scrap, or other material and enriched by solvent extraction methods. An alternative to electrolytic refining is fire refining of blister or of scrap, in which case, the fire-refined product is cast into ingots, bars, billets, or cakes and is not processed electrolytically.

Refined copper cathode, which contains greater than 99.3% copper, is the predominant form traded. Tough-pitch copper is refined copper cast into shapes. Oxygen-free copper, which is preferred for special electrical uses, is refined copper melted and recast in a deoxidizing atmosphere. Deoxidized copper is refined copper treated with deoxidizers to reduce cuprous oxide and remove oxygen. Normal refinery shapes cast from cathodes and fire-refined copper are wire bars, billets, slabs, ingots, and bars. Since the late 1970's, the continuous cast wire rod nearly has eliminated the wire bar as an intermediate shape used for making wire rod from refined copper. Wire rod is used to make wire of all types. Wire bar currently comprises less than 1% of the copper market. Billets made from refined copper, scrap, or alloys are large cylindrical shapes used for extruding tubing or

TABLE 8

## WORLD COPPER MINE CAPACITY

(Thousand metric tons, recoverable copper)

| Region | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 2000 |
|---|---|---|---|---|---|---|---|---|
| Africa: | | | | | | | | |
| Zambia | 627 | 612 | 620 | 608 | 594 | 594 | 521 | 393 |
| Zaire | 779 | 814 | 814 | 829 | 829 | 809 | 822 | 825 |
| Other[1] | 341 | 332 | 304 | 310 | 308 | 305 | 283 | 167 |
| Total | 1,747 | 1,758 | 1,738 | 1,747 | 1,731 | 1,708 | 1,626 | 1,385 |
| Asia: | | | | | | | | |
| Middle East | 119 | 196 | 226 | 226 | 242 | 254 | 252 | 257 |
| Philippines | 244 | 226 | 216 | 212 | 211 | 229 | 248 | 255 |
| Centrally planned economies | 595 | 610 | 615 | 615 | 615 | 615 | 615 | 615 |
| Other | 147 | 147 | 147 | 147 | 153 | 153 | 123 | 147 |
| Total | 986 | 983 | 978 | 974 | 979 | 997 | 986 | 1,017 |
| Europe: | | | | | | | | |
| Market economy countries | 492 | 453 | 452 | 455 | 465 | 457 | 424 | 403 |
| Centrally planned economies | 1,335 | 1,340 | 1,313 | 1,333 | 1,333 | 1,333 | 1,333 | 1,361 |
| Total | 1,827 | 1,793 | 1,765 | 1,788 | 1,798 | 1,790 | 1,757 | 1,764 |
| Central and South America: | | | | | | | | |
| Chile | 1,752 | 1,815 | 2,079 | 2,322 | 2,323 | 2,433 | 2,452 | 2,604 |
| Peru | 443 | 422 | 450 | 437 | 470 | 470 | 405 | 474 |
| Other[2] | 63 | 67 | 68 | 68 | 68 | 84 | 142 | 221 |
| Total | 2,258 | 2,304 | 2,597 | 2,827 | 2,861 | 2,987 | 2,999 | 3,299 |
| Oceania: | | | | | | | | |
| Australia | 372 | 399 | 443 | 422 | 435 | 400 | 400 | 376 |
| Indonesia | 150 | 170 | 200 | 200 | 230 | 230 | 230 | 260 |
| Papua New Guinea | 344 | 372 | 372 | 372 | 372 | 372 | 372 | 370 |
| Total | 866 | 941 | 1,015 | 994 | 1,037 | 1,002 | 1,002 | 1,006 |
| North America: | | | | | | | | |
| Canada | 953 | 973 | 946 | 923 | 921 | 1,006 | 989 | 890 |
| Mexico | 354 | 383 | 385 | 380 | 378 | 372 | 372 | 354 |
| United States | 1,790 | 1,907 | 1,999 | 2,058 | 2,074 | 2,210 | 2,248 | 2,195 |
| Total | 3,097 | 3,263 | 3,330 | 3,361 | 3,373 | 3,588 | 3,609 | 3,439 |
| Total mine capacity | 10,900 | 11,244 | 11,656 | 11,931 | 12,035 | 12,340 | 12,249 | 12,275 |
| Of which: | | | | | | | | |
| Market economy countries | 8,964 | 9,287 | 9,721 | 9,976 | 10,080 | 10,385 | 10,295 | 10,293 |
| Centrally planned economies | 1,936 | 1,957 | 1,935 | 1,955 | 1,955 | 1,955 | 1,954 | 1,982 |
| MEC capacity in exploration[3] | — | — | 1 | 11 | 60 | 82 | 135 | 855 |
| U.S. capacity in exploration[3] | — | — | — | — | 42 | 59 | 59 | 108 |
| Total planned capacity[4] | 10,900 | 11,244 | 11,655 | 11,920 | 11,933 | 12,199 | 12,055 | 11,312 |

[1]Includes capacity of 1,000 tons for Republic of Congo (Brazzaville), a centrally planned economy.
[2]Includes capacity of 5,000 tons for Cuba, a centrally planned economy.
[3]Capacity in exploration stages without announced intention to develop and financial arrangements secured.
[4]Probable capacity, including announced properties in process of development.

sometimes wire rod. Slabs are the precursors to flat products such as sheet. Ingots are small shapes that are usually remelted and used for making alloys.

There are more than 370 copper and copper alloys divided into broad categories of wrought and cast metals. A unified numbering system (UNS) for metals and materials was developed by the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers. This system designates each alloy by five digits preceded by the letter C. The UNS is administered by the Copper Development Association and is widely used by ingot-makers, brass mills, and foundries in the United States. The major classes are coppers that contain greater than 99.3% copper; high-copper alloys, which contain at least 94% copper; brasses, which contain zinc as the dominant alloying agent; bronzes, which normally contain tin as the dominant alloying agent, but which also may contain such other metals as aluminum, lead, phosphorus, and silicon but only small amounts of zinc; copper-nickels, which contain nickel as the principal alloy metal; nickel silver, which contains copper, nickel, and zinc as the principal metals; leaded coppers, which are cast alloys containing 20% or more of lead, but no zinc or tin; and special alloys, which are copper alloys with compositions not covered in the above groups. Master alloys and hardeners are copper-based alloys cast with a high alloying element content and are used in producing copper alloys. Hardeners and master alloys not only permit closer composition control than possible by addition of pure metals, but also permit easier introduction of a deoxidizer, such as phosphorus. Beryllium copper master alloy, containing 7% to 10% beryllium, and phosphor copper, containing 10% to 14% phosphorus, are examples. The ASTM specifications for refined copper are designated in part 6, section B5-77 of the ASTM specifications, and are under the jurisdiction of ASTM Committee B-5 on copper and copper alloys.

### Products for Trade and Industry

At least four physicochemical properties, singly or in combination, account for the widespread use of copper and its alloys. Foremost among these is electrical conductivity. Among the electrically conductive metals, copper is second in conductivity only to silver. Electrical uses, which account for about 70% of copper demand, include electrical power transmission, motors and generators, housing and industrial wiring, automotive and appliance wiring, telecommunications, electronic circuit boards, specialized electronic equipment, and numerous other electrical and electronic applications.

The chemical stability and workability of copper are among the reasons that copper and its alloys have been extensively used in tubing and valves for systems carrying potable water, saltwater, and other aqueous fluids. Because of its good thermal conductivity, again being second only to silver in thermal conductivity, copper and its alloys were extensively used as materials of construction for heat exchangers used in motor vehicles, refrigeration, air-conditioning units, and numerous other applications. Because of its resistance to salt, copper was widely used in marine environments and automotive brake components.

Copper also was used widely, for other than electrical conductivity, in industrial machinery and transportation equipment. Because of its aesthetic appeal and resistance to weathering, copper was used in construction for roofing, flashing, decorative hardware, and guttering and downspouts. Miscellaneous uses of copper included ammunition, industrial and agricultural chemicals, pigments, fine instruments and watches, jewelry, cooking utensils, decorative items, and coinage.

Electrical uses of copper have accounted for an increasing market share over the past 20 years. Growth in consumer and business electronics and building wire demand have contributed to electrical demand growth, while materials substitution in plumbing, automotive radiators, coinage, etc., and increased imports of copper-containing manufactured goods such as automobiles, machinery, and air-conditioning units have reduced or stabilized demand for other uses. The growth in electrical demand has occurred, despite the substitution of aluminum in overhead power transmission lines; development of microwave, digital, and fiber-optic technologies for telecommunications; and downsizing of motors and switch gear. Specialty alloys, such as beryllium copper used for electronic connectors, have experienced strong growth in demand. The growth in electrical uses and the shift from wire bar technology to continuous cast wire rod has increased the demand for electrolytic copper at the expense of fire refined material. In 1989, only one domestic secondary refinery produced fire refined wire bar.

### Industry Structure

Copper smelting operations have been traced back to at least 5000 B.C., but modern history and growth in demand for copper began with the discovery and commercial development of electricity in the latter part of the 19th century.[23] World copper production was estimated to be only about 50,000 tons in 1850. However, by the turn of the century, it reached an estimated 500,000 tons per year. By 1912, world mine production had reached 1 million tons. World production continued to grow, almost uninterrupted, to almost 9 million tons in 1989. More than 90% of cumulative world mine production has occurred since 1900; 60% since 1960.

In 1989, copper was mined in about 60 countries. The top 13 producing countries accounted for 85% of production. The United States and Chile were the leading producers, each accounting for about 17% of production. Copper was smelted in 40 countries and refined in 42 countries. Industrialized countries in Europe and the Far East, which lacked sufficient raw materials, encouraged mine production in the LDC's to assure supplies. These countries have long dominated world smelting and refining capacity. Thus, in 1989, Japan was second only to the United States in smelter and refinery production despite having only nominal mine production. To assure its supply of concentrates, Japanese smelters and refiners invested heavily in world mine capacity, particularly in Chile, but also in other countries. In 1989, Japanese companies owned a 15% and 33% interest, respectively, in the Chino and Morenci Mines in the United States.

European smelting-refining companies, similarly lacking in copper resources, invested in mines in Africa, Asia, and Oceania. The new Escondida Project in Chile, slated to come on-stream at the beginning of 1991, was owned by a consortium of Australian, British, and Japanese companies and, in exchange for concentrate supply contracts, financed in part by interests in Japan, Finland, and the Federal Republic of Germany. Similarly, U.S.-based Freeport-McMoRan Inc., owners of Freeport Indonesia Inc., secured a $500 million loan package to expand its concentrator and develop its Grasburg, Indonesia, deposit from banks in eight countries, one-half of which will receive Freeport concentrates.

However, in recent years the concentrate exporting countries have sought to increase their local smelting and refining capacities to supply growing domestic demand for refined copper and to maximize foreign exchange earnings. Traditional copper concentrate exporting countries with expanded smelting capacity included Australia, Chile, Mexico, and the Philippines. The PASAR smelter and refinery was commissioned in 1983 and subsequently expanded. To assure supplies to the Philippine Government-controlled (60%) operations, Philippine mines were ordered to ship a minimum of 30% of their concentrates to PASAR despite its high smelting and refining charges. In addition, newly industrialized countries such as the Republic of Korea have added capacity to meet their growing demand for refined copper. Similarly, Brazil became an exporter of brass mill products and major new brass mills were being constructed in the Republic of Korea, Philippines, and Taiwan.

In the 1950's, eight privately owned U.S. and Western European companies controlled three-fourths of world copper

TABLE 9

## APPARENT CONSUMPTION OF COPPER, BY END-USE SECTOR[1]

(Thousand metric tons of copper and percent of consumption)

| Year | Electrical[2] | | Construction | | Machinery | | Transportation | | Ordnance | | Other uses | | Total consumption (quantity) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity | Percent | Quantity | Percent | Quantity | Percent | Quantity | Percent | Quantity | Percent | Quantity | Percent | |
| 1960 | 755 | 52 | 261 | 18 | 203 | 14 | 102 | 7 | 29 | 2 | 102 | 7 | 1,452 |
| 1961 | 728 | 48 | 303 | 20 | 228 | 15 | 106 | 7 | 30 | 2 | 121 | 8 | 1,517 |
| 1962 | 820 | 50 | 328 | 20 | 246 | 15 | 115 | 7 | 33 | 2 | 98 | 6 | 1,640 |
| 1963 | 822 | 48 | 377 | 22 | 274 | 16 | 120 | 7 | 34 | 2 | 86 | 5 | 1,712 |
| 1964 | 870 | 49 | 409 | 23 | 231 | 13 | 124 | 7 | 36 | 2 | 107 | 6 | 1,776 |
| 1965 | 1,031 | 52 | 416 | 21 | 238 | 12 | 139 | 7 | 40 | 2 | 119 | 6 | 1,982 |
| 1966 | 1,064 | 48 | 465 | 21 | 266 | 12 | 177 | 8 | 155 | 7 | 89 | 4 | 2,216 |
| 1967 | 918 | 50 | 367 | 20 | 220 | 12 | 129 | 7 | 147 | 8 | 55 | 3 | 1,836 |
| 1968 | 974 | 51 | 382 | 20 | 210 | 11 | 134 | 7 | 134 | 7 | 76 | 4 | 1,909 |
| 1969 | 1,009 | 49 | 432 | 21 | 247 | 12 | 144 | 7 | 144 | 7 | 82 | 4 | 2,058 |
| 1970 | 1,000 | 55 | 346 | 19 | 182 | 10 | 127 | 7 | 91 | 5 | 73 | 4 | 1,819 |
| 1971 | 1,038 | 55 | 377 | 20 | 189 | 10 | 132 | 7 | 57 | 3 | 94 | 5 | 1,886 |
| 1972 | 1,264 | 59 | 386 | 18 | 193 | 9 | 129 | 6 | 64 | 3 | 107 | 5 | 2,142 |
| 1973 | 1,378 | 62 | 378 | 17 | 178 | 8 | 133 | 6 | 44 | 2 | 111 | 5 | 2,223 |
| 1974 | 1,287 | 60 | 365 | 17 | 214 | 10 | 129 | 6 | 43 | 2 | 107 | 5 | 2,145 |
| 1975 | 914 | 62 | 236 | 16 | 118 | 8 | 88 | 6 | 44 | 3 | 74 | 5 | 1,473 |
| 1976 | 1,154 | 60 | 327 | 17 | 154 | 8 | 154 | 8 | 19 | 1 | 115 | 6 | 1,924 |
| 1977 | 1,242 | 60 | 373 | 18 | 186 | 9 | 145 | 7 | 21 | 1 | 103 | 5 | 2,070 |
| 1978 | 1,422 | 60 | 427 | 18 | 190 | 8 | 166 | 7 | 47 | 2 | 118 | 5 | 2,370 |
| 1979 | 1,412 | 58 | 463 | 19 | 219 | 9 | 170 | 7 | 24 | 1 | 146 | 6 | 2,434 |
| 1980 | 1,438 | 66 | 327 | 15 | 174 | 8 | 109 | 5 | 22 | 1 | 109 | 5 | 2,179 |
| 1981 | 1,590 | 70 | 273 | 12 | 159 | 7 | 136 | 6 | 23 | 1 | 91 | 4 | 2,271 |
| 1982 | 1,251 | 71 | 229 | 13 | 123 | 7 | 70 | 4 | 18 | 1 | 70 | 4 | 1,762 |
| 1983 | 1,368 | 68 | 322 | 16 | 161 | 8 | 80 | 4 | 20 | 1 | 60 | 3 | 2,012 |
| 1984 | 1,397 | 66 | 359 | 17 | 148 | 7 | 106 | 5 | 21 | 1 | 85 | 4 | 2,116 |
| 1985 | 1,480 | 69 | 343 | 16 | 150 | 7 | 86 | 4 | 21 | 1 | 64 | 3 | 2,144 |
| 1986 | 1,410 | 66 | 384 | 18 | 150 | 7 | 107 | 5 | 21 | 1 | 64 | 3 | 2,136 |
| 1987 | 1,494 | 68 | 395 | 18 | 132 | 6 | 88 | 4 | 22 | 1 | 66 | 3 | 2,197 |
| 1988[r] | 1,592 | 72 | 332 | 15 | 133 | 6 | 66 | 3 | 22 | 1 | 66 | 3 | 2,211 |
| 1989 | 1,571 | 72 | 327 | 15 | 131 | 6 | 65 | 3 | 22 | 1 | 65 | 3 | 2,182 |

[r]Revised.

[1]Copper Development Association (CDA) categories have been redistributed on a copper content basis (the alloy component has been subtracted). The electrical component has been extracted from all end-use categories except electrical and ordnance. Adjustments were also made for the new scrap component, which was subtracted. Ordnance data reflect U.S. Department of Commerce ACM military shipments to 1983; estimated data, thereafter, reflect CDA data for 1989.

[2]Includes wire and other forms used in electrical, communications, and other special uses.

production outside the U.S.S.R. By 1983, many mines in the less developed countries had been partially or totally nationalized so that more than 50% of the world's copper mine production was from Government-owned corporations. Most notable of the state-controlled mining companies that came into existence during the 1960's and 70's were the following: CODELCO-Chile, the world's largest copper producer; Zambia Consolidated Copper Mines Ltd. (ZCCM), which was formed in 1982 through the merger of state-owned Nchanga Consolidated Copper Mines Ltd. (NCCM) and Roan Consolidated Mines Ltd. (RCM), and was accountable for all of Zambia's mine production; La Générale des Carrières et des Mines du Zaire (Gécamines), which, in 1987, acquired Japanese and state-owned Société de Développement Industriel et Minière du Zaire (Sodimiza) to account for all of Zaire's production; and Empresa Minera del Centro del Perú (Centromín Perú), Empresa-Minera del Perú (Minero Perú), and Empresa Minera Especial Tintaya S.A. (Tintaya), which combined accounted for about one-third of Peru's mine capacity.

Since 1983, state control of copper production has declined slightly to about 50% of world capacity owing to contraction of some state-controlled operations and capacity growth in the private sector. All of the greenfield copper projects that came on-stream since 1983 or were slated to come on-stream over the next several years were privately owned.

Following the supply-demand imbalance in 1982, which led to accumulation of massive world refined copper inventories, copper prices were severely depressed. The fall-off in copper revenues resulted in sustained economic losses by some copper producers and mine closures. In some countries, such as Chile and the Philippines, price support mechanisms were instituted to aide the private mining sector.

Significant restructuring by both state-controlled and privately held copper producers occurred in efforts to rationalize production and reduce operating costs. In Zaire, Gécamines, which operated about 1 dozen mines in three geographic regions along the Copperbelt of Central Africa, launched a 5-year, $870 million rehabilitation project in 1985, including plans for a new refinery. In Zambia, ZCCM began a 5-year plan in 1986 to streamline and rationalize production to stem the decline in annual output. The decline was ascribed to low equipment availability owing to a shortage of spare parts, insufficient skilled labor, an exodus of engineering staff, unreliable transportation to African ports, and a shortage of sulfuric acid for expanded leach operations. As part of the revitalization, the Chambishi Mine was closed, new reserves at Mufulira were developed, the worker training budget was increased 16-fold, and various national economic policies were adopted to ensure capital.

In the Philippines, most of seven mining companies continued to sustain losses, even after the recovery of copper prices in 1987. Atlas Consolidated Mining Development Corp., the largest Philippine producer, closed several open pit operations but was expanding high-grade underground operations and developing a new open pit to replenish reserves.

In Mexico, the two State-controlled mining companies, Mexicana de Cobra S.A., which operated the La Caridad Mine, and Cia Minera de Cananea S.A., which operated the Cananea Mine, together accounting for about 98% of production in Mexico, were offered for sale in 1988 in an effort to reduce Federal debt by selling nonstrategic assets. Cananea remained unsold through 1989.

In Chile, capital investments in excess of $2 billion and devaluation of currency helped to halve operating costs at CODELCO-Chile's four divisions over the decade ending in 1985, to make it one of the world's lowest cost copper producers. CODELCO-Chile, which operated the world's largest open pit (Chuquicamata) and underground (El Teniente) mines, continued to invest heavily to maintain and expand production in light of rapidly declining ore grades. In 1988, CODELCO-Chile announced a $1.25 billion, 5-year investment program that was projected to boost production by 200,000 tons to 1.38 million tons. Despite these investments, production by CODELCO-Chile remained nearly constant between 1986 and 1988, with most of Chilean production increases over that period coming from the private sector. However, production in Chile rose significantly in 1989, owing to capacity increases at Chuquicamata.

In the United States, major rationalization and ownership changes, restructuring, labor concessions, and major capital investments revitalized the copper industry and reduced average production costs from more than 80 cents per pound in 1982 to less than 60 cents per pound in 1989. Production rose from 1.04 million tons in 1983 to 1.5 million in 1989, just slightly short of the record production level set in 1973. Foremost in technology changes were expansion of lower cost SX-EW technology, in-pit crushing and conveying systems, and flash smelting technology. By 1989, with the sale of Kennecott to RTZ, oil companies, which in the late 1970's had seen domestic copper companies as attractive acquisitions, had divested their domestic copper holdings.

Though about 20 different companies operated a total of more than 60 copper-producing mines in the United States, 4 companies, Phelps Dodge Corp., Cyprus Minerals, Asarco, and Magma accounted for 90% of domestic capacity. Major industry ownership changes occurred as companies sought to raise capital for production increases and become more self-sufficient through vertical integration of mines, smelters, refineries, and rod mills.

Several companies, including Inspiration Resources, Noranda, and AMAX, totally divested their U.S. copper holdings. In 1986, Kennecott, the largest domestic producer (then owned by BP Minerals), in exchange for labor concessions, agreed to reopen its shuttered Bingham Canyon Mine and invest $400 million in modernization of its Utah operations. To raise capital, it sold its Chino and Ray Mines. Phelps Dodge emerged as the largest and lowest cost domestic copper producer following the purchase of Chino, restructuring of its labor force, major investments in electrowinning capacity, and investment in in-pit crushing and conveying technology.

Magma invested $200 million in a new flash smelter and acid plant at San Manuel. The new smelter provided the sulfuric acid necessary to develop open pit and in situ copper oxide reserves and to lower overall production costs. Asarco acquired the Ray Mine, full control of the Mission Complex reserves and other properties, switching from a custom smelter to an integrated producer. Between 1986 and 1989, Cyprus Minerals also acquired several properties from other companies.

The U.S. primary smelting industry underwent significant contraction with the coincidence of depressed copper prices and a yearend 1987 compliance deadline with the clean air regulations. Between 1983 and 1986, 7 of 13 primary smelters, most of which were noncompliance reverberatory smelters operating under interim compliance orders, were permanently closed. Insufficient smelting capacity for processing its concentrates prompted the acquisition of the Inspiration smelter and Lakeshore roast-leach plant by Cyprus Minerals and Chino smelter by Phelps Dodge. With the recovery of copper mine production, the United States became a significant exporter of concentrates.

The erosion of U.S. ownership of world copper production, which has been the case since the nationalizations of the 1960's, took on a new dimension in the 1980's, with foreign companies investing in domestic mines. In addition to foreign ownership of Kennecott, first by BP and later by RTZ, and Japanese investment in the Chino and Morenci Mines, Copper Range sold its mine, smelter, and refinery in White Pine, MI, in 1989 to a Canadian subsidiary of Metallgesellschaft AG. of Germany. Mitsubishi Metals of Japan planned to construct a copper smelter in Texas.

While companies tended to integrate their unwrought copper production facilities, the 25-year-old trend away from the strong ties between downstream processors and mine producers continued. In 1986, Anaconda sold its American Brass divisions. Ownership of Chase Brass, which had been reorganized in 1986 into separate operating divisions along product lines, remained partially with BP Minerals America when RTZ purchased Kennecott. Phelps Dodge sold or closed much of its wire production facilities. Where the brass industry was dominated by a few full-line mills, it evolved into four distinct industries with mills having single or limited product lines: Strip, sheet, and plate; plumbing and commercial tube; alloy wire and rod; and unalloyed copper wire rod for electrical wire production. Only the copper wire rod mills retained their association with the primary producers. Low processing margins and increased import competition during the period of low copper prices hastened the trend toward sell-off or closure of unprofitable operations and specialization of product line.[24] Imports of semifabricated products doubled over a 10-year period, reaching their peak in 1984 of more than 260,000 tons. Though still high by historic standards, import penetration has declined slightly owing to successful antidumping suits filed by the domestic industry, restructuring of the domestic industry, and a weakened U.S. dollar.

Production and consumption of brass and bronze ingot in the United States declined markedly between the late 1960's and early 1980's owing to the substitution of plastics and aluminum for brass and bronze castings, increased import penetration, and more stringent environmental regulation being applied to ingot makers and foundries. Over that time period, domestic production of alloy ingot fell by 40%, and more than one-half of the approximately 40 ingot makers were closed. The foundry industry underwent a similar contraction, with alloy ingot consumption falling by a commensurate amount. However, since about 1985, domestic production and consumption of alloy ingot stabilized at about 180,000 tons per year.

## Geology—Resources

According to their mode of origin, copper deposits may be grouped in the following broad genetic classes: (1) porphyry copper deposits and their associated skarn, hydrothermal veins, and replacement breccia deposits; (2) deposits associated with ultramafic, mafic and alkaline ultrabasic, and carbonatite rocks; (3) volcanogenic and metavolcanogenic deposits; (4) sedimentary and metasedimentary deposits; and, (5) veins and replacement bodies associated with metamorphic sequences, not otherwise classified. As a percentage of total world capacity, the predominant type mined was that of the porphyry copper and associated deposits (59%), followed by stratiform sedimentary replacement and metasedimentary deposits (23%), volcanogenic massive sulfide deposits (7%), veins and replacement bodies (7%), and ultrabasic massive sulfide and carbonatite deposits (4%). Though the massive sulfide and vein and replacement deposits were much more numerous than the porphyry and stratiform sedimentary deposits, they tended to be smaller in both capacity and reserves, but generally contained a wider variety of other mineral coproducts. In the United States, porphyry copper deposits made up about 93% and stratiform sedimentary and metasedimentary deposits about 6% of established mine capacity.

In recent years, plate tectonic theory has been emphasized in defining copper deposits as they relate to the Earth's lithospheric plates, their edges, subduction zones, and spreading axes in space and time. For example, deposits of the porphyry copper type occur mainly in magmatic, volcanic arc, and back-arc regions of plates overlying subduction zones; hence, their predominant location along areas such as the continental edges of North and South America. Copper deposits found in ultramafic sequences are characteristic of oceanic plate settings and ophiolite rock groups. Alkaline ultrabasic rocks and carbonatites intrude stable continental cratons and are presumed to have come from mantle-derived magmas contaminated with crustal rocks. At Palabora, the Republic of South Africa, a carbonatite is host to a copper deposit; as a significant producer of copper, this is a unique occurrence. Sedimentary copper deposits generally occur in rocks typical of passive continental margin and interior environments and intracontinental rift systems. In addition, these deposits may have been redistributed by later diagenetic or metamorphic hydrothermal systems, but retain their stratiform identity. Stratiform applies to a layered mineral deposit of any origin. Stratibound refers to a deposit confined by a single stratigraphic horizon.

Copper occurs in about 250 minerals; however, only a few are commercially important. The most common are chalcopyrite ($CuFeS_2$), covellite ($CuS$), chalcocite ($Cu_2S$), bornite ($Cu_5FeS_4$), enargite ($Cu_3AsS$), and tetrahedrite ($(CuFe)_{12}Sb_4S_{13}$). Metals may be leached out of the rock above the water table by circulating ground water, oxidized, and enriched in the underlying supergene zone. The supergene capping of an ore body often contains the highest concentration of copper as chalcocite or as various copper oxide and silicate minerals. Native copper also occurs in the oxidized or supergene zones.

The definitions for reserves and reserve base are published in U.S. Geological Survey Circular 831, "Principles of a Resource/Reserve Classification for Minerals." In this system, the reserve base is the measured plus indicated (demonstrated) resource from which reserves are estimated. Reserves are that part of the reserve base thought to be economically recoverable with existing technology at operating or developing properties. Among individual countries, Chile had the largest share (22%) of the reserve base, followed by the United States (16%), the U.S.S.R. (9.7%), and Australia (7.3%). Peru, Zaire, and Zambia also had large copper reserves with about 5% each. More than 90% of U.S. copper reserves was in five States—Arizona, Michigan, Montana, New Mexico, and Utah. The U.S. Geological Survey (USGS) estimated total world land-based copper resources, comprised of the reserve base and a larger body of less well characterized resource, was about 1.6 billion tons.

Copper reserves reported at operating or developing properties were sufficient to meet a projected cumulative demand of nearly 130 million tons of primary copper through the year 2000. In addition, some of the material already identified in the reserve base, which was presumed to be uneconomic to mine, may become economic with new technology and/or higher copper prices. However, the rate of increase in the reserve base has declined since 1976. The world reserve base, including measured and indicated ore, increased by about 140% from 1965 to 1976, corresponding to a 56% growth in world production and 48% growth in consumption over the same period. Since 1976, however, the reserve base has increased by only 23% and production by only 17%, while consumption grew by an impressive 36%. Since the late 1970's, the preoccupation with gold exploration and general neglect of base-metal exploration led to a significant decline of reserves in Canada, Peru, the Philippines, and other countries. Unless substantial new discoveries occur immediately, some countries' output will decline by the late 1990's. According to a recent Canadian analysis, to maintain 1988 Canadian production, each mine approaching exhaustion must be replaced by a new operation, based on a discovery some 6 years earlier.[25] Canadian copper production is forecast to fall off sharply by 1994 because mine reserves would be exhausted. The large reserves of copper in Canada were discovered during the period of high base-metal exploration that existed through the late 1950's to the early 1970's.

## Technology

***Exploration.***—Exploration for copper deposits in the United States generally takes

TABLE 10

**COPPER RESERVES AND RESERVE-BASE**

(Million metric tons, contained copper)

| Area and country | Reserves | Reserve base |
|---|---|---|
| North and Central America: | | |
| Canada | 13 | 24 |
| Mexico | 14 | 20 |
| United States | 55 | 90 |
| Other | — | 15 |
| Total | 82 | 149 |
| South America: | | |
| Chile | 85 | 120 |
| Peru | 8 | 31 |
| Other | 1 | 21 |
| Total | 94 | 172 |
| Europe: | | |
| Poland | 10 | 15 |
| U.S.S.R. | 37 | 54 |
| Other | 13 | 13 |
| Total | 60 | 82 |
| Africa: | | |
| Zaire | 26 | 30 |
| Zambia | 16 | 34 |
| Other | 4 | 4 |
| Total | 46 | 68 |
| Asia: | | |
| Indonesia | 3 | 5 |
| Philippines | 10 | 16 |
| Other | 17 | 28 |
| Total | 30 | 49 |
| Oceania: | | |
| Australia | 17 | 41 |
| Papua New Guinea | 7 | 13 |
| Total | 24 | 54 |
| Grand total | 336 | 574 |
| Of which: | | |
| Market economy countries | 281 | 492 |
| Centrally planned economies | 55 | 82 |

place in potential areas within which the anticipated copper deposit is masked by postore cover in the form of alluvium and volcanic or sedimentary rock. Following discovery of a potential deposit by geophysical and chemical means, successively and increasingly intensive drilling campaigns to characterize and quantify the deposit are undertaken before a decision is made to bring a deposit into production. Continued drilling programs to extend identified reserves may continue throughout the production life of the deposit. Copper exploration was seriously lacking through most of the 1970's and 1980's, but has received renewed vigor since the high prices of the late 1980's. In the United States, recent exploration and development has focused on oxide ores suitable for processing by low-cost, leaching SX-EW technology and on the stratiform ores of Montana.

Studies of the geologic environments of identified deposits may lead to a basis for predictive metallogeny of other parts of the same area. For example, the USGS considered the Midcontinent rift area of the United States as a particularly important geologic environment for certain types of mineral deposits. The rift structure extends for 2,000 kilometers from Kansas, northeast through the Lake Superior region, and bends southeast into Michigan. A new USGS project was designed to characterize the rift and provide metallogenetic analysis of types of minerals deposits that may be expected. Identified occurrences included the copper-nickel sulfides of the Duluth complex, stratiform deposits of the Keweenaw Peninsula, MI, and copper-molybdenum bearing breccia pipes of Ontario.[26]

***Mining and Beneficiation.***—Since the turn of the century, the evolution of technology for large-scale mining, milling, and concentrating low-grade ores has resulted in a continued shift away from mining small, high-grade, massive sulfide deposits by labor-intensive underground methods. Today, open pit mining accounts for almost 60% of MEC production and more than 80% of domestic production. Open pit mining requires a relatively shallow deposit with typical waste-to-ore stripping ratios between 1:1 and 2:1. A typical surface copper mine uses rotary blasthole drills and a shovel-truck combination for the loading and hauling operation. Underground mining methods vary with the geophysical nature of the ore and host rock, but typically have lower waste-to-ore ratios and higher grades and employ some form of large-scale block-caving such as that employed at San Manuel in the United States and El Teniente in Chile.[27] Following extraction, run-of-the-mine ore is milled (successively crushed and ground) to liberate the copper sulfide minerals and beneficiated or concentrated via froth flotation to produce a concentrate containing about 30% copper suitable for modern smelting.

Faced with higher energy costs, deeper mines with longer haul distances, high labor rates, and lower ore grades, the domestic industry has fought to maintain and subsequently lower production costs over the past few decades. Major improvements in energy use and labor management in mining and milling technology have been made in recent years through improved strategies of materials transport, grinding, and concentration. Technological improvements include in-pit crushing and conveying systems to replace truck-haulage to the mill; semiautogenous and autogenous grinding circuits; column and cyclone flotation cells; increased equipment scale, including trucks and flotation cells; computer-controlled truck dispatch systems; and improved on-line sampling and automated reagent control in the mill.

An important factor in domestic mine cost savings has been the development and rapid expansion of SX-EW technology for the treatment of acid soluble oxide or chalcocite ores. In this process, dilute sulfuric acid is percolated through the ore, either in dumps, pads, or in situ. The copper-bearing solution (leachate) is collected and processed through solvent extraction to concentrate the copper in solution. Copper is recovered from the concentrated solution by electrowinning where copper is plated directly from solution onto a starter cathode. The resultant electrolytically pure copper bypasses the traditional smelting and refining steps. Recent advances in the organic extractants and in electrowinning have improved the economics of this process. In addition to processing oxidized ores, mines have realized tremendous cost savings by leaching existing waste and ore dumps and by adjusting cutoff grades to the concentrator upward, with lower grade material being processed by SX-EW.

Growth in SX-EW capacity has been rapid since the mid-1970's. In the United States, SX-EW capacity increased from only 37,000 tons in 1974 to 358,000 tons of copper in 1989. Similarly, SX-EW capacity for the world, which was estimated to be 910,000 tons of copper per year in 1989, was expected to exceed 1.3 million tons by 1995.

***Smelting.***—Most copper concentrates are processed through three-stage smelting to produce anode suitable for electrolytic refining. Concentrate is processed in the primary smelting reactor to produce a copper and iron sulfide matte containing up to 60% copper. The matte is oxidized in a converter, forming iron oxides that are removed in the slag and blister copper containing in excess of 98% copper. Sulfur is removed as sulfur dioxide in the gas streams. Blister copper is fire refined in an anode furnace to remove oxygen and other impurities. The anodes are interspersed with either copper, stainless steel, or titanium starter sheets in an electrolytic cell or tank, and copper is plated from the anode to the cathode. The resulting cathode is 99.9% pure and suitable for most electrical applications of copper. Valuable impurities, including the precious metal values, collect as sludge in the bottom of the electrolytic cell.

In 1970, environmental constraints and energy costs became a prime concern of the domestic smelting industry. Through the late 1970's and mid-1980's, domestic smelters were able to use interim methods such as tall stacks and intermittent operation to meet sulfur dioxide emissions standards. However, by the 1987 compliance date, most remaining smelters had abandoned traditional reverberatory smelting and had adopted one of the various oxygen enriched smelting furnaces (Outokumpu flash, Noranda, Inco flash, Mitsubishi continuous). These furnaces generally required lower energy input and provided a more concentrated sulfur dioxide gas stream, which allowed for sulfuric acid production as a means of sulfur dioxide capture. The byproduct sulfuric acid has provided a readily available, inexpensive source of acid for expansion of the SX-EW capacity.

Flash smelting involves the blowing of concentrate, flux, and oxygen into a hot furnace. The sulfur and iron in the concentrate react rapidly (flash) with the oxygen, and release a tremendous amount of heat. Flash processes using oxygen or oxygen-enriched air are generally autogenous, requiring no external fuel input. In 1988, Magma commissioned the world's largest single furnace Outokumpu flash smelter. The majority of new smelters constructed worldwide since 1970 were Outokumpu flash smelters. However, in the United States, two new Inco furnaces, at Hayden, AZ, and Hurley, NM, were commissioned since 1980. The Noranda process smelter, installed by Kennecott, was not autogenous but had the advantage of being able to process larger size material, including scrap, and produce a higher grade copper matte.[28] Cyprus operated the only domestic electric furnace, the Copper Hill smelter, having shutdown in 1987. Though electric furnaces require a large electrical energy input, they produce a low-copper slag suitable for direct disposal and can process a variety of materials.

Asarco, which operated one of the two remaining reverberatory smelters at its El Paso smelter, announced plans to install a Contop (Continuous Top-Blowing process) flash smelter. In this newly developed, autogenous process, concentrate is continuously melted in a cyclone furnace located on top of a large settling chamber. The high temperature of the flash smelting, combined with top blowing of the slag in the settling chamber, volatilizes most of the impurities such as lead, arsenic, etc., and is well suited to ores having high-impurity levels. It also provides for a low-copper slag that can be dumped without further treatment. Also, because of its relatively low capital requirement and compact size, it was reportedly well-suited for retrofit installation.[29]

The rapid advancement in continuous cast technology for rod and sheet since the middle 1970's and the increasing dominance of the electrical end-use market has promoted the need for high-purity forms of copper. Technical improvements at the refinery level have included the use of permanent stainless steel or titanium starter sheets, improved solution chemistry, and automated system control leading to greater current efficiency and reduced impurity levels. As a result of reagent and production refinements, almost all domestic SX-EW production is high-quality cathode, which does not require further refining. The increase in continuous cast wire rod capacity has rendered the wire bar, an intermediate cast shape, almost obsolete and has effectively shifted intermediary casting from the refinery to the mill. Though it has not replaced deep-well casting of intermediate, cake slab, and billet, continuous casting technology also has been developed for the sheet and tube sectors.

***Recycling.***—The Institute of Scrap Recycling Industries Inc. (ISRI), recognized more than 50 classes of copper and copper alloy scrap. Although there were several grades of scrap within each, the major unalloyed scrap categories were No. 1 copper, which contained greater than 99% copper and often could be simply remelted, and No. 2 copper, which contained between 94.5% to 99% copper and usually had to be rerefined. In recent years, about 1.6 million tons of copper-base scrap, containing an estimated 1.3 million tons of copper, was consumed annually in the United States. The largest scrap categories were as follows: No.1 copper, 26%; No. 2 copper, 25%; yellow brass, 21%; cartridge cases, 9%; automobile radiators, 7%; low-grade ashes and residues, 4%; red brass, 3%; and refinery brass, 2%. A wide variety of alloys made up the remaining 3%. Brass and copper tube mills consumed 65% of No. 1 copper and most of the cartridge cases and yellow brass, while the secondary smelters and ingot makers consumed 85% of the No. 2 scrap and most of the auto radiators and red brass scrap. With a few exceptions, U.S. wire rod mills did not consume scrap directly. One U.S. wire rod producing company constructed a continuous-process scrap refining and wire rod casting plant in which it processed No. 1 return scrap from making wire in its own plants.

Scrap was classified into two general categories called old scrap and new scrap, depending on its origins. New scrap, or manufacturing scrap, was generated during the fabrication of copper products and was returned to the mill for reprocessing (return scrap) or sold; it was not considered a new source of copper supply by the Bureau of Mines. New scrap was termed "run-a-round" or home scrap when it was generated internally at the plant consuming it.

Old scrap was generated from wornout, discarded, or obsolete copper products and was considered to be a reservoir of recoverable copper, and thus, was a source of supply. Since World War II, the ever-increasing reservoir of copper products in use, much of which was eventually recycled as "old" copper, provided annually between 19% and 33% of U.S. apparent demand and, on average, provided about 18% of world copper demand. It was estimated that the world copper reservoir of items in use or abandoned in place from which old scrap can be recovered exceeded 173 million tons. The U.S. old scrap reservoir was estimated to exceed 66 million tons or 38% of the world's total.

The rate of old scrap recovery was limited by copper's long life and its essential uses. On average, the rate of old scrap recovered in the United States, as a percentage of total scrap consumption, declined from 50%-60% in the 1940's to about 40% in the 1980's. The decline in the old scrap component, relative to new scrap consumed, could be correlated not only to an increasing manufacturing base from which to generate new scrap, but to a changing demand pattern in which electrical uses became more dominant. Essential electrical uses, which now form greater than 70% of the market, were less likely to be scrapped. The long service life for utility and building cable, among other reasons, results in a practical limit to the amount and rate at which old scrap from this source can be recovered. The average life for old copper items has been estimated at about 20 years. Historically, old scrap recovery not only improved during periods of high refined copper prices, but also increased at any time that primary supplies became scarce, including the deep depression years of the 1930's.

In the United States, about 44% of total annual copper consumption was from copper in old and purchased new scrap. A similar percentage, 36%, was consumed in the EC, which collectively comprised one of the largest sources of copper scrap in the world. The intensity of scrap consumption varied in different parts of the copper industry. For example, scrap made up nearly all of the copper raw material for ingot makers, who made specialty alloy ingot for use in foundries. The same was true for mills producing yellow and leaded-yellow brass rod and for many copper tube mills. In both Europe and the United States, many of the smelters and refiners used scrap as feed, a trend that had been increasing. In recent years, about 40% of refined copper produced in Western Europe and about 24% of refined copper in the United States was derived from copper scrap. Copper scrap provided an average of about 19% of the world's refined copper annually. Direct melt copper and copper alloy scrap, used mostly by brass mills and foundries, was more than double that used to make refined copper.

## Economic Factors

***Prices.***—Each copper product, including scrap, from mine through refinery has a distinct pricing mechanism linked, for the most part, to its copper content and the market price for refined copper. For example, copper concentrates, which contain between 20% and 30% copper, were purchased on the basis of recoverable copper content and anticipated smelter and refinery charges for processing.

Copper concentrates were sold under long-term contracts and included provisions for the delivery of specified quantities and the formula by which the price paid was to be calculated. Contracts tended to be for periods as long as 10 years, though various terms were renegotiated at shorter intervals, and thus provided smelters with secure sources of materials. Without such contracts, new mines would find development financing difficult. Contracts provided for two types of charges. A treatment charge was assessed for every ton of concentrate by the smelter, and a refining charge was assessed for every pound of recoverable copper contained. There was generally a provision for the smelter to participate in copper price rises. There also were penalties for undesirable impurities, such as antimony, arsenic, and bismuth, and credits or additional payment for precious metals in the concentrates. Anticipated material losses were figured into credit terms.

Refined copper prices varied according to its form and purity. Historically, the price for refined wirebar was the "bellwether" price for refined copper, because this was the dominant form traded. With the advent of continuous casting for wire rod, however, high-grade cathode became the dominant form traded. In 1989, wirebar comprised less than 1% of refined copper trade. Copper wire rod prices were based on the refined copper cathode price plus a processing premium. In the case of scrap, the spread between the purchase price of scrap and refined copper must be sufficient to allow for processing costs.

Refined prices not only reflect the refined shape and its quality, but also to the manner in which it was priced, i.e., through producer's annually negotiated contracts or through the London Metal Exchange (LME) or COMEX. Trading in copper began on the LME January 1, 1877, and on the COMEX May 15, 1929. Futures contracts changed gradually over the years to correspond to the most active markets. The LME dropped its wirebar and standard cathode contracts and beginning January 1989, traded only the Grade A (high-grade) cathode contract. Similarly, COMEX converted to the high-grade cathode contract on January 1, 1990. The spot, or first position, price is most often quoted for the exchanges. To this price, however, various premiums and other charges were added to determine the actual price paid by the buyer.

Historically, the U.S. copper producers' price series was related to annually negotiated contract sales with price changes occurring at periodic intervals. When quoted, this price normally included a charge for delivery and insurance. Most U.S. producers abandoned classic producer pricing during the 1970's and 1980's when inventories accumulated on the exchanges and the COMEX price became more influential and have adopted the first position COMEX price as a basis for contract pricing. During tight markets, however, such as that which has existed since late 1987, the speculative influence of a COMEX-based pricing system can prove to be less than satisfactory for the consumer. The conventional producer pricing system tended to provide less volatility in the market. Periods of speculative interest have usually been brief, however. The long period of stock surpluses since 1982 dampened speculative interest until the end of 1987. Since that time, both producers and consumers increasingly used futures contracts and the newly introduced copper options to hedge their sales and purchases and protect themselves against fluctuations in the market.

Table 11 gives average U.S. producers' copper price by decade in both constant 1987 dollars and current dollars. Based on constant dollars, one must look to the depression era of the 1930's to find prices as low as those occurring in the 1979-88 decade. Since that time, current dollar prices have approached the long-term 1901-89 constant dollar average of $1.32 per pound.

TABLE 11

### AVERAGE COPPER PRICES, BY DECADE[1]

(Cents per pound)

| Period | Average annual price | Based on constant 1987 dollars |
|---|---|---|
| 1870-79 | 22.88 | 330.64 |
| 1880-89 | 15.42 | 210.86 |
| 1890-99 | 12.25 | 169.33 |
| 1901-09 | 15.05 | 213.10 |
| 1910-19 | 18.87 | 217.56 |
| 1920-29 | 14.63 | 114.10 |
| 1930-39 | 9.67 | 87.52 |
| 1940-49 | 14.87 | 97.96 |
| 1950-59 | 29.66 | 131.00 |
| 1960-69 | 35.51 | 121.71 |
| 1970-79 | 65.69 | 133.22 |
| 1979-88 | 82.99 | 92.03 |
| Averages: | | |
| 1870-1988 | 27.59 | 160.40 |
| 1901-88 | 31.37 | 133.75 |

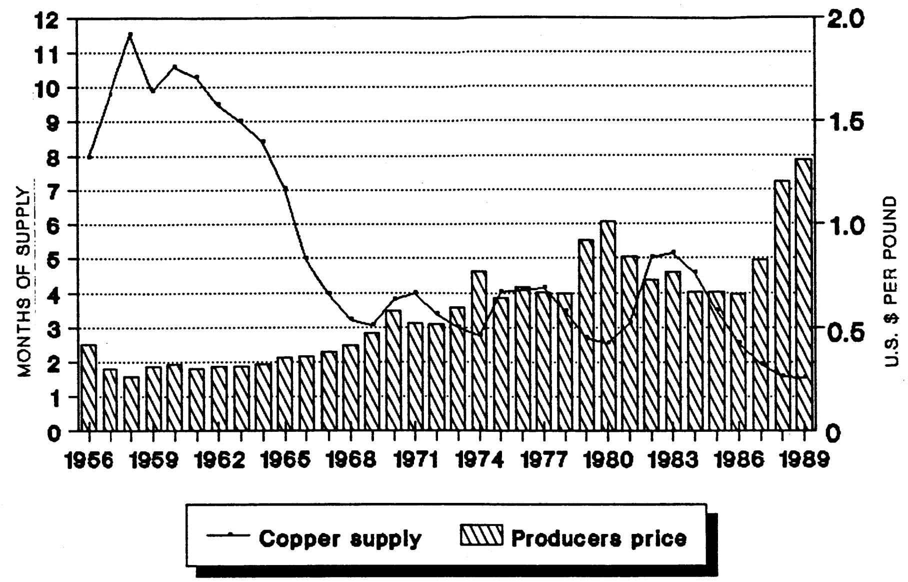
[1]Bureau of Mines. Nonferrous Metal Prices in the United States through 1988. Special publication, 1989, p. 33.

Copper prices not only responded to changes in the world economy but also to large copper inventory accumulation, copper cartel actions to restrict production, which were most effective before World War II, and from time to time to speculative influences on the commodity exchanges. The relationship of copper prices to U.S. supply levels are shown in figure 3. Significant events affecting copper supply and demand, prices, and inventory levels have been described in a recent paper by the Bureau of Mines.[30]

Surplus refined copper inventories not only have accumulated in response to periods of economic recession, but also as a result of U.S. Government purchases for, and release from, the National Defense Stockpile. High commercial inventory levels had a depressing effect on prices when these surplus supplies were released onto the market to compete with newly mined copper. In addition, whenever commercial refined copper stocks, for whatever reason, fell below 1 month's supply at prevailing consumption rates, prices took a sharp upward climb. Trends in U.S. copper inventories since 1955 are shown in table 12.

FIGURE 3

GRAPH DEPICTING SUPPLY LEVELS VS. PRICES




*Source: Bureau of Mines; Aug. 1990.*

***Governmental Monetary, Trade, and Other Policies.***—Government policies to control prices, levy tariffs, impose import quotas and export controls, provide price supports, lend monies for expansion and exploration, guarantee production purchases, levy taxes, and expand or contract the money supply all have had significant impact on copper supply and demand. In the United States, nearly all of these mechanisms were applied at one time or another. For example, prices were controlled at the end of World War I, during and after World War II, during the Korean war (1950-53), and near the end of the Vietnam war (1971-74).

U.S. export controls on copper and copper scrap were implemented during World War II and off and on through much of the 1950's and 1960's owing to recurring supply shortages during this period. On November 17, 1965, the U.S. Government announced a four-point program to reduce inflationary pressures on the price of copper that might impair the defense effort in Vietnam. The program called for release of material from the National Defense Stockpile, control of exports of copper and copper scrap for an indefinite period, legislation to suspend the 1.7% per pound import duty on copper, and the imposition of higher margin requirements on copper trading by COMEX to lessen speculation in the metal. Export controls on copper products were terminated finally in September 1970 as a result of the dramatic reversal in supply balance that year from shortage to surplus.

Many other countries also have had export controls on copper products. The EC imposed export controls on scrap from 1971 to yearend 1989. Some countries, such as Taiwan, used import or export licensing mechanisms to enforce trade restrictions. Because of pollution problems at the Tafa Industrial District, imports of pollution-prone materials such as insulated electric wire or cable have been banned by Taiwan's Environmental Protection Administration since October 1989. Sweden maintained export restrictions on copper waste and scrap. Japan has maintained restrictions on copper waste and scrap since 1965. After June 1986, scrap export from Japan was possible only through a license granted by the Agency for National Resources and Energy. Australia also maintained an export prohibition on copper and copper alloy scrap. New Zealand maintained export restrictions on copper ores, concentrates, matte, unwrought copper, and copper waste. In addition, New Zealand had discretionary import licensing on copper bars and rods.

Most developed countries had most-favored-nation (MFN) duties on copper and copper products. Although copper ores and concentrates were frequently MFN duty free, duties often increased with various stages of processing. Most countries applied tariffs on wrought copper products and copper chemicals. All developed countries also granted duty-free or preferential rates under the 1974 Trade Act, Generalized System of Preferences (GSP) schemes for developing countries.

The U.S. GSP was started on January 1, 1976, and provided for duty-free treatment for up to 10 years on a wide range of articles, including copper, imported directly from any developing country designated as a beneficiary developing country. There were program limitations to GSP status based on the value of the imported article. The EC scheme for GSP granted duty-free access to imports of copper semimanufactures and manufactures from 89 developing and 38 least developed countries. The EC also granted duty free treatment to members of the Lome Convention and Mediterranean countries,

TABLE 12

## U.S. REFINED COPPER INVENTORIES, END OF YEAR[1]

(Thousand metric tons)

| Year | Consumers: Brass mills | Consumers: Wire mills | Consumers: Other[2] | Producers[3] | COMEX[4] | Total industry | U.S. Government[5] | Total United States |
|---|---|---|---|---|---|---|---|---|
| 1955 | 39 | 20 | 4 | 31 | 0.32 | 93 | 802 | 895 |
| 1956 | 46 | 36 | 9 | 71 | .80 | 163 | 845 | 1,009 |
| 1957 | 46 | 48 | 3 | 99 | .70 | 196 | 918 | 1,113 |
| 1958 | 47 | 34 | 8 | 44 | 10 | 142 | 1,031 | 1,172 |
| 1959 | 30 | 16 | 11 | 16 | 12 | 85 | 1,035 | 1,120 |
| 1960 | 29 | 32 | 4 | 89 | 2 | 157 | 1,040 | 1,197 |
| 1961 | 34 | 26 | 8 | 44 | 8 | 120 | 1,036 | 1,156 |
| 1962 | 31 | 34 | 6 | 64 | 4 | 139 | 1,029 | 1,168 |
| 1963 | 30 | 15 | 4 | 47 | 1 | 97 | 1,018 | 1,115 |
| 1964 | 31 | 19 | 2 | 31 | 3 | 86 | 994 | 1,079 |
| 1965 | 35 | 20 | 5 | 32 | 9 | 101 | 814 | 915 |
| 1966 | 61 | 41 | 4 | 39 | 4 | 148 | 410 | 559 |
| 1967 | 35 | 20 | 4 | 24 | 12 | 96 | 250 | 346 |
| 1968 | 36 | 24 | 4 | 44 | 11 | 118 | 242 | 361 |
| 1969 | 36 | 34 | 4 | 35 | 4 | 112 | 230 | 342 |
| 1970 | 38 | 95 | 4 | 118 | 16 | 271 | 230 | 501 |
| 1971 | 37 | 84 | 5 | 68 | 18 | 213 | 228 | 441 |
| 1972 | 25 | 45 | 5 | 52 | 52 | 179 | 228 | 407 |
| 1973 | 27 | 39 | 5 | 34 | 5 | 110 | 226 | 335 |
| 1974 | 33 | 98 | 6 | 92 | 39 | 268 | 32 | 300 |
| 1975 | 28 | 108 | 6 | 188 | 91 | 420 | 24 | 444 |
| 1976 | 33 | 103 | 6 | 172 | 182 | 497 | 44 | 541 |
| 1977 | 31 | 105 | 6 | 212 | 167 | 522 | 21 | 543 |
| 1978 | 28 | 63 | 7 | 153 | 163 | 414 | 21 | 435 |
| 1979 | 25 | 44 | 9 | 64 | 90 | 232 | 20 | 252 |
| 1980 | 22 | 50 | 10 | 49 | 163 | 294 | 20 | 314 |
| 1981 | 26 | 109 | 9 | 151 | 170 | 465 | 20 | 485 |
| 1982 | 25 | 125 | 9 | 268 | 248 | 675 | 20 | 695 |
| 1983 | 26 | 116 | 5 | 154 | 371 | 672 | 20 | 692 |
| 1984 | 27 | 134 | 11 | 125 | 251 | 548 | 20 | 564 |
| 1985 | 20 | 100 | 5 | 66 | 109 | 300 | 20 | 320 |
| 1986 | 14 | 66 | 5 | [r]35 | 84 | 205 | 20 | [r]224 |
| 1987 | 15 | 28 | [r]3 | 29 | 17 | 93 | 20 | [r]112 |
| 1988 | 17 | 29 | 4 | 16 | 12 | 78 | 20 | 98 |
| 1989 | 12 | 32 | 9 | 18 | 15 | 84 | 20 | 106 |

[r]Revised.

[1]Semifabricated forms such as rod, sheet, etc., at consumers are not included. Data source was various issues of Bureau of Mines Mineral Industry Surveys and unpublished Bureau worksheets for the years 1955-70. Data for 1955-86 have been published in the Minerals Yearbook, 1986, copper chapter.

[2]Stocks held by ingot-makers, miscellaneous manufacturers, foundries, and chemical plants. Data for the years 1955-64 estimated based on partial data.

[3]Inventories held by primary and secondary refineries.

[4]Data from Commodity Exchange Inc., New York.

[5]General Services Administration Inventory of the National Defense Stockpile.

including Yugoslavia. Imported copper ores and concentrates enjoyed duty-free MFN status in Japan and accounted for about 70% of total Japanese imports. MFN rates for matte and copper scrap were also zero. Other unwrought copper was subject to MFN rates ranging from 3.2% to 7.3% on the value. Imports of copper manufactures were subject to even higher rates.

In recent years, some countries sought to promote copper production through temporary guaranteed price-support systems, as in Brazil, Chile (small- and medium-size mining sector), and the Philippines. Some countries used protective tariffs to aid domestic copper industries, as in Japan and the Republic of Korea; import restrictions, as in Brazil; and direct financial aid through loan guarantees and assumptions of company debt, as in the Philippines. In addition to drastic devaluations of currencies, these policies were effective in maintaining production in the face of falling dollar-denominated prices.

U.S. monetary policies have had a significant effect on the "real" price of copper, as well as on the general economic well-being and international competitiveness of the U.S. copper industry. The stable gold price following the Gold Reserve Act of 1934 had a general stabilizing effect on most industrial metal prices. Beginning with the monetary arrangements of the Bretton Woods Agreement of July 1945, which established the World Bank and the International Monetary Fund, a number of events had significant effect on the value of copper. One of the reasons for the extreme variability and inflation in copper prices since the 1960's was the destabilization of monetary arrangements that followed the U.S. Coinage Act of 1965, the cessation of silver certificates in 1967, the elimination of the gold reserve requirement in 1968, and the abandonment of fixed exchange rates in 1973. International debt reached record heights as a result of the Vietnam war and extensive borrowing done by the less developed countries in pursuit of economic expansion during the 1960's and early 1970's. These debts were compounded by the Organization of Petroleum Exporting Countries cartel action to increase the price of petroleum in 1974 and again in 1978. Oil shortages, inflationary prices, and economic downturns began to adversely affect world markets. Many of the developing countries adopted austerity measures because of heavy debt burdens, including devaluation of currencies by as much as 600% against the U.S. dollar. When inflationary pressures built up in the United States, the Federal Reserve Board restrained the money supply and increased interest rates.

The sustained strength of the U.S. dollar through the mid-1970's and 1980's and the series of devaluations by other countries to improve their balance of payments severely impacted the competitiveness of the U.S. copper industry. The effects of a strong dollar, high interest rates, and of high energy, labor, and environmental compliance costs combined with the effect of copper surpluses and a depressed world market proved to be insurmountable for some mines. In response, the U.S. industry implemented innovative technology and productivity measures to cut costs. Considerable financial restructuring that often involved ownership changes also was necessary to gain sufficient capital to carry out the changes.

### Operating Factors

***Costs.—Production.***—In recent years all domestic and most world producers endeavored to cut production costs in an effort to remain competitive through periods of prolonged depressed prices, such as that experienced during the mid-1980's. Domestic producers adjusted mine plans, reduced stripping ratios, and raised cutoff grades. Large capital investments were made in new in-pit crushing and conveying systems and on mill and concentrator expansions or replacements. Lower cost SX-EW capacity was expanded to process both oxidized ores and the higher grade waste dumps resulting from increased cutoff grades. Consolidation of assets through ownership changes improved operating efficiencies. Overall labor costs were reduced through improved employee productivity and wage and work-rule concessions by union and nonunion miners. Productivity at mines, in terms of worker hours per ton of copper produced, declined from more than 40 hours in 1980 to 28 hours in 1983 to an average 18 hours in the 1985-90 period. Similar cost savings were realized through smelter renovations and renegotiation of smelter contracts.

Byproduct values and the combined affects of inflation, Governmental monetary policy, and exchange rates also affected operating costs. A study prepared by the Minerals Availability Field Office, Bureau of Mines, Denver, CO, compared operating cost factors for 89 mines operating in both 1981 and 1987. Table 13 shows the impact that technical factors, byproduct values, and the combined affects of inflation and exchange rate (I/ER) had on production costs. In the United States, technological improvements overcame a competitive disadvantage from shifting byproduct credits and I/ER. Conversely, devaluation of the kwacha and improved byproduct prices allowed Zambia to remain competitive despite deteriorating technical factors.[31]

TABLE 13

**FACTORS AFFECTING COPPER PRODUCTION COSTS FOR MAJOR MEC COPPER PRODUCERS[1]**

(U.S. dollars per pound of copper)

| | Production costs at common mines, 1981 | Cost changes, 1981-87 | | | Production costs at common mines, 1987 |
|---|---|---|---|---|---|
| | | Byproduct credit[2] | Inflation-exchange rate[3] | Technical factors[4] | |
| Canada | 0.48 | 0.06 | 0.24 | -0.35 | 0.45 |
| Chile | .46 | .05 | -.21 | .00 | .30 |
| Mexico | .61 | .06 | -.19 | .01 | .49 |
| Peru | .63 | .00 | .16 | -.24 | .55 |
| Philippines | .63 | -.09 | -.05 | -.02 | .47 |
| United States | .84 | .04 | .33 | -.68 | .53 |
| Zaire | .48 | .02 | -.39 | .34 | .45 |
| Zambia | .71 | -.04 | -.43 | .19 | .43 |

[1]Porter, K. E. and P. R. Thomas. International Competitiveness of U.S. Copper Production, 1981-87. Bureau of Mines, Mineral Issues 1989, Table 2—3, p. 14.

[2]A decrease in byproduct prices between 1981 and 1987 results in an increase in production costs.

[3]Represents the combined effect of changes in inflation and exchange rates. A negative value reflects an over devaluation of local currency in relation to local inflation.

[4]Included are the impacts of changes in stripping ratios, feed grades, smelting and refining charges, labor force and wage rates, technology, and other changes that were implemented to reduce costs and improve competitive positions. It was not possible to disaggregate this category into individual factors.

***Capital.***—An analysis of total development costs for 60 new mine projects in Australia, Brazil, Botswana, Burma, Canada, Chile, Indonesia, Pakistan, Panama, Papua New Guinea, Peru, the Philippines, Portugal, Turkey, and the United States indicated an average of $8,100 per ton of copper capacity must be invested to bring a new mine on-stream. Mine expansions at established mines, on the other hand, averaged $3,200 per ton of copper capacity. A new SX-EW plant cost an average of $2,400 per ton and a new smelter an average of $1,800 per ton of copper to construct. New mine costs varied widely with location, size, and type of mine; for example, the 300,000-ton-per-year Escondida open pit mine in Chile was estimated to cost about $3,200 per ton of copper, whereas the proposed Geddes underground mine in British Columbia and Olympic Dam Mine in Australia were around $10,000 per ton, according to published estimates.

Total project financing also varied with location, size, and type of mine. Financing required for expansion at an existing mine ranged from $48 million for the Morenci, AZ, expansion to $500 million for the Chuquicamata, Chile, expansion. Of the total 60 projects analyzed, the average new mine would cost $300 million to develop. Of 11 new mine projects in Peru, the average cost was about $400 million. Some individual projects, such as the Escondida Mine were to cost more than $1 billion to bring into production. The average of 19 SX-EW projects was $63 million, including expansions at existing plants.

***Environmental Requirements.***—The many environmental protection laws and regulations that have been promulgated in the United States since the late 1960's have impacted the copper industry in many ways. Most of the cost of compliance with environmental regulation was incurred at the smelter level. Although some regulations have resulted in offsetting costs through production of an additional salable product, such as sulfuric acid and reduced operating costs in modernized smelters, the net effect has been to increase total operating costs.

Laws and regulations in force that affect U.S. copper operations include those promulgated under the Federal Clean Water Act, the Clean Air Act of 1970, the National Environmental Policy Act of 1969, the Solid Waste Disposal Act (RCRA) of 1976, the Federal Surface Mining Control and Reclamation Act, the Toxic Substances Control Act, CERCLA, and numerous State laws concerned with mining techniques, reclamation of mined lands, air and water pollution, and solid waste disposal. Transportation of mineral and hazardous substances is also regulated. Ground water regulations in Arizona were being developed and could have a greater impact on the copper industry than surface water quality. The new Arizona Aquifer Protection Permit program was expected to have important impact by 1990. Arizona already had a Groundwater Protection Permit Program.[32]

Under the 1980 Bevill Amendment to RCRA, solid wastes from the extraction, beneficiation, and processing of ores and minerals were temporarily exempted from regulation as hazardous wastes under subtitle C, pending a comprehensive study to determine potential hazard and feasibility of treatment. EPA published an interim interpretation that placed wastes from exploration, mining, milling, smelting, and refining within the exclusion pending completion of a report to Congress. Acting under a court-ordered deadline, in 1986 EPA issued its regulatory determination in which it concluded that subtitle C regulation was not warranted at that time for mining and beneficiation wastes.

However, EPA's determination of the scope of the Bevill exclusion was challenged in court, and in October 1988, the court found that the intent of the Bevill exclusion was to include only those wastes from processing ores that met a special waste criteria of high volume and low hazard. In compliance with the court, on October 20, 1988, (see 53 FR 41288) EPA published a proposal to define the scope of the exclusion and listed 15 wastes it believed met the necessary criteria. On April 17, 1989, (see 54 FR 15316) the agency published a revised list containing 6 wastes that it believed met all the necessary criteria, and an additional 33 wastes that they proposed to conditionally retain pending further study. EPA felt that these 33 wastes met the high-volume criteria but that they had insufficient data to determine if they met a low-hazard criterion, established, for the first time, in the April proposal.

On September 1, 1989, (see 54 FR 36592) EPA published a Final Rule for Bevill exclusion criteria and proposed a final list of 5 wastes to be temporarily retained within Bevill, including slag from primary copper processing, as well as a reduced list of only 20 mineral processing wastes for conditional retention. Four wastes, including acid plant and scrubber blowdown from primary copper processing, were permanently removed from the Bevill exclusion. Two other copper associated wastes, bleed electrolyte from primary copper refining and wastewater from primary selenium production, were omitted for further consideration of exclusion. This final rule contained a modified definition of "processing of ores and minerals" that incorporated leaching operations and roast leaching operations and a modified definition of "large volume." On September 25 (see FR 39298), EPA narrowed the list of conditionally retained wastes to only 13.

On January 23, 1990, EPA issued a final rule that retained 15 wastes, in addition to the 5 retained in the September 1 notice, within the exclusion pending preparation of a final report to Congress and subsequent Regulatory Determination. In addition to copper slag, the copper processing wastes retained were calcium sulfate wastewater treatment plant sludge from primary copper processing and slag tailings from primary copper processing.[33]

The major thrust to the Clean Water Act (an amalgam of numerous acts and amendments, including the Federal Water Pollution Control Act of 1972 and Clean Water Act of 1977 and some 23 amendments) and its legal interpretations is through its elimination of pollutant discharge into navigable waterways through the National Pollutant Discharge Elimination System (NPDES), which provides for a permitting system to cleanup discharge of process wastewater, mine drainage water, stormwater runoff, and nonpoint sources. At U.S. copper mills, processing plants, and semifabricating plants most process water was reclaimed and reused, particularly in the southwest where there is a chronic water deficit. Mine water discharge problems usually occur when a mine and mill shuts down, largely because there is no place, such as a mill, to use the continuously discharging mine water.[34]

***Energy Requirements.***—Open pit mining may extend to as much as 1,500 feet below the rim, and the energy required for hauling rock from such depths becomes an important cost factor. Hauling by truck was estimated to consume as much as 54% of total processes in the pit, including drilling, blasting, loading, hauling, and ancillary processes. Grinding and concentration consume about 45% of the energy used in the milling. The lower the ore grade, the more ore that must be processed and the finer the grinding required and thus, more energy consumed.

Major improvements in energy use in mining and milling have been made in recent years through improved strategies in grinding, concentration, and ore transportation. The use of larger flotation cells has improved process efficiency and also lessened energy usage. Hydrometallurgical processes for copper recovery, such as the SX-EW recovery of copper, required more energy than pyrometallurgical processes. Electrowinning consumes 21 to 24 million British Thermal Units (Btu) per ton of cathode, or almost 20% of the total required from mine to refining stages. The in situ extraction of copper was the least energy consuming process, despite the low (50%) recovery. Energy consumption in dump leaching was higher owing to pumping requirements for leachate circulation and cementation. The combined total energy required for dump leaching, cementation, and refining is about 94 million Btu per ton of cathode copper.[35]

Flash furnace technology and the Noranda and Mitsubishi continuous smelting technologies have resulted in energy savings. Energy consumption in millions of Btu per ton of refined copper recovered were reported as follows: Outokumpu flash smelting (18.92 million Btu), Inco flash smelting (21.25 million Btu), Noranda continuous smelting (24 million Btu), Mitsubishi continuous smelting (19.16 million Btu), and Oxy Fuel Reverberatory smelting (26.62 million Btu).[36]

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[1]All quantities in this chapter are given in metric tons unless otherwise specified.

[2]California Mining Journal. Nevada Enacts Mine Reclamation Law. Aug. 1989, p. 10

[3]Montana Standard. County Stands to Gain From Ore Tax Change. Butte, MT, Apr. 1, 1989, p. 2.

[4]The Wall Street Journal. Labor of Love, How Cyprus Mine in Arizona Wooed Most Workers Away From Their Union Loyalties. Aug. 8, 1989, p. A6.

[5]American Metal Market. Copper Firms Lag on Incentive Plans. V. 97, No. 119, June 20, 1989, pp. 1, 20.

[6]Southwestern Pay Dirt. Cyprus Miami Workers Receive Bonus. Jan. 1990, p. 9A.

[7]ASARCO Incorporated. 1989 Company Annual Report, pp. 21-22.

[8]Cyprus Minerals Co. 1989 Company Annual Report, pp. 5, 9, 27.

[9]Southwestern Pay Dirt. SRP Adds Extra Charge for Electricity to Cyprus Miami. Aug. 1989, p. 5A.

[10]Magma Copper Co. 1989 Company Annual Report, 44 pp.

[11]Phelps Dodge Corp. 1989 Company Annual Report, pp. 4, 21.

[12]Southwestern Pay Dirt. Arizona Mine Valuations Up Sharply. Nov. 1989, p. 12.

[13]The Wallace Miner. Seepage From Tailings Pond Draws Concern. Wallace, ID, Mar. 30, 1989, p. 2.

[14]Southwestern Pay Dirt. New Mexico Agency Weighs Comment on Cyprus Deming Mill. Nov. 1989, p. 20A.

[15]———. Cyprus May Go Joint Venture on Long-Closed Copper Mine. Sept. 1989, pp. 10A-12A.

[16]Pages 27-28 of work cited in footnote 8.

[17]Southwestern Pay Dirt. Pinos Altos Joint Venture Pact Near Completion. Sept. 1989, p. 6A.

[18]Southwestern Pay Dirt. Magma Still Smelting for Cyprus; Arbitration Seen for Fuss. Aug. 1989, p. 3A.

[19]Corporacion Nacional del Cobre de Chile. 14th Annual Report, 1989, 41 pp.

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[21]Pages 24.2-24.3 of work cited in footnote 20.

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[24]The Copper Mill Products Industry. Prepared by CRU Consultants Inc. Dec. 1989, pp. 3.1-3.20. Available from Center For Metals Production, Pittsburgh.

[25]Cranstone, D. A. and A. Lemieux. Base Metals: Today's Exploration Challenge. Congres Annuel de l'Assoc. des Prospecteurs du Quebec, Val-d'Or, Quebec, Canada. Sept. 14-16, 1988, 6 pp.

[26]U.S. Department of Defense. Strategic and Critical Materials Report to the Congress. Feb. 1990, pp. 4-5.

[27]Bureau of Mines. Copper. Ch. in An Appraisal of Minerals Availability for 34 Commodities. BuMines B 692, 1987, pp. 81-94.

[28]Davenport, W. G., and E. H. Partelpoeg. Flash Smelting, Analysis, Control and Optimization. Pergamon Press, New York, 1987, pp. 1-16.

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[31]Porter, K. E., and P. R. Thomas. International Competitiveness of U.S. Copper Production, 1981-87. BuMines Mineral Issues, 1989, pp. 8-22.

[32]Helmer, E. D. The Clean Water Act; Its Effect on a Copper Producer. Magma Copper Co., San Manuel, AZ, 7 pp.

[33]Federal Register. V. 55, No. 15, Jan. 23, 1990, pp. 2322-2354.

[34]Work cited in footnote 31.

[35]U.S. Department of Energy. An Environmental Protection Agency, Mining Waste Exclusion: Section 3010 Notification for Mineral Processing Facilities, Designated Facility Definition, Standards Applicable to Generators of Hazardous Waste Assessment of Energy Requirements in Proven and New Copper Processes, Final Report. (U.S. Dept. Energy contract DE-AS07-78CS40132), Dec. 1980, 361 pp.

[36]Work cited in footnote 35.

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TABLE 14

## MINE PRODUCTION OF RECOVERABLE COPPER IN THE UNITED STATES, BY MONTH AND BY STATE

(Metric tons)

| | 1985 | 1986 | 1987[r] | 1988[r] | 1989 |
|---|---|---|---|---|---|
| Month: | | | | | |
| January | 92,696 | 98,725 | 101,563 | 110,863 | 127,188 |
| February | 87,087 | 86,953 | 92,154 | 102,507 | 121,491 |
| March | 100,168 | 96,343 | 105,904 | 120,936 | 134,205 |
| April | 93,639 | 93,840 | 98,040 | 111,851 | 125,521 |
| May | 96,832 | 97,117 | 104,404 | 120,981 | 127,860 |
| June | 90,223 | 95,879 | 102,007 | 115,826 | 121,759 |
| July | 90,711 | 94,777 | 104,000 | 116,131 | 122,518 |
| August | 87,444 | 94,418 | 107,004 | 128,163 | 127,516 |
| September | 81,896 | 97,201 | 105,180 | 120,031 | 122,490 |
| October | 94,218 | 99,969 | 104,586 | 123,646 | 125,174 |
| November | 91,384 | 92,253 | 108,324 | 121,308 | 118,169 |
| December | 98,525 | 96,738 | 110,430 | 124,685 | 123,567 |
| Total | 1,104,823 | 1,144,213 | 1,243,596 | 1,416,928 | 1,497,458 |
| State: | | | | | |
| Arizona | 795,622 | 786,111 | 751,031 | 842,728 | 898,315 |
| New Mexico | W | W | 246,532 | 258,660 | 259,432 |
| Michigan, Montana, Utah | W | 78,950 | 222,432 | 295,489 | 314,313 |
| Other States[1] | 309,201 | 279,152 | 23,601 | 20,051 | 25,398 |
| Total | 1,104,823 | 1,144,213 | 1,243,596 | 1,416,928 | 1,497,458 |

[r]Revised. W Withheld to avoid disclosing company proprietary data, included in "Other States."

[1]Includes California, Colorado, Idaho, Illinois, Missouri, and Tennessee. 1985 includes Michigan, Montana, New Mexico, and Utah; 1986 includes New Mexico; 1987 includes Washington.

TABLE 15

## TWENTY-FIVE LEADING COPPER-PRODUCING MINES IN THE UNITED STATES IN 1989, IN ORDER OF OUTPUT

| Rank | Mine | County and State | Operator | Source of copper | Capacity (thousand metric tons) |
|---|---|---|---|---|---|
| 1 | Morenci | Greenlee, AZ | Phelps Dodge Corp. | Copper-molybdenum ore, concentrated and leached | 305 |
| 2 | Bingham Canyon | Salt Lake, UT | Kennecott, Utah Copper Corp. | do. | 245 |
| 3 | Tyrone | Grant, NM | Phelps Dodge Corp. and Burro Chief Copper Co. | Copper ore, concentrated and leached | 160 |
| 4 | Chino | do. | Phelps Dodge Corp. | Copper-molybdenum ore, concentrated and leached | 150 |
| 5 | San Manuel | Pinal, AZ | Magma Copper Co. | do. | 130 |
| 6 | Ray | do. | ASARCO Incorporated | Copper ore, concentrated and leached | 125 |
| 7 | Sierrita | Pima, AZ | Cyprus Sierrita Corp. | Copper-molybdenum ore, concentrated and leached | 117 |
| 8 | Bagdad | Yavapai, AZ | Cyprus Bagdad Copper Co. | do. | 97 |
| 9 | Pinto Valley | Gila, AZ | Pinto Valley Copper Corp. | do. | 92 |
| 10 | Inspiration | do. | Cyprus Miami Mining Corp. | Copper ore, leached | 65 |
| 11 | Mission Complex | Pima, AZ | ASARCO Incorporated | Copper ore, concentrated | 70 |
| 12 | White Pine | Ontonagon, MI | Copper Range Co. | do. | 50 |
| 13 | Continental | Silver Bow, MT | Montana Resources Inc. | Copper-molybdenum ore, concentrated | 50 |
| 14 | Troy | Lincoln, MT | ASARCO Incorporated | Copper-silver ore, concentrated | 18 |
| 15 | San Xavier | Pima, AZ | do. | Copper ore, concentrated | 15 |
| 16 | Casteel | Iron, MO | The Doe Run Co. | Lead-copper ore, concentrated | NA |
| 17 | Twin Buttes | Pima, AZ | Cyprus Sierrita Corp. | Copper ore, leached | 20 |
| 18 | Miami | Gila, AZ | Pinto Valley Copper Corp. | do. | 6 |
| 19 | Silver Bell | Pima, AZ | ASARCO Incorporated | do. | 5 |
| 20 | Pinos Altos | Grant, NM | Cyprus Pinos Altos Corp. | Copper ore, concentrated | 8 |
| 21 | Buick | Iron, MO | The Doe Run Co. | Lead-zinc ore, concentrated | NA |
| 22 | Lakeshore | Pinal, AZ | Cyprus Casa Grande Corp. | Copper ore, leached | 5 |
| 23 | Magmont | Iron, MO | Cominco American Incorporated | Lead-zinc ore, concentrated | NA |
| 24 | Viburnum No. 28 | do. | The Doe Run Co. | Lead-copper ore, concentrated | NA |
| 25 | Fletcher | Reynolds, MO | do. | Lead-zinc ore, concentrated | NA |

NA Not available.

TABLE 16

## MINE PRODUCTION OF COPPER-BEARING ORES AND RECOVERABLE COPPER CONTENT OF ORES PRODUCED IN THE UNITED STATES, BY SOURCE AND TREATMENT PROCESS

(Metric tons)

| Source and treatment process | 1985 | | 1986 | | 1987 | | 1988 | | 1989 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Gross weight | Recoverable copper | Gross weight | Recoverable copper | Gross weight | Recoverable copper | Gross weight | Recoverable copper[r] | Gross weight | Recoverable copper |
| Mined copper ore: | | | | | | | | | | |
| Concentrated | 164,029,000 | 905,537 | 170,020,000 | 906,072 | 201,434,000 | 991,857 | [r]222,268,000 | 1,113,287 | 230,526,000 | 1,126,382 |
| Leached[1] | 1,161,000 | 98,453 | 2,456,000 | 135,448 | 1,198,000 | [r]162,324 | 1,308,000 | [1]227,992 | 6,736,000 | [1]311,885 |
| Total | 165,190,000 | 1,003,990 | 172,476,000 | 1,041,520 | 202,632,000 | [r]1,154,181 | [r]223,576,000 | 1,341,279 | 237,262,000 | 1,438,267 |
| Copper precipitates shipped; leached from tailings, dump, and in-place material | 118,096 | 82,948 | 111,050 | 79,031 | 110,511 | 70,136 | [r]69,683 | 49,299 | 47,388 | 34,485 |
| Miscellaneous: | | | | | | | | | | |
| Silver ore | 1,004,000 | 3,745 | 552,000 | 2,599 | 275,000 | 1,194 | 464,000 | 2,098 | 538,000 | 2,355 |
| Lead ore | 6,433,000 | 13,410 | 3,336,000 | 7,405 | W | 4,463 | 5,357,000 | 8,176 | — | — |
| Other copper-bearing ores[2] | 4,867,000 | 729 | 2,513,000 | 13,659 | 5,766,000 | 13,622 | 4,864,000 | 16,077 | 14,653,000 | 22,352 |
| Grand total[3] | XX | 1,104,823 | XX | 1,144,213 | XX | [r]1,243,596 | XX | 1,416,928 | XX | 1,497,458 |

[r]Revised. W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1]Includes electrowon from concentrates roast-leached.

[2]Includes copper-lead ore, gold ore, gold-silver ore, lead-zinc ore, molybdenum ore, tungsten ore, zinc ore, fluorspar, flux ores, cleanup, ore shipped directly to smelters, and tailings.

[3]Data may not add to totals shown because of independent rounding.

TABLE 17

## RECOVERABLE COPPER, GOLD, AND SILVER CONTENT OF CONCENTRATED COPPER ORE IN 1989

| State | Ore concentrated (thousand metric tons) | Recoverable metal content | | | | Value of gold and silver per metric ton of ore |
|---|---|---|---|---|---|---|
| | | Copper | | Gold (troy ounces) | Silver (troy ounces) | |
| | | Metric tons | Percent | | | |
| Arizona | 141,808 | 667,911 | 0.47 | 44,959 | 5,311,926 | $0.32 |
| Other[1] | 88,718 | 480,769 | .54 | W | 11,582,676 | W |
| Total or average | 230,526 | 1,148,680 | .50 | W | 16,894,602 | W |

W Withheld to avoid disclosing company proprietary data.
[1]Includes Idaho, Michigan, Montana, Nevada, New Mexico, and Utah.

TABLE 18

## BLISTER AND ANODE COPPER PRODUCED IN THE UNITED STATES, BY SOURCE OF MATERIAL

(Metric tons)

| Source | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|
| Ores and concentrates: | | | | | |
| Domestic | 939,257 | [1]908,087 | [1]972,141 | [1]1,042,954 | [1]1,120,445 |
| Foreign | 1,424 | W | W | W | W |
| Secondary materials | 250,138 | 287,841 | 276,640 | 320,201 | 359,066 |
| Total | 1,190,819 | 1,195,928 | 1,248,781 | 1,363,155 | 1,479,511 |

W Withheld to avoid disclosing company proprietary data; included with "Domestic."
[1]Includes production from foreign ores and concentrates.

TABLE 19

## REFINERY PRODUCTION IN THE UNITED STATES

(Metric tons)

| | 1985 | 1986[r] | 1987 | 1988[r] | 1989 |
|---|---|---|---|---|---|
| PRIMARY | | | | | |
| Electrolytic[1] | 966,778 | 948,623 | 965,621 | 1,178,028 | 1,164,948 |
| Electrowon | 90,463 | 125,357 | 161,287 | 227,992 | 311,885 |
| Fire refined | W | W | W | W | W |
| Total[2] | 1,057,241 | 1,073,981 | 1,126,908 | 1,406,020 | 1,476,833 |
| SECONDARY | | | | | |
| Electrolytic | 264,834 | 292,686 | 311,312 | 347,442 | 376,595 |
| Fire refined | 106,953 | 113,258 | 103,426 | 98,985 | 100,323 |
| Total[2] | 371,787 | 405,944 | 414,738 | 446,427 | 476,918 |
| Grand total[2] | 1,429,028 | 1,479,925 | 1,541,646 | 1,852,447 | 1,953,751 |
| Primary domestic materials[3] | 1,003,713 | [4]1,073,981 | [4]1,126,908 | [4]1,406,020 | 1,351,748 |
| Primary foreign materials[3] | 53,528 | W | W | W | 125,085 |
| Secondary materials | 371,787 | 405,944 | 414,738 | 446,427 | 476,918 |
| Total[2] | 1,429,028 | 1,479,925 | 1,541,646 | 1,852,447 | 1,953,751 |

[r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes fire-refined copper.
[2]Data may not add to totals shown because of independent rounding.
[3]The separation of refined copper into metal of domestic and foreign origins can only be approximated at this stage of processing.
[4]Includes primary foreign materials.

TABLE 20

## APPARENT CONSUMPTION OF COPPER POWDER AND FLAKES IN THE UNITED STATES

| Year | Production (metric tons) | Imports | | Exports | | Apparent consumption[1] (metric tons) |
|---|---|---|---|---|---|---|
| | | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | |
| 1978 | 16,992 | 1,153 | $4,300 | 1,713 | $4,597 | 16,432 |
| 1979 | 17,411 | 1,062 | 4,832 | 1,781 | 6,453 | 16,692 |
| 1980 | 13,203 | 896 | 4,675 | 1,766 | 6,397 | 12,333 |
| 1981 | 13,594 | 1,239 | 5,635 | 1,129 | 4,441 | 13,704 |
| 1982 | 9,686 | 1,064 | 4,521 | 959 | 3,834 | 9,791 |
| 1983 | 11,455 | 1,400 | 5,300 | 786 | 2,799 | 12,069 |
| 1984 | 12,783 | 1,490 | 5,341 | 893 | 3,419 | 13,380 |
| 1985 | 9,776 | 1,143 | 4,601 | 1,141 | 4,074 | 9,778 |
| 1986 | 7,898 | 1,277 | 5,198 | 1,367 | 5,353 | 7,808 |
| 1987 | 8,440 | 1,154 | 5,843 | 2,240 | 11,239 | 7,354 |
| 1988 | 9,370 | 1,430 | 9,180 | 2,664 | 11,074 | 8,136 |
| 1989 | 9,389 | 1,369 | 9,730 | 2,452 | 9,842 | 8,306 |

[1]Production plus imports minus exports.

Sources: Bureau of Mines and U.S. Department of Commerce, Bureau of the Census.

TABLE 21

## PRODUCTION, SHIPMENTS, STOCKS, IMPORTS, AND EXPORTS OF COPPER SULFATE IN THE UNITED STATES

(Metric tons)

| Year | Production | | Shipments[1] | Stocks, Dec. 31 | Imports | Exports |
|---|---|---|---|---|---|---|
| | Quantity | Copper content | | | | |
| 1985 | 32,740 | 8,265 | 31,952 | 4,353 | 2,958 | NA |
| 1986 | 34,154 | 8,616 | 33,540 | 4,967 | 2,683 | NA |
| 1987 | 33,340 | 8,418 | 35,338 | 2,969 | 4,765 | NA |
| 1988 | 34,184 | 8,630 | 32,943 | 4,210 | 10,992 | NA |
| 1989 | 33,187 | 8,349 | 33,912 | 3,485 | 13,456 | 571 |

NA Not available.

[1]Includes consumption by producing companies.

TABLE 22

## BYPRODUCT SULFURIC ACID (100% BASIS) PRODUCED IN THE UNITED STATES[1]

(Metric tons)

| Plant type | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|
| Copper[2] | 2,230,257 | 2,308,804 | 2,542,602 | 2,892,655 | 3,075,859 |
| Lead[3] | 267,159 | 122,228 | 116,311 | 133,672 | 155,899 |
| Zinc[4] | 430,946 | 379,803 | 410,460 | 416,617 | 409,564 |
| Total | 2,928,362 | 2,810,835 | 3,069,373 | 3,442,944 | 3,641,322 |

[1]Includes acid from foreign materials.

[2]Excludes acid made from pyrite concentrates.

[3]Includes acid produced at molybdenum plants to avoid disclosing company proprietary data.

[4]Excludes acid made from native sulfur.

TABLE 23

## COPPER RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY

(Metric tons)

| | 1985 | 1986 | 1987 | 1988[r] | 1989[r] |
|---|---|---|---|---|---|
| KIND OF SCRAP | | | | | |
| New scrap: | | | | | |
| Copper-base | 621,984 | 635,495 | 689,999 | 764,490 | 731,629 |
| Aluminum-base | 13,330 | 22,891 | 25,871 | 24,104 | 23,761 |
| Nickel-base | 328 | 221 | 240 | 118 | 47 |
| Zinc-base | 35 | 27 | 12 | — | — |
| Total | 635,677 | 658,634 | 716,122 | 788,712 | 755,437 |
| Old scrap: | | | | | |
| Copper-base | 487,199 | 461,490 | 481,460 | 498,797 | 526,534 |
| Aluminum-base | 15,459 | 15,859 | 16,401 | 19,271 | 16,957 |
| Nickel-base | 689 | 84 | 70 | 86 | 78 |
| Zinc-base | 60 | 36 | 6 | 25 | 27 |
| Total | 503,407 | 477,469 | 497,937 | 518,179 | 543,596 |
| Grand total | 1,139,084 | 1,136,103 | 1,214,059 | 1,306,891 | 1,299,033 |
| FORM OF RECOVERY | | | | | |
| As unalloyed copper: | | | | | |
| At electrolytic plants | 264,835 | 292,686 | 311,312 | 347,442 | 376,595 |
| At other plants | 122,834 | 121,760 | 112,445 | 109,036 | 110,385 |
| Total | 387,669 | 414,446 | 423,757 | 456,478 | 486,980 |
| In brass and bronze | 716,833 | 671,184 | 736,725 | 800,221 | 767,951 |
| In alloy iron and steel | 2,498 | 1,366 | 973 | 763 | 546 |
| In aluminum alloys | 29,423 | 45,781 | 47,932 | 45,632 | 41,356 |
| In other alloys | 1,803 | 359 | 506 | 327 | 252 |
| In chemical compounds | [1]858 | 2,967 | 4,166 | 3,470 | 1,948 |
| Total | 751,415 | 721,657 | 790,302 | 850,413 | 812,053 |
| Grand total | 1,139,084 | 1,136,103 | 1,214,059 | 1,306,891 | 1,299,033 |

[r]Revised.

[1]Data do not include copper sulfate.

TABLE 24

## COPPER RECOVERED AS REFINED COPPER AND IN ALLOYS AND OTHER FORMS FROM COPPER-BASE SCRAP PROCESSED IN THE UNITED STATES, BY TYPE OF OPERATION

(Metric tons)

| Type of operation | Fron new scrap | | From old scrap | | Total | |
|---|---|---|---|---|---|---|
| | 1988[r] | 1989 | 1988[r] | 1989 | 1988[r] | 1989 |
| Ingot makers | 24,383 | 22,523 | 127,317 | 120,621 | 151,700 | 143,144 |
| Refineries[1] | 146,258 | 140,836 | 300,169 | 336,082 | 446,427 | 476,918 |
| Brass and wire-rod mills | 573,071 | 549,399 | 35,590 | 35,031 | 608,661 | 584,430 |
| Foundries and manufacturers | 20,403 | 18,542 | 32,626 | 33,181 | 53,029 | 51,723 |
| Chemical plants | 375 | 329 | 3,095 | 1,619 | 3,470 | 1,948 |
| Total | 764,490 | 731,629 | 498,797 | 526,534 | 1,263,287 | 1,258,163 |

[r]Revised.

[1]Electrolytically refined and fire-refined scrap based on source of material at smelter level.

TABLE 25

## PRODUCTION OF SECONDARY COPPER AND COPPER-ALLOY PRODUCTS IN THE UNITED STATES, BY ITEM PRODUCED FROM SCRAP

(Metric tons)

| Item produced from scrap | 1988 | 1989 |
|---|---|---|
| UNALLOYED COPPER PRODUCTS | | |
| Electrolytically refined copper | 347,442 | 376,595 |
| Fire-refined copper | r98,985 | 100,323 |
| Copper powder | 9,370 | 9,389 |
| Copper castings | 681 | 673 |
| Total | r456,478 | 486,980 |
| ALLOYED COPPER PRODUCTS | | |
| Brass and bronze ingots: | | |
| Tin bronzes | 24,952 | 18,984 |
| Leaded red brass and semired brass | 108,376 | 109,746 |
| High-leaded tin bronze | 8,022 | 8,137 |
| Yellow brass | 8,831 | 8,181 |
| Manganese bronze | 8,691 | 8,437 |
| Aluminum bronze | 8,804 | 7,274 |
| Nickel silver | 3,538 | 4,701 |
| Silicon bronze and brass | 5,437 | 5,702 |
| Copper-base hardeners and master alloys | r7,080 | 10,771 |
| Miscellaneous | r6,564 | 4,024 |
| Total | r190,295 | 185,957 |
| Brass mill and wire-rod mill products | 750,096 | 713,363 |
| Brass and bronze castings | r40,975 | 46,938 |
| Brass powder | 252 | 259 |
| Copper in chemical products | 3,470 | 1,948 |
| Grand total[1] | r1,441,564 | 1,435,445 |

rRevised.
[1]Data may not add to totals shown because of independent rounding.

TABLE 26

## COMPOSITION OF SECONDARY COPPER-ALLOY PRODUCTION IN THE UNITED STATES

(Metric tons)

| | Copper | Tin | Lead | Zinc | Nickel | Aluminum | Total[1] |
|---|---|---|---|---|---|---|---|
| Brass and bronze ingot production:[2] | | | | | | | |
| 1988r | 152,173 | 6,156 | 10,957 | 20,623 | 351 | 35 | 190,295 |
| 1989 | 150,248 | 5,693 | 10,003 | 19,499 | 481 | 32 | 185,957 |
| Secondary metal content of brass mill products: | | | | | | | |
| 1988 | [3]611,763 | 780 | 1,721 | 133,663 | 2,168 | 1 | [3]750,096 |
| 1989 | [3]582,692 | 585 | 2,180 | 125,059 | 2,848 | 1 | [3]713,363 |
| Secondary metal content of brass and bronze castings: | | | | | | | |
| 1988r | 37,064 | 863 | 1,249 | 1,705 | 39 | 55 | 40,975 |
| 1989 | 42,396 | 922 | 1,303 | 2,005 | 138 | 175 | 46,938 |

rRevised.
[1]Data may not add to totals shown because of independent rounding.
[2]About 96% from scrap and 4% from other than scrap in 1988 and in 1989.
[3]Includes copper recovered from scrap at wire mills to avoid disclosing company proprietary data.

TABLE 27

## STOCKS AND CONSUMPTION OF PURCHASED COPPER SCRAP IN THE UNITED STATES IN 1989, BY CLASS OF CONSUMER AND TYPE OF SCRAP

(Metric tons, gross weight)

| Class of consumer and type of scrap | Stocks, Jan. 1[1] | Net receipts | Consumption | | | Stocks, Dec. 31 |
|---|---|---|---|---|---|---|
| | | | New scrap | Old scrap | Total | |
| SECONDARY SMELTERS/REFINERS | | | | | | |
| No. 1 wire and heavy | 1,598 | 131,664 | 87,370 | 34,810 | 122,180 | 11,082 |
| No. 2 wire, mixed heavy and light | 21,370 | 338,572 | 41,155 | 301,751 | 342,906 | 17,036 |
| Composition or soft red brass | 1,973 | 38,479 | 6,166 | 32,657 | 38,823 | 1,629 |
| Railroad-car boxes | 88 | 534 | — | 523 | 523 | 99 |
| Yellow brass | 2,434 | 64,938 | 38,098 | 27,252 | 65,350 | 2,022 |
| Cartridge cases | 13 | 526 | — | 508 | 508 | 31 |
| Automobile radiators (unsweated) | 3,806 | 92,238 | — | 94,444 | 94,444 | 1,600 |
| Bronze | 1,092 | 15,159 | 2,594 | 12,808 | 15,402 | 849 |
| Nickel silver and cupronickel | 578 | 3,837 | 837 | 3,304 | 4,141 | 274 |
| Low brass | 697 | 2,598 | 385 | 2,214 | 2,599 | 696 |
| Aluminum bronze | 34 | 226 | 17 | 194 | 211 | 49 |
| Refinery brass | 2,036 | 40,157 | 1,716 | 38,589 | 40,305 | 1,888 |
| Low-grade scrap and residues | 25,938 | 93,299 | 56,493 | 45,854 | 102,347 | 16,890 |
| Total | 61,657 | 822,227 | 234,831 | 594,908 | 829,739 | 54,145 |
| BRASS AND WIRE-ROD MILLS[2] | | | | | | |
| No. 1 wire and heavy | 15,101 | 265,038 | 245,751 | 19,287 | 265,038 | 8,804 |
| No. 2 wire, mixed heavy and light | 2,229 | 46,316 | 35,584 | 10,732 | 46,316 | 1,916 |
| Yellow brass | 7,575 | 247,535 | 239,954 | 7,581 | 247,535 | 11,692 |
| Cartridge cases and brass | 15,960 | 125,669 | 125,235 | 434 | 125,669 | 10,843 |
| Bronze | 625 | 4,613 | 4,613 | — | 4,613 | 792 |
| Nickel silver and cupronickel | 2,079 | 19,199 | 18,927 | 272 | 19,199 | 1,955 |
| Low brass | 2,286 | 17,162 | 17,085 | 77 | 17,162 | 1,476 |
| Aluminum bronze | — | 9 | 9 | — | 9 | — |
| Total | 45,855 | 725,541 | 687,158 | 38,383 | 725,541 | 37,478 |
| FOUNDRIES, CHEMICAL PLANTS, AND OTHER MANUFACTURERS | | | | | | |
| No. 1 wire and heavy | 2,197 | 28,262 | 8,748 | 19,220 | 27,968 | 2,491 |
| No. 2 wire, mixed heavy and light | 178 | 3,416 | 941 | 2,485 | 3,426 | 168 |
| Composition or soft red brass | 3,333 | 13,907 | 5,510 | 8,254 | 13,764 | 3,476 |
| Railroad-car boxes | 255 | 2,980 | 1 | 2,663 | 2,664 | 571 |
| Yellow brass | 378 | 5,626 | 1,718 | 3,786 | 5,504 | 500 |
| Cartridge cases | — | 46 | — | 46 | 46 | — |
| Automobile radiators (unsweated) | 175 | 1,902 | 629 | 1,322 | 1,951 | 126 |
| Bronze | 858 | 903 | 40 | 857 | 897 | 864 |
| Nickel silver and cupronickel | 59 | 222 | 94 | 127 | 221 | 60 |
| Low brass | 145 | 2,345 | 2,374 | 57 | 2,431 | 59 |
| Aluminum bronze | 767 | 2,476 | 1,393 | 1,083 | 2,476 | 767 |
| Low-grade scrap and residues | 7 | 144 | 64 | 67 | 131 | 20 |
| Total[3] | 8,352 | 62,229 | 21,512 | 39,967 | 61,479 | 9,102 |
| GRAND TOTAL | | | | | | |
| No. 1 wire and heavy | 18,896 | 424,964 | 341,869 | 73,317 | 415,186 | 22,377 |
| No. 2 wire, mixed heavy and light | 23,777 | 388,304 | 77,680 | 314,968 | 392,648 | 19,120 |
| Composition or soft red brass | 5,306 | 52,386 | 11,676 | 40,911 | 52,587 | 5,105 |
| Railroad-car boxes | 343 | 3,514 | 1 | 3,186 | 3,187 | 670 |
| Yellow brass | 10,387 | 320,099 | 279,770 | 38,619 | 318,389 | 14,214 |

See footnotes at end of table.

TABLE 27—Continued

## STOCKS AND CONSUMPTION OF PURCHASED COPPER SCRAP IN THE UNITED STATES IN 1989, BY CLASS OF CONSUMER AND TYPE OF SCRAP

(Metric tons, gross weight)

| Class of consumer and type of scrap | Stocks, Jan. 1[1] | Net receipts | Consumption: New scrap | Consumption: Old scrap | Consumption: Total | Stocks, Dec. 31 |
|---|---|---|---|---|---|---|
| Cartridge cases | 15,973 | 126,241 | 125,235 | 988 | 126,223 | 10,874 |
| Automobile radiators (unsweated) | 3,981 | 94,140 | 629 | 95,766 | 96,395 | 1,726 |
| Bronze | 2,575 | 20,675 | 7,247 | 13,665 | 20,912 | 2,505 |
| Nickel silver and cupronickel | 2,716 | 23,258 | 19,858 | 3,703 | 23,561 | 2,289 |
| Low brass | 3,128 | 22,105 | 19,844 | 2,348 | 22,192 | 2,231 |
| Aluminum bronze | 801 | 2,711 | 1,419 | 1,277 | 2,696 | 816 |
| Low-grade scrap and residues[4] | 27,981 | 133,600 | 58,273 | 84,510 | 142,783 | 18,798 |
| Total | 115,864 | 1,611,997 | 943,501 | 673,258 | 1,616,759 | 100,725 |

[1]Revised from 1988 closing stocks.
[2]Brass and wire-rod mill stocks include home scrap; purchased scrap consumption is assumed equal to receipts, so lines in "BRASS AND WIRE-ROD MILLS" and "GRAND TOTAL" sections do not balance.
[3]Of the total shown, chemical plants reported the following: unalloyed copper scrap, 342 tons new and 1,687 tons old.
[4]Includes refinery brass.

TABLE 28

## CONSUMPTION OF COPPER AND BRASS MATERIALS IN THE UNITED STATES, BY ITEM

(Metric tons)

| Item | Brass mills | Wire-rod mills | Foundries, chemical plants, miscellaneous users | Secondary smelters-refiners | Total |
|---|---|---|---|---|---|
| 1988:[r] | | | | | |
| Copper scrap | [1]757,042 | W | 64,320 | 784,479 | 1,605,841 |
| Refined copper[2] | 493,215 | 1,667,190 | 47,412 | 2,607 | 2,210,424 |
| Hardners and master alloys | 3,104 | — | 3,929 | — | 7,033 |
| Brass ingots | — | — | 151,169 | — | 151,169 |
| Slab zinc | 82,727 | — | 4,496 | 3,735 | 90,958 |
| Miscellaneous | — | — | — | 97 | 97 |
| 1989: | | | | | |
| Copper scrap | [1]725,541 | W | 61,479 | 829,739 | 1,616,759 |
| Refined copper[2] | 461,021 | 1,698,351 | 42,434 | 1,337 | 2,203,143 |
| Hardners and master alloys | 7,331 | — | 3,573 | — | 10,904 |
| Brass ingots | — | — | 136,421 | — | 136,421 |
| Slab zinc | 70,584 | — | 22,017 | 3,139 | 95,740 |
| Miscellaneous | — | — | — | 19 | 19 |

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with consumption of copper scrap at brass mills.
[1]Includes consumption of copper scrap at wire-rod mills to avoid disclosing company proprietary data.
[2]Detailed information on consumption of refined copper can be found in table 32.

TABLE 29

## PRODUCTION, SHIPMENTS, AND STOCKS OF BRASS AND WIRE-ROD MILL SEMIFABRICATES

(Metric tons)

| | Production | Shipments | Stocks, Dec. 31 |
|---|---|---|---|
| BRASS MILLS | | | |
| 1987 | 1,301,804 | 1,316,632 | 54,759 |
| 1988 | 1,342,595 | 1,337,432 | 72,443 |
| 1989 | 1,345,745 | 1,352,379 | 66,785 |
| WIRE-ROD MILLS | | | |
| 1987 | 1,422,450 | 1,505,776 | 96,746 |
| 1988 | 1,516,461 | 1,531,055 | 82,153 |
| 1989 | 1,523,794 | 1,513,107 | 90,831 |

TABLE 30

## APPARENT CONSUMPTION OF COPPER IN THE UNITED STATES

(Metric tons)

| Period | Refined copper production | Copper in old scrap | Net refined imports | Stock change during period | Apparent consumption |
|---|---|---|---|---|---|
| 1985 | 1,057,241 | 503,407 | 339,788 | -244,000 | 2,144,436 |
| 1986[r] | 1,073,981 | 477,469 | 489,532 | -96,000 | 2,136,982 |
| 1987 | 1,126,908 | 497,937 | 459,962 | -112,000 | 2,196,807 |
| 1988[r] | 1,406,020 | 518,179 | 273,346 | -14,000 | 2,211,545 |
| 1989: | | | | | |
| January | 118,077 | 43,065 | 26,537 | 1,000 | 186,679 |
| February | 112,632 | 47,036 | 20,002 | 4,000 | 175,670 |
| March | 123,953 | 51,044 | 12,837 | 2,000 | 185,834 |
| April | 114,684 | 45,519 | 7,378 | -1,000 | 168,581 |
| May | 129,187 | 46,939 | 19,867 | 3,000 | 192,993 |
| June | 123,254 | 46,118 | 19,277 | -3,000 | 191,649 |
| July | 118,886 | 39,325 | 2,021 | 5,000 | 155,232 |
| August | 126,367 | 46,707 | 8,585 | -10,000 | 191,659 |
| September | 119,994 | 47,021 | 4,856 | -7,000 | 178,871 |
| October | 126,112 | 48,090 | 16,757 | 6,000 | 184,959 |
| November | 131,359 | 41,678 | 26,026 | 4,000 | 195,063 |
| December | 132,328 | 41,054 | 5,777 | 4,000 | 175,159 |
| Total | 1,476,833 | 543,596 | 169,920 | 8,000 | 2,182,349 |

[r]Revised.

TABLE 31

## FOUNDRIES AND MISCELLANEOUS MANUFACTURERS[2] CONSUMPTION OF BRASS INGOT AND REFINED COPPER AND COPPER SCRAP IN THE UNITED STATES, BY GEOGRAPHIC DIVISION AND STATE

| Geographic division and State | Tin bronzes | Leaded red brass and semi-red brass | Yellow, leaded and low brass[1] | Manganese bronze | Nickel silver[2] | Aluminum bronze | Total brass ingot | Hardeners and master alloys[3] | Refined copper consumed | Copper scrap consumed |
|---|---|---|---|---|---|---|---|---|---|---|
| 1985 | 27,328 | 87,053 | 8,014 | 6,216 | 1,788 | 7,052 | 137,451 | 3,133 | 54,390 | 66,557 |
| 1986 | 33,651 | 81,288 | 9,702 | 5,735 | 2,336 | 5,506 | 138,218 | 3,146 | 43,416 | 63,323 |
| 1987 | 31,198 | 79,074 | 7,365 | 7,433 | 2,239 | 5,545 | 132,854 | 3,193 | 40,649 | 67,316 |
| 1988[r] | 33,336 | 89,024 | 8,669 | 6,660 | 1,959 | 7,593 | 151,169 | 3,929 | 46,412 | 60,706 |
| 1989: | | | | | | | | | | |
| Atlantic: | | | | | | | | | | |
| Middle: New Jersey, New York, Pennsylvania | 7,385 | 8,266 | 913 | 827 | 184 | 695 | 18,366 | 97 | 8,221 | 8,276 |
| South: Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia | 8,531 | 5,732 | 361 | 418 | 248 | 714 | 16,035 | 33 | 5,866 | 5,300 |
| Central: | | | | | | | | | | |
| East North: Illinois, Indiana, Michigan, Ohio, Wisconsin | 10,915 | 41,085 | 3,882 | 2,701 | 769 | 2,261 | 64,526 | 2,911 | 13,661 | 27,512 |
| South: Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas | 3,808 | 6,945 | 396 | 389 | 82 | 469 | 12,147 | 57 | 6,538 | 4,065 |
| West North: Iowa, Kansas, Minnesota, Missouri, Nebraska, South Dakota | 1,547 | 5,336 | 567 | 363 | 6 | 620 | 8,576 | 135 | 4,376 | 4,382 |
| Mountain and Pacific: | | | | | | | | | | |
| Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington | 1,481 | 9,886 | 1,020 | 916 | 29 | 346 | 14,000 | 321 | 1,130 | 8,695 |
| New England: | | | | | | | | | | |
| Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont | 408 | 819 | 603 | 236 | 335 | 354 | 2,771 | 19 | 1,705 | 1,220 |
| Total | 34,075 | 78,069 | 7,742 | 5,850 | 1,653 | 5,459 | 136,421 | 3,573 | 41,497 | 59,450 |

[r]Revised.
[1]Includes silicon bronze and brass.
[2]Includes copper nickel and nickel bronze and brass.
[3]Includes special alloys.

TABLE 32

## REFINED COPPER CONSUMED IN THE UNITED STATES, BY CLASS OF CONSUMER

(Metric tons)

| Class of consumer | Cathodes | Wirebars | Ingots and ingot bars | Cakes and slabs | Billets | Other | Total |
|---|---|---|---|---|---|---|---|
| 1988:[r] | | | | | | | |
| Wire-rod mills | 1,667,190 | — | — | — | — | — | 1,667,190 |
| Brass mills | 279,810 | 14,037 | 37,168 | 63,037 | 99,025 | 138 | 493,215 |
| Chemical plants | W | — | — | — | — | 1,002 | 1,002 |
| Ingot makers | W | — | W | — | 2,607 | 2,607 | |
| Foundries | 1,562 | W | 8,350 | — | W | 4,586 | 14,498 |
| Miscellaneous[1] | 18,878 | W | 8,703 | W | W | 4,331 | 31,912 |
| Total | 1,967,440 | 14,037 | 54,221 | 63,037 | 99,025 | 12,664 | 2,210,424 |
| 1989: | | | | | | | |
| Wire-rod mills | 1,698,351 | — | — | — | — | — | 1,698,351 |
| Brass mills | 265,634 | 5,810 | 19,735 | 64,921 | 104,863 | 59 | 461,021 |
| Chemical plants | W | 314 | — | — | — | 623 | 937 |
| Ingot makers | W | — | W | — | — | 1,337 | 1,337 |
| Foundries | 3,437 | W | 6,913 | W | W | 4,531 | 14,882 |
| Miscellaneous[1] | 14,143 | W | 7,800 | W | W | 4,671 | 26,615 |
| Total | 1,981,565 | 6,124 | 34,448 | 64,921 | 104,863 | 11,221 | 2,203,143 |

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1]Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and other manufacturers.

TABLE 33

## STOCKS OF COPPER IN THE UNITED STATES, END OF PERIOD

(Thousand metric tons)

| Period | Blister and materials in process of refining[1] | Refined copper | | | | | |
|---|---|---|---|---|---|---|---|
| | | Electrolytic refiners | Wire-rod mills | Brass mills | Other[2] | New York Commodity Exchange | Total |
| 1985 | 146 | 66 | 100 | 20 | 25 | 109 | 320 |
| 1986 | [r]136 | [r]35 | 66 | 14 | 25 | 84 | [r]224 |
| 1987 | 150 | 29 | 28 | 15 | [r]23 | 17 | [r]112 |
| 1988 | [r]121 | 16 | 29 | 17 | 24 | 12 | 98 |
| 1989: | | | | | | | |
| January | 127 | 17 | 30 | 14 | 25 | 13 | 99 |
| February | 129 | 18 | 29 | 16 | 24 | 16 | 103 |
| March | 120 | 13 | 24 | 16 | 25 | 27 | 105 |
| April | 115 | 15 | 28 | 16 | 25 | 20 | 104 |
| May | 119 | 17 | 29 | 14 | 24 | 23 | 107 |
| June | 103 | 13 | 29 | 16 | 25 | 21 | 104 |
| July | 106 | 16 | 32 | 16 | 26 | 19 | 109 |
| August | 110 | 14 | 25 | 21 | 25 | 14 | 99 |
| September | 128 | 15 | 23 | 19 | 25 | 10 | 92 |
| October | 143 | 16 | 31 | 16 | 26 | 9 | 98 |
| November | 129 | 19 | 32 | 17 | 26 | 8 | 102 |
| December | 132 | 18 | 32 | 12 | 29 | 15 | 106 |

[r]Revised.

[1]Includes copper in transit from smelters in the United States to refineries therein.

[2]Includes secondary smelters, chemical plants, foundries, and miscellaneous plants; includes 20,000 tons in the National Defense Stockpile.

TABLE 34

# DEALERS' MONTHLY AVERAGE BUYING PRICE FOR COPPER SCRAP AND CONSUMERS' ALLOY-INGOT PRICES AT NEW YORK, BY TYPE

(Cents per pound)

| Year and month | Scrap | | | Ingot | |
|---|---|---|---|---|---|
| | No. 1 heavy copper | No. 2 heavy copper | Red brass | No. 115 brass (85-5-5-5) | Yellow brass (405) |
| 1988:[r] | | | | | |
| January | 102.78 | 94.10 | 83.50 | 100.50 | 84.25 |
| February | 87.15 | 77.58 | 77.43 | 98.59 | 82.34 |
| March | 90.56 | 82.24 | 73.50 | 97.71 | 81.46 |
| April | 88.44 | 79.48 | 73.00 | 99.00 | 82.75 |
| May | 88.30 | 79.24 | 70.45 | 99.00 | 82.75 |
| June | 93.87 | 83.75 | 71.80 | 99.00 | 86.59 |
| July | 88.70 | 79.58 | 71.08 | 99.00 | 89.75 |
| August | 88.18 | 79.20 | 70.50 | 99.00 | 89.75 |
| September | 98.14 | 88.36 | 70.50 | 99.71 | 90.18 |
| October | 101.29 | 93.64 | 78.79 | 105.43 | 94.18 |
| November | 111.27 | 98.03 | 82.50 | 109.68 | 99.22 |
| December | 116.15 | 103.98 | 89.47 | 110.00 | 99.75 |
| Average | 96.24 | 86.60 | 76.04 | 101.39 | 88.58 |
| 1989: | | | | | |
| January | 114.62 | 103.50 | 52.75 | 112.00 | 101.25 |
| February | 110.75 | 97.97 | 57.50 | 116.00 | 104.75 |
| March | 119.31 | 108.32 | 57.50 | 116.00 | 106.90 |
| April | 119.21 | 110.93 | 57.95 | 116.00 | 107.75 |
| May | 109.47 | 100.16 | 59.00 | 118.27 | 115.02 |
| June | 100.45 | 91.18 | 59.00 | 117.83 | 115.25 |
| July | 144.44 | 88.63 | 59.00 | 117.50 | 113.95 |
| August | 108.78 | 99.78 | 59.65 | 117.63 | 112.95 |
| September | 115.57 | 105.50 | 62.00 | 123.09 | 116.75 |
| October | 116.14 | 106.64 | 62.00 | 120.50 | 116.75 |
| November | 104.95 | 97.25 | 62.00 | 119.70 | 115.50 |
| December | 95.73 | 88.05 | 60.78 | 119.50 | 115.25 |
| Average | 113.29 | 99.83 | 59.09 | 117.84 | 111.84 |

[r]Revised.

Source: American Metal Market.

TABLE 35

## AVERAGE MONTHLY PRICES FOR REFINED COPPER IN THE UNITED STATES AND ON THE LONDON METAL EXCHANGE

(Cents per pound)

| Month | 1988 | | | | 1989 | | | |
|---|---|---|---|---|---|---|---|---|
| | U.S. producers delivered cathode[2] | COMEX first position | LME cash[1] | | U.S. producers delivered | | COMEX first position[4] | LME cash Grade A[1 5] |
| | | | Standard | Grade A | Cathode[2] | Wirebar[3] | | |
| January | 132.50 | 123.22 | 115.93 | 120.66 | 157.77 | 164.18 | 154.92 | 153.88 |
| February | 107.52 | 99.73 | 102.30 | 105.62 | 140.21 | 146.33 | 136.45 | 140.37 |
| March | 109.72 | 103.92 | 103.51 | 106.96 | 148.49 | 154.89 | 144.39 | 147.99 |
| April | 103.64 | 97.50 | 100.00 | 103.64 | 143.49 | 150.26 | 140.46 | 141.36 |
| May | 104.37 | 99.27 | 100.77 | 110.84 | 127.15 | 132.72 | 123.07 | 124.20 |
| June | 114.28 | 108.97 | 104.95 | 115.15 | 115.90 | 110.34 | 112.41 | 115.44 |
| July | 104.85 | 98.78 | 96.77 | 100.35 | 113.49 | 119.27 | 109.58 | 113.57 |
| August | 101.45 | 96.21 | 96.18 | 99.78 | 127.43 | 133.87 | 124.68 | 125.23 |
| September | 116.12 | 111.24 | 105.13 | 110.38 | 138.44 | 143.60 | 134.94 | 130.80 |
| October | 138.05 | 133.48 | 127.65 | 133.24 | 131.66 | 137.61 | 127.59 | 129.79 |
| November | 152.32 | 147.08 | 143.82 | 149.81 | 118.11 | 123.68 | 113.96 | 117.50 |
| December | 161.27 | 155.81 | 153.94 | 158.62 | 109.22 | 115.60 | 106.96 | 109.67 |
| Average | 120.51 | 114.60 | 112.58 | 117.92 | 130.95 | 136.03 | 128.91 | 129.15 |

[1]Based on average monthly rates of exchange.
[2]Listed as "U.S. producer cathode."
[3]Listed as "Electrolytic wirebar (Warrenton Refining Co.)."
[4]Listed as "COMEX high grade first position."
[5]Quotations for "Standard" no longer available. Suspended Jan. 1, 1989.
Sources: Metals Week and American Metal Market.

TABLE 36

## U.S. EXPORTS OF COPPER, BY COUNTRY

| Country | Ore and concentrate (copper content) | | Ash and residues[1] (copper content) | | Refined | | Unalloyed copper scrap | | Blister and precipitates | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1988 | 211,147 | $420,003 | 4,380 | $10,276 | 58,325 | $138,539 | 119,773 | $164,933 | 33,337 | $65,978 |
| 1989: | | | | | | | | | | |
| Australia | 194 | 254 | 34 | 49 | 12 | 20 | — | — | — | — |
| Belgium | 42 | 75 | 600 | 4,574 | 19 | 57 | 3,624 | 4,640 | — | — |
| Brazil | 16,632 | 34,117 | — | — | 17 | 72 | 809 | 1,529 | — | — |
| Bulgaria | 4,560 | 9,350 | — | — | — | — | — | — | — | — |
| Canada | 10,999 | 18,453 | 5,680 | 7,693 | 4,731 | 7,327 | 38,062 | 47,784 | 9 | 44 |
| China | 3,654 | 8,016 | — | — | 12,874 | 31,452 | 6,048 | 3,297 | — | — |
| Dominican Republic | 17 | 89 | — | — | 84 | 172 | — | — | — | — |
| Finland | 7,241 | 10,933 | — | — | — | — | — | — | — | — |
| France | 80 | 80 | 3 | 5 | 689 | 2,059 | 53 | 66 | — | — |
| Germany, Federal Republic of | 13,966 | 34,579 | 334 | 2,255 | 1,298 | 3,621 | 13,217 | 24,251 | 22 | 34 |
| Hong Kong | 3 | 3 | — | — | 583 | 2,084 | 1,126 | 893 | — | — |
| India | 31 | 18 | 49 | 70 | — | — | 1,092 | 1,658 | — | — |
| Israel | 5 | 5 | — | — | 70 | 139 | 1 | 9 | — | — |
| Italy | — | — | — | — | 591 | 1,365 | 254 | 355 | — | — |
| Japan | 163,998 | 330,566 | 132 | 458 | 47,538 | 120,506 | 20,331 | 45,476 | 504 | 994 |
| Korea, Republic of | 27,552 | 45,034 | 6 | 26 | 1,247 | 2,849 | 32,600 | 60,535 | 6,674 | 17,843 |
| Mexico | 8 | 8 | — | — | 7,345 | 20,880 | 7,837 | 18,616 | 828 | 1,282 |
| Netherlands | — | — | 7 | 14 | 663 | 2,040 | 3,428 | 6,605 | — | — |
| Philippines | 2,714 | 4,971 | — | — | 2 | 3 | 121 | 28 | — | — |

See footnotes at end of table.

TABLE 36—Continued

## U.S. EXPORTS OF COPPER, BY COUNTRY

| Country | Ore and concentrate (copper content) | | Ash and residues[1] (copper content) | | Refined | | Unalloyed copper scrap | | Blister and precipitates | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Singapore | 8 | $ 8 | — | — | 1,204 | $3,067 | 121 | $ 123 | — | — |
| Spain | 15 | 18 | — | — | — | — | 869 | 877 | — | — |
| Switzerland | — | — | — | — | 226 | 644 | 111 | 225 | — | — |
| Taiwan | 8,712 | 21,340 | 1 | $2 | 47,755 | 96,069 | 23,136 | $23,726 | — | — |
| United Kingdom | 503 | 521 | 2 | 3 | 1,086 | 2,511 | 1,229 | 2,198 | — | — |
| Venezuela | — | — | — | — | 1,296 | 3,732 | 18 | 13 | — | — |
| Yugoslavia | 5,634 | 20,668 | — | — | — | — | — | — | — | — |
| Other | 263 | 219 | 60 | 7 | 859 | 2,344 | 848 | 1,291 | 4 | $ 12 |
| Total | 266,831 | 539,325 | 6,908 | 15,156 | 130,189 | 303,013 | 154,935 | 244,195 | 8,041 | 20,209 |

| Country | Pipes and tubing | | Plates and sheets | | Wire and cable, bare | | Wire and cable insulated | | Other copper manufactures[2] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1988 | 7,749 | $28,623 | 863 | $4,141 | 12,422 | $53,449 | 118,636 | $667,158 | 2,350 | $7,861 |
| 1989: | | | | | | | | | | |
| Australia | 79 | 465 | 5 | 48 | 70 | 480 | 1,306 | 9,858 | 84 | 775 |
| Bahamas | 15 | 33 | 1 | 3 | 145 | 574 | 141 | 747 | 3 | 49 |
| Belgium | 133 | 239 | — | — | 25 | 222 | 230 | 2,552 | 118 | 356 |
| Brazil | 222 | 738 | 1 | 3 | 41 | 569 | 288 | 3,520 | 2,549 | 8,162 |
| Canada | 7,170 | 18,971 | 883 | 3,293 | 6,598 | 28,169 | 16,104 | 73,365 | 12,135 | 36,426 |
| China | 261 | 956 | 1 | 10 | 87 | 124 | 449 | 3,210 | 2,652 | 6,590 |
| Dominican Republic | 24 | 75 | 9 | 38 | 583 | 3,119 | 468 | 1,983 | 1,176 | 3,803 |
| Ecuador | 24 | 86 | 1 | 10 | 43 | 179 | 35 | 320 | 105 | 431 |
| Egypt | 170 | 1,259 | 70 | 322 | (3) | 4 | 972 | 4,147 | 1 | 11 |
| France | 58 | 184 | 34 | 227 | 100 | 1,313 | 853 | 8,783 | 279 | 1,873 |
| Germany, Federal Republic of | 44 | 554 | 131 | 796 | 274 | 2,778 | 3,190 | 20,464 | 101 | 1,850 |
| Hong Kong | 119 | 507 | 159 | 999 | 345 | 1,342 | 851 | 5,531 | 5 | 51 |
| India | 26 | 115 | 17 | 309 | 17 | 192 | 243 | 2,708 | 862 | 1,599 |
| Israel | 85 | 475 | 37 | 442 | 53 | 627 | 233 | 2,759 | 13 | 93 |
| Italy | 57 | 261 | 31 | 169 | 132 | 1,084 | 232 | 3,486 | 14 | 261 |
| Jamaica | 60 | 242 | 4 | 16 | 334 | 1,720 | 234 | 1,028 | 663 | 1,945 |
| Japan | 110 | 821 | 649 | 4,693 | 386 | 2,747 | 855 | 10,811 | 1,257 | 5,137 |
| Korea, Republic of | 98 | 1,280 | 22 | 437 | 214 | 1,849 | 462 | 5,004 | 204 | 672 |
| Kuwait | 479 | 2,093 | — | — | 13 | 112 | 16 | 219 | — | — |
| Mexico | 4,932 | 14,967 | 640 | 2,992 | 14,616 | 62,387 | 46,891 | 178,066 | 5,861 | 20,468 |
| Netherlands | 503 | 1,979 | 87 | 792 | 66 | 542 | 598 | 12,005 | 597 | 3,634 |
| Philippines | 748 | 2,741 | 8 | 53 | 168 | 728 | 374 | 2,072 | 8 | 34 |
| Saudi Arabia | 665 | 2,633 | — | — | 150 | 862 | 608 | 3,314 | 27 | 97 |
| Singapore | 162 | 694 | 29 | 160 | 86 | 1,013 | 769 | 6,585 | 348 | 922 |
| Sweden | 2 | 17 | 1 | 5 | 15 | 202 | 149 | 4,209 | 5 | 34 |
| Switzerland | 5 | 69 | — | — | 132 | 2,601 | 588 | 3,373 | 36 | 697 |
| Taiwan | 989 | 3,357 | 860 | 3,904 | 150 | 1,413 | 939 | 6,924 | 3,004 | 7,876 |
| Trinidad and Tobago | 5 | 30 | 13 | 4 | 99 | 398 | 53 | 440 | 316 | 981 |
| United Kingdom | 253 | 1,180 | 77 | 668 | 733 | 6,895 | 3,865 | 33,827 | 130 | 1,787 |
| Venezuela | 271 | 1,412 | 12 | 66 | 103 | 734 | 515 | 4,384 | 974 | 2,979 |
| Yugoslavia | — | — | — | — | 4 | 27 | 21 | 177 | — | — |
| Other | 3,271 | 12,485 | 108 | 750 | 1,698 | 9,730 | 6,724 | 39,611 | 1,891 | 6,168 |
| Total | 21,767 | 73,061 | 3,890 | 21,209 | 27,560 | 135,499 | 90,393 | 461,725 | 35,418 | 115,763 |

[1]Includes matte.
[2]Excludes copper wire cloth.
[3]Less than 1/2 unit.
Source: Bureau of the Census.

TABLE 37

## U.S. EXPORTS OF COPPER SCRAP, BY COUNTRY

| Country | Unalloyed copper scrap | | | | Copper-alloy scrap | | | |
|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1989 | | 1988 | | 1989 | |
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| Belgium | 2,813 | $4,057 | 3,621 | $4,640 | 8,715 | $8,870 | 5,866 | $7,744 |
| Brazil | 594 | 936 | 809 | 1,529 | 589 | 907 | 1,797 | 2,425 |
| Canada | 29,174 | 32,357 | 38,062 | 47,784 | 23,607 | 38,567 | 30,464 | 48,588 |
| Chile | — | — | 127 | 244 | — | — | 2 | 8 |
| China | 427 | 496 | 6,048 | 3,297 | 1,040 | 838 | 8,996 | 7,331 |
| France | 48 | 51 | 53 | 66 | 699 | 797 | 831 | 1,503 |
| Germany, Federal Republic of | 9,751 | 13,596 | 13,217 | 24,251 | 20,986 | 33,248 | 39,877 | 55,734 |
| Hong Kong | 1,433 | 1,149 | 1,126 | 893 | 206 | 212 | 1,435 | 1,365 |
| India | 2,015 | 2,358 | 1,092 | 1,658 | 13,184 | 14,371 | 25,554 | 32,530 |
| Indonesia | — | — | 413 | 457 | — | — | — | — |
| Italy | 834 | 1,065 | 254 | 355 | 1,948 | 2,450 | 4,935 | 5,922 |
| Japan | 16,130 | 25,810 | 20,331 | 45,476 | 17,225 | 31,365 | 18,826 | 46,793 |
| Korea, Republic of | 19,541 | 39,041 | 32,600 | 60,535 | 44,044 | 70,221 | 29,230 | 47,194 |
| Mexico | 11,496 | 20,353 | 7,837 | 18,616 | 10,094 | 23,637 | 14,934 | 27,911 |
| Netherlands | 924 | 2,037 | 3,428 | 6,605 | 1,115 | 2,214 | 3,300 | 5,692 |
| Norway | — | — | 222 | 447 | — | — | 19 | 6 |
| Philippines | — | — | 121 | 28 | — | — | 84 | 182 |
| Singapore | 2,098 | 3,066 | 121 | 123 | 1,138 | 1,260 | 1,219 | 1,605 |
| Spain | 3,379 | 2,228 | 869 | 877 | 10,099 | 3,936 | 4,165 | 2,927 |
| Sweden | 15 | 40 | — | — | 1,614 | 3,866 | 2,106 | 3,764 |
| Switzerland | 15 | 3 | 111 | 225 | 53 | 63 | 10 | 24 |
| Taiwan | 16,292 | 12,185 | 23,136 | 23,726 | 39,596 | 36,697 | 14,592 | 19,052 |
| Trinidad and Tobago | — | — | 22 | 21 | 956 | 1,037 | 148 | 132 |
| United Kingdom | 2,311 | 3,103 | 1,229 | 2,198 | 2,698 | 5,181 | 5,564 | 7,765 |
| Venezuela | 305 | 607 | 18 | 13 | 150 | 416 | 102 | 190 |
| Other | 178 | 395 | 68 | 131 | 193 | 407 | 622 | 821 |
| Total | 119,773 | 164,933 | 154,935 | 244,195 | 199,949 | 280,560 | 214,678 | 327,208 |

Source: Bureau of the Census.

TABLE 38

## U.S. IMPORTS FOR CONSUMPTION OF UNMANUFACTURED COPPER (COPPER CONTENT), BY COUNTRY

| Country | Ore and concentrate | | Matte | | Blister and anode | | Refined | | Unalloyed scrap | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1988 | 2,776 | $7,917 | 5,462 | $10,399 | 98,453 | $197,621 | 331,671 | $810,495 | 37,152 | $87,124 | 475,512 | $1,113,556 |
| 1989: | | | | | | | | | | | | |
| Australia | 343 | 985 | — | — | (1) | 181 | — | — | — | — | 343 | 1,166 |
| Brazil | — | — | — | — | — | — | 18,220 | 50,691 | — | — | 18,220 | 50,691 |
| Canada | 731 | 454 | — | — | 188 | 1,116 | 180,814 | 508,425 | 19,368 | 58,200 | 201,101 | 568,195 |
| Cape Verde | — | — | — | — | 745 | 1,655 | — | — | — | — | 745 | 1,655 |
| Chile | 3,566 | 8,164 | — | — | 33,713 | 93,133 | 75,436 | 215,088 | 4,805 | 15,495 | 117,520 | 331,880 |
| China | — | — | — | — | — | — | 65 | 223 | — | — | 65 | 223 |
| Costa Rica | — | — | — | — | — | — | — | — | 539 | 1,212 | 539 | 1,212 |
| Dominican Republic | — | — | — | — | — | — | — | — | 467 | 1,377 | 467 | 1,377 |
| Germany, Federal Republic of | — | — | — | — | (1) | 9 | 281 | 1,065 | 295 | 273 | 576 | 1,347 |
| Guatemala | — | — | — | — | — | — | — | — | 243 | 425 | 243 | 425 |
| Jamaica | — | — | — | — | — | — | — | — | 188 | 333 | 188 | 333 |
| Japan | — | — | — | — | 22,298 | 79,301 | 3 | 120 | — | — | 22,301 | 79,421 |
| Mexico | 40,974 | 38,781 | 2,238 | 5,192 | 6,645 | 24,902 | 165 | 441 | 3,568 | 5,048 | 53,590 | 74,364 |
| Netherlands | — | — | — | — | (1) | 3 | 2,431 | 8,432 | 276 | 1,090 | 2,707 | 9,525 |
| Niger | — | — | — | — | — | — | 828 | 2,536 | — | — | 828 | 2,536 |
| Norway | — | — | — | — | — | — | 55 | 154 | — | — | 55 | 154 |
| Panama | — | — | — | — | — | — | — | — | 638 | 1,305 | 638 | 1,305 |
| Peru | 232 | 661 | — | — | 2,952 | 8,258 | 9,240 | 24,865 | — | — | 12,424 | 33,784 |
| South Africa, Republic of | — | — | — | — | — | — | 1,083 | 3,657 | — | — | 1,083 | 3,657 |
| Sweden | 600 | 1,534 | — | — | (1) | 6 | — | — | — | — | 600 | 1,540 |
| Tanzania | — | — | — | — | 987 | 2,877 | — | — | — | — | 987 | 2,877 |
| Trinidad and Tobago | — | — | — | — | — | — | — | — | 305 | 642 | 305 | 642 |
| United Kingdom | — | — | 3 | 19 | (1) | 10 | 19 | 98 | 1 | 2 | 23 | 129 |
| Venezuela | — | — | — | — | — | — | — | — | 588 | 1,292 | 588 | 1,292 |
| Zaire | — | — | — | — | 9,689 | 24,672 | 11,437 | 30,618 | — | — | 21,126 | 55,290 |
| Other | 69 | 165 | 11 | 21 | (1) | 6 | 33 | 196 | 297 | 559 | 410 | 947 |
| Total | 46,515 | 50,744 | 2,252 | 5,232 | 77,217 | 236,129 | 300,110 | 846,609 | 31,578 | 87,253 | 457,672 | 1,225,967 |

1 Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 39

## U.S. IMPORTS FOR CONSUMPTION OF COPPER MANUFACTURES, BY COUNTRY

| Country | Pipes and tubing | | Plates and sheets | | Wire and cable, bare | | Oxides and hydroxides | | Other copper manufactures[1] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) | Quantity (metric tons) | Value (thousands) |
| 1988 | 62,633 | $255,551 | 26,049 | $88,228 | 7,843 | $20,846 | 5,089 | $10,436 | 9,698 | $29,610 |
| 1989: | | | | | | | | | | |
| Argentina | — | — | 211 | 602 | — | — | — | — | 72 | 141 |
| Australia | — | — | 541 | 1,987 | — | — | 2,249 | 5,745 | — | — |
| Austria | 116 | 588 | 17 | 64 | 7 | 99 | — | — | — | — |
| Belgium | — | — | 147 | 839 | — | — | — | — | 1 | 9 |
| Brazil | 27 | 101 | 893 | 2,959 | 20 | 99 | — | — | 409 | 1,113 |
| Canada | 4,313 | 17,898 | 6,046 | 23,158 | 219 | 814 | 61 | 91 | 6,433 | 22,877 |
| Chile | 913 | 3,309 | 1,780 | 6,033 | — | — | 75 | 173 | 7,622 | 22,955 |
| China | — | — | 28 | 101 | — | — | — | — | 8 | 36 |
| Finland | 76 | 549 | 3,444 | 13,066 | 219 | 1,230 | — | — | 894 | 3,788 |
| France | 842 | 3,450 | 9 | 110 | 46 | 612 | 4 | 4 | 6 | 32 |
| Germany, Federal Republic of | 549 | 3,685 | 2,071 | 8,455 | 424 | 4,184 | 1 | 17 | 1,435 | 5,669 |
| Israel | — | — | — | — | 83 | 503 | — | — | — | — |
| Italy | 2,213 | 8,929 | 68 | 209 | 74 | 951 | — | — | 16 | 69 |
| Japan | 16,467 | 76,463 | 3,245 | 17,398 | 650 | 4,410 | 28 | 157 | 468 | 2,174 |
| Korea, Republic of | 5 | 23 | 26 | 94 | 31 | 135 | — | — | 1 | 16 |
| Luxembourg | — | — | 278 | 3,025 | — | — | — | — | — | — |
| Mexico | 7,157 | 26,849 | 80 | 376 | 1,446 | 7,367 | 594 | 1,347 | — | — |
| Netherlands | (2) | 7 | 215 | 916 | 17 | 90 | — | — | (2) | 2 |
| Norway | — | — | — | — | — | — | 109 | 305 | — | — |
| Peru | — | — | — | — | 9,457 | 25,341 | — | — | 300 | 992 |
| Poland | — | — | — | — | 76 | 224 | — | — | 17 | 38 |
| Singapore | — | — | — | — | 127 | 780 | — | — | — | — |
| Sweden | 73 | 344 | 12,638 | 49,418 | 2 | 14 | — | — | 19 | 89 |
| Switzerland | 5 | 15 | 3 | 30 | 13 | 87 | — | — | 25 | 170 |
| Taiwan | 11 | 95 | 118 | 861 | 169 | 730 | 15 | 17 | — | — |
| Turkey | — | — | — | — | 379 | 1,773 | — | — | — | — |
| United Kingdom | 179 | 1,767 | 411 | 4,443 | 53 | 682 | 60 | 138 | 40 | 316 |
| Venezuela | 67 | 207 | — | — | — | — | — | — | 18 | 39 |
| Yugoslavia | 31 | 89 | 273 | 829 | 10 | 36 | — | — | 16 | 29 |
| Other | 21 | 68 | 33 | 122 | 29 | 151 | 20 | 53 | 47 | 161 |
| Total | 33,065 | 144,436 | 32,575 | 135,095 | 13,551 | 50,312 | 3,216 | 8,047 | 17,847 | 60,715 |

[1]Excludes copper wire cloth.
[2]Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 40

## U.S. IMPORTS FOR CONSUMPTION OF COPPER SCRAP, BY COUNTRY

| Country | Unalloyed copper scrap: Quantity (metric tons) | Unalloyed copper scrap: Value (thousands) | Copper-alloy scrap: Gross weight (metric tons) | Copper-alloy scrap: Copper content[1] (metric tons) | Copper-alloy scrap: Value (thousands) |
|---|---|---|---|---|---|
| 1988 | 37,152 | $87,124 | 49,526 | 35,848 | $75,768 |
| 1989: | | | | | |
| Bahamas | 15 | 19 | 61 | — | 53 |
| Barbados | 51 | 90 | 32 | — | 23 |
| Belgium | — | — | 1,431 | — | 972 |
| Canada | 19,368 | 58,200 | 38,755 | — | 78,684 |
| Chile | 4,805 | 15,495 | 3,347 | — | 8,470 |
| China | — | — | 136 | — | 235 |
| Costa Rica | 539 | 1,212 | 133 | — | 224 |
| Dominican Republic | — | — | 1,067 | — | 2,130 |
| France | 467 | 1,377 | 187 | — | 1,005 |
| Germany, Federal Republic of | 295 | 273 | 212 | — | 893 |
| Guatemala | 243 | 425 | 315 | — | 352 |
| Haiti | 44 | 93 | 108 | — | 170 |
| Honduras | 34 | 92 | 62 | — | 22 |
| Hong Kong | — | — | 92 | — | 176 |
| Jamaica | 188 | 333 | 320 | — | 230 |
| Japan | — | — | 305 | — | 287 |
| Mexico | 3,568 | 5,048 | 20,707 | — | 33,098 |
| Netherlands | 276 | 1,090 | — | — | — |
| Netherlands Antilles | 28 | 62 | 309 | — | 429 |
| Panama | 638 | 1,305 | 848 | — | 1,342 |
| Singapore | — | — | 178 | — | 364 |
| Sweden | — | — | 19 | — | 42 |
| Switzerland | — | — | 43 | — | 156 |
| Taiwan | — | — | 3,479 | — | 5,917 |
| Trinidad and Tobago | 305 | 642 | 301 | — | 414 |
| United Kingdom | 1 | 2 | 274 | — | 747 |
| Venezuela | 588 | 1,292 | 6,144 | — | 11,015 |
| Other | 125 | 203 | 459 | — | 1,225 |
| Total | 31,578 | 87,253 | 79,324 | [e]57,000 | 148,675 |

[e]Estimated.

[1]Under the Harmonized Tariff System that was implemented January 1989, copper content is no longer available. Total content for 1989 is estimated to be 72% of gross weight.

TABLE 41

## COPPER: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

| Country | 1985 | 1986 | 1987 | 1988[p] | 1989[e] |
|---|---|---|---|---|---|
| Albania[e] | 16.2 | 17.6 | 17.8 | 15.0 | 16.0 |
| Argentina | .4 | .3 | .4 | .5 | .6 |
| Australia | 259.8 | 248.4 | 232.7 | 238.3 | [2]289.2 |
| Bolivia | 1.7 | .3 | ([3]) | .2 | [2].3 |
| Botswana[4] | 21.7 | [r]21.3 | 18.9 | 24.4 | [2]22.6 |
| Brazil | 41.0 | 40.2 | 37.8 | 44.4 | 45.8 |
| Bulgaria[e] | 80.0 | 80.0 | 80.0 | 80.0 | 80.0 |
| Burma | 16.7 | 11.4 | 17.3 | 13.8 | 5.0 |
| Canada: | | | | | |
| By concentration or leaching[5] | 738.6 | [r]697.9 | 790.2 | 753.5 | 716.9 |
| Leaching (electrowon) | — | .7 | 3.9 | 5.0 | 5.0 |
| Chile[6] | 1,359.8 | 1,399.4 | 1,412.9 | 1,472.0 | [2]1,645.0 |
| China[e] | 185.0 | 185.0 | 250.0 | [r]375.0 | 375.0 |
| Congo | .5 | .7 | 1.3 | [e]1.0 | 1.0 |
| Cuba | 3.1 | 3.3 | 3.5 | 3.0 | 3.0 |
| Cyprus[7] | 1.1 | .6 | .1 | .3 | [2].3 |
| Czechoslovakia[e] [8] | [r]6.3 | [r]5.3 | [r]5.3 | [r]5.0 | 5.0 |
| Ecuador[e] | .1 | .1 | .1 | .1 | .1 |
| Finland | [r]27.9 | [r]26.0 | 20.4 | 20.2 | 14.5 |
| France | .2 | .3 | .3 | .3 | .3 |
| German Democratic Republic[e] | 12.0 | [r]11.0 | [r]11.0 | [r]10.0 | 9.0 |
| Germany, Federal Republic of[8] | .9 | .8 | 1.5 | .7 | .1 |
| Honduras | 5.1 | [e]5.0 | .6 | .6 | .6 |
| India | 45.9 | 48.1 | 56.5 | 55.7 | 57.4 |
| Indonesia[8] | 88.7 | 95.8 | 102.1 | 121.5 | [2]144.0 |
| Iran[e] | [r]40.0 | [r]50.0 | [r]40.0 | [r]51.0 | 60.0 |
| Italy | .1 | — | — | — | — |
| Japan | 43.2 | 34.9 | 23.8 | 16.7 | [2]14.7 |
| Korea, North[e] | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| Korea, Republic of | .3 | .2 | .2 | ([3]) | ([3]) |
| Malaysia | 30.5 | 28.3 | 29.9 | 22.0 | [2]25.4 |
| Mexico: | | | | | |
| By concentration or leaching | 169.1 | 181.1 | 244.0 | 268.8 | 250.0 |
| Leaching (electrowon) | 8.0 | 8.0 | 9.7 | 11.4 | 10.0 |
| Mongolia[e] | 128.0 | 136.0 | 140.0 | 160.0 | 160.0 |
| Morocco | 22.0 | 20.2 | 16.6 | 14.5 | 13.3 |
| Mozambique[e] | .1 | [r].1 | .2 | [r].1 | .1 |
| Namibia | 48.0 | 49.6 | 37.6 | 40.9 | [2]26.9 |
| Nepal | ([3]) | ([3]) | ([3]) | ([3]) | ([2] [3]) |
| Norway | 19.0 | 21.9 | 22.0 | 15.9 | 16.5 |
| Oman | [r]17.7 | [r]18.2 | 18.1 | 17.1 | 16.6 |
| Papua New Guinea | 175.0 | 178.2 | 217.7 | 218.6 | [2]204.0 |
| Peru:[6] | | | | | |
| By concentration or leaching | [r]389.3 | [r]370.9 | 391.1 | 301.7 | [2]353.1 |
| Leaching (electrowon) | [r]30.9 | [r]29.0 | 26.5 | 21.1 | [2]19.7 |
| Philippines | 222.2 | 222.6 | 216.1 | 218.1 | [2]189.5 |
| Poland | 431.3 | 434.0 | 438.0 | 437.0 | 436.0 |
| Portugal[6] | .3 | .2 | 1.1 | 5.2 | 103.7 |
| Romania[e] [8] | 26.0 | 27.0 | 26.0 | 26.0 | 25.0 |
| Saudi Arabia[e] | — | — | — | .3 | .6 |

See footnotes at end of table.

TABLE 41—Continued

## COPPER: WORLD MINE PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

| Country | 1985 | 1986 | 1987 | 1988[p] | 1989[e] |
|---|---|---|---|---|---|
| South Africa, Republic of[8] | 195.4 | 184.2 | 188.1 | 168.5 | [2]196.6 |
| Spain | 61.1 | 53.5 | 16.3 | 18.1 | 27.4 |
| Sweden | 91.8 | 87.4 | 85.0 | 74.4 | 71.0 |
| Turkey[9] | [r]26.8 | [e]23.8 | 25.8 | [r e]31.2 | 35.9 |
| U.S.S.R.[e 8] | 600.0 | 620.0 | 630.0 | 640.0 | 640.0 |
| United Kingdom | .6 | .6 | .8 | .7 | .6 |
| United States:[8] | | | | | |
| By concentration or leaching | 1,012.2 | 1,018.8 | 1,082.5 | 1,191.7 | [2]1,185.6 |
| Leaching (electrowon) | 90.4 | 125.4 | 161.1 | 228.0 | [2 10]311.9 |
| Yugoslavia[9] | 142.5 | 138.5 | 130.5 | 103.5 | 105.0 |
| Zaire: | | | | | |
| By concentration or leaching | 244.0 | 212.5 | [e]217.5 | [e]250.0 | 225.0 |
| Leaching (electrowon) | 313.9 | 319.2 | 307.5 | [e]280.0 | 250.0 |
| Zambia:[11] | | | | | |
| By concentration or leaching (smelted) | 354.7 | 322.6 | 318.7 | 284.1 | 295.0 |
| Leaching (electrowon) | 103.9 | [r]139.8 | 144.5 | 147.7 | 150.0 |
| Zimbabwe[e] | 21.6 | 21.4 | 19.8 | 16.9 | 16.4 |
| Total | [r]7,987.6 | [r]7,992.6 | 8,306.3 | 8,536.7 | 8,887.2 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Data represent copper content by analysis of concentrates produced except where otherwise noted. Table includes data available through June 27, 1990.

[2]Reported figure.

[3]Less than 50 tons.

[4]Copper content of pelletized nickel-copper matte produced in smelter.

[5]Anode copper recovered in Canada from domestic concentrates plus exports of payable copper in concentrates and matte.

[6]Recoverable copper content by analysis of concentrates for export plus nonduplicative total of copper content of all metal and metal products produced indigenously from domestic ores and concentrates; includes leach production for electrowinning in Chile and Portugal.

[7]Copper content of cement copper.

[8]Recoverable content.

[9]Copper content by analysis of ore mined.

[10]Includes electrowon from concentrates roast-leached.

[11]Data are for fiscal years beginning Apr. 1 of year stated. Zambian-mined copper reported recovered during smelting and electrowinning.

TABLE 42

## COPPER: WORLD SMELTER PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

| Country[2] and metal origin | 1985 | 1986 | 1987 | 1988[p] | 1989[e] |
|---|---|---|---|---|---|
| Albania, primary[e] | 12.6 | 13.7 | 14.0 | 14.5 | 14.5 |
| Australia: | | | | | |
| Primary | 167.7 | 169.6 | 172.9 | 177.8 | [3]203.0 |
| Secondary | 7.7 | 9.2 | [e]8.5 | [e]9.0 | [3]10.0 |
| Total | 175.4 | 178.8 | [e]181.4 | [re]186.8 | [3]213.0 |
| Austria, secondary | 25.9 | 25.5 | 29.1 | 34.5 | 33.7 |
| Belgium:[e] | | | | | |
| Primary | .9 | [r].9 | [r].1 | [r].2 | .2 |
| Secondary | 114.2 | [r]105.0 | [r]92.1 | [r]93.2 | 93.4 |
| Total | 115.1 | [r]105.9 | [r]92.2 | [r]93.4 | 93.6 |
| Brazil, primary | 93.9 | 116.0 | 147.0 | 147.9 | 150.0 |
| Bulgaria:[e] | | | | | |
| Primary | 87.0 | 87.0 | 87.0 | 87.0 | 87.0 |
| Secondary | 3.0 | 3.0 | 4.0 | 5.0 | 5.0 |
| Total | 90.0 | 90.0 | 91.0 | 92.0 | 92.0 |

See footnotes at end of table.

TABLE 42—Continued

## COPPER: WORLD SMELTER PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

| Country[2] and metal origin | 1985 | 1986 | 1987 | 1988[p] | 1989[e] |
|---|---|---|---|---|---|
| Canada: | | | | | |
| Primary | 493.3 | 472.7 | 499.4 | 537.0 | 510.0 |
| Secondary[e] | 17.0 | 12.0 | 14.0 | 14.0 | 16.0 |
| Total[e] | 510.3 | 484.7 | 513.4 | [r]551.0 | 526.0 |
| Chile, primary[4] | 1,088.4 | 1,123.9 | 1,107.0 | 1,189.4 | 1,250.0 |
| China, primary[e] | 225.0 | 225.0 | 300.0 | [r]400.0 | 450.0 |
| Czechoslovakia:[e] | | | | | |
| Primary | [r]6.3 | [r]5.3 | [r]5.3 | [r]5.0 | 5.0 |
| Secondary | [r]20.2 | [r]20.9 | [r]21.9 | [r]22.1 | 22.0 |
| Total | [r]26.5 | [r]26.2 | [r]27.2 | [r]27.1 | 27.0 |
| Finland: | | | | | |
| Primary | 68.9 | 84.5 | 77.4 | 79.0 | 79.5 |
| Secondary[e] | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| Total[e] | [r]80.9 | 96.5 | 89.4 | [r]91.0 | 91.5 |
| France, secondary | 7.0 | 6.1 | 7.0 | 8.5 | 8.4 |
| German Democratic Republic, primary[e] | 14.0 | 15.0 | [r]17.0 | [r]25.0 | 24.0 |
| Germany, Federal Republic of: | | | | | |
| Primary | 152.4 | 161.9 | 165.0 | 171.5 | 171.5 |
| Secondary | 94.6 | 76.7 | 42.7 | 50.0 | 50.5 |
| Total | 247.0 | 238.6 | 207.7 | 221.5 | 222.0 |
| Hungary, secondary[e] | .1 | .1 | .1 | .1 | .1 |
| India, primary | 32.5 | 39.1 | 32.9 | 44.8 | [3]42.7 |
| Iran, primary[e] | [r]40.0 | [r]50.0 | [r]40.0 | [r]52.0 | 80.1 |
| Japan: | | | | | |
| Primary | 802.3 | 827.7 | 871.0 | 854.6 | [3]882.3 |
| Secondary | 130.3 | 134.4 | 109.0 | 139.4 | [3]123.2 |
| Total | 932.6 | 962.1 | 980.0 | 994.0 | [3]1,005.5 |
| Korea, North:[e] | | | | | |
| Primary | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| Secondary | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| Total | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 |
| Korea, Republic of, primary | [r]112.7 | [r]123.2 | 143.8 | 123.5 | [3]123.6 |
| Mexico, primary | 68.2 | 74.7 | 127.6 | 151.8 | 175.0 |
| Namibia, primary | 43.3 | 45.7 | 35.5 | 42.2 | [3]38.0 |
| Norway, primary | 38.2 | 35.2 | 29.7 | 31.7 | 35.0 |
| Oman, primary | 14.2 | 14.7 | 15.7 | 16.8 | 15.3 |
| Peru, primary | [r]320.1 | [r]327.2 | 323.0 | 246.9 | 241.4 |
| Philippines, primary | 133.8 | 124.3 | 124.7 | [e]159.2 | [3]105.0 |
| Poland:[e] | | | | | |
| Primary | 370.0 | 375.0 | 385.0 | 385.0 | 385.0 |
| Secondary | 20.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| Total | 390.0 | 400.0 | 410.0 | 410.0 | 410.0 |
| Portugal:[e] | | | | | |
| Primary | 2.6 | 3.0 | 2.0 | 2.5 | .7 |
| Secondary | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 |
| Total | 4.6 | 6.0 | 4.0 | 4.5 | 2.7 |
| Romania:[e] | | | | | |
| Primary | 32.0 | 32.0 | 30.0 | 28.0 | 42.0 |
| Secondary | 6.0 | 7.0 | 8.0 | 8.0 | 8.0 |
| Total | 38.0 | 39.0 | 38.0 | 36.0 | 50.0 |

See footnotes at end of table.

TABLE 42—Continued

## COPPER: WORLD SMELTER PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

| Country[2] and metal origin | 1985 | 1986 | 1987 | 1988[p] | 1989[e] |
|---|---|---|---|---|---|
| South Africa, Republic of, primary[e] | [3]191.7 | 192.0 | 192.0 | 180.0 | 190.0 |
| Spain: | | | | | |
| Primary | 88.0 | 100.0 | 95.0 | 95.6 | [3]120.0 |
| Secondary | [r]32.5 | 35.2 | 47.6 | 50.0 | [3]32.3 |
| Total | [r]120.5 | 135.2 | 142.6 | 145.6 | [3]152.3 |
| Sweden: | | | | | |
| Primary | 74.7 | 83.4 | 92.9 | 90.4 | 95.0 |
| Secondary | 26.0 | 19.1 | 12.7 | 25.5 | 25.0 |
| Total | 100.7 | 102.5 | 105.6 | 115.9 | 120.0 |
| Taiwan, primary | 46.7 | 50.4 | 47.0 | 43.3 | [3]43.2 |
| Turkey: | | | | | |
| Primary | 33.5 | 35.2 | [e]19.3 | [e]12.8 | 20.9 |
| Secondary | .4 | .3 | [e].1 | [e].1 | .2 |
| Total | 33.9 | 35.5 | [e]19.4 | 12.9 | [3]21.1 |
| U.S.S.R.:[e] | | | | | |
| Primary | 750.0 | 770.0 | 780.0 | 800.0 | 800.0 |
| Secondary | 143.0 | 145.0 | 147.0 | 150.0 | 150.0 |
| Total | 893.0 | 915.0 | 927.0 | 950.0 | 950.0 |
| United States: | | | | | |
| Primary[5] | 940.7 | 908.1 | 972.1 | 1,043.0 | [3]1,120.4 |
| Secondary | 250.1 | 287.8 | 276.6 | 320.2 | [3]359.1 |
| Total | 1,190.8 | 1,195.9 | 1,248.7 | 1,363.2 | [3]1,479.5 |
| Yugoslavia: | | | | | |
| Primary | 137.0 | 196.4 | 103.4 | 106.5 | 110.0 |
| Secondary | 52.2 | 31.5 | 62.4 | 65.5 | 65.0 |
| Total | 189.2 | 227.9 | 165.8 | 172.0 | 175.0 |
| Zaire, primary: | | | | | |
| Electrowon | 313.9 | 319.2 | 307.5 | 306.8 | 275.0 |
| Other | 172.9 | 178.9 | 179.9 | [e]160.0 | 150.0 |
| Total | 486.8 | 498.1 | 487.4 | [r][e]466.8 | 425.0 |
| Zambia, primary:[6] | | | | | |
| Electrowon | [r]70.7 | [r]88.7 | 74.8 | 95.9 | 100.0 |
| Other | [r]387.0 | [r]349.5 | 347.9 | 308.9 | 325.0 |
| Total | [r]457.7 | [r]438.2 | 422.7 | 404.8 | 425.0 |
| Zimbabwe, primary[7] | 20.4 | 20.4 | 18.8 | 16.1 | [3]15.7 |
| Grand total[8] | [r]8,629.6 | [r]8,816.2 | 8,923.3 | 9,284.6 | 9,534.9 |
| Of which: | | | | | |
| Primary: | | | | | |
| Electrowon | [r]384.6 | [r]407.9 | 382.3 | 402.7 | 375.0 |
| Other | [r]7,277.8 | [r]7,446.4 | 7,616.3 | 7,844.8 | 8,116.0 |
| Secondary | [r]967.2 | [r]961.9 | 924.8 | 1,037.1 | 1,043.9 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]This table includes total production of copper metal at the unrefined stage, including low-grade cathode produced by electrowinning methods. The smelter feed may be derived from ore, concentrates, copper precipitate or matte (primary), and/or scrap (secondary). To the extent possible, primary and secondary output of each country is shown separately. In some cases, total smelter production is officially reported, but the distribution between primary and secondary has been estimated. Table includes data available through June 27, 1990.

[2]Argentina presumably produces some smelter copper utilizing its own small mine output together with domestically produced cement copper and possibly using other raw materials including scrap, but the levels of such output cannot be reliably estimated.

[3]Reported figure.

[4]Data include electrowon production; estimated to be 35,000 to 45,000 metric tons per year that is fire refined and cast into wirebars; detailed data are not available.

[5]Figures for U.S. primary smelter production may include a small amount of copper derived from precipitates shipped directly to the smelter for further processing; production derived from electrowinning and fire refining is not included. Copper content of precipitates shipped directly to smelter are as follows, in metric tons: 1985—90,938; 1986—89,122; 1987—71,173; 1988—49,356; and 1989—34,485.

[6]For fiscal years beginning Apr.1 of year stated. Electrowon is based on total primary production and represents metal that is further refined; also includes a small amount of leach material from the Chanobie Mine. Smelter production also includes toll material processed for Zaire.

[7]Refined figure; unrefined data not available. Includes production from low-grade electrowon cathodes produced in nickel processing.

[8]Data may not add to totals shown because of independent rounding.

TABLE 43

## COPPER: WORLD REFINERY PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

| Country | 1985 | 1986 | 1987 | 1988[p] | 1989[e] |
|---|---|---|---|---|---|
| Albania, primary[e] | 11.5 | 11.7 | 12.0 | 13.0 | 13.0 |
| Australia: | | | | | |
| Primary | 163.8 | 164.0 | 178.9 | 191.2 | [2]230.0 |
| Secondary | 30.5 | 21.1 | 28.8 | 26.7 | [2]25.0 |
| Total[3] | 194.3 | 185.1 | 207.8 | 217.9 | [2]255.0 |
| Austria: | | | | | |
| Primary | 8.2 | 7.1 | 3.9 | 3.6 | 4.0 |
| Secondary | 35.0 | 32.6 | 32.9 | 38.4 | 40.0 |
| Total[3] | 43.2 | 39.6 | 36.8 | 41.9 | 44.0 |
| Belgium: | | | | | |
| Primary | 340.5 | 337.8 | 345.9 | 364.3 | 365.0 |
| Secondary | 115.0 | 120.0 | 130.0 | 140.0 | 145.0 |
| Total | 455.5 | 457.8 | 475.9 | 504.3 | 510.0 |
| Brazil: | | | | | |
| Primary | 93.9 | 116.0 | 147.0 | 147.9 | 150.0 |
| Secondary | 49.0 | 50.0 | 52.2 | 38.1 | 40.0 |
| Total[3] | 142.9 | 166.0 | 199.2 | 185.9 | 190.0 |
| Bulgaria:[e] | | | | | |
| Primary | 73.0 | 75.0 | 75.0 | 75.0 | 70.0 |
| Secondary | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Total | 93.0 | 95.0 | 95.0 | [r]95.0 | 90.0 |
| Canada: | | | | | |
| Primary | [r]414.6 | [r]469.4 | 461.2 | 490.7 | 472.2 |
| Secondary[e] | [r]25.0 | [r]24.0 | [r]30.0 | [r]38.0 | 39.0 |
| Total[e] | [r]439.6 | [r]493.4 | [r]491.2 | [r]528.7 | 511.2 |
| Chile, primary | 884.3 | 942.3 | 970.3 | 1,012.7 | 1,071.0 |
| China, primary and secondary[e] | 400.0 | 400.0 | 400.0 | [r]510.0 | 550.0 |
| Czechoslovakia: | | | | | |
| Primary[e] | 6.3 | 5.3 | 5.3 | 5.0 | 5.0 |
| Secondary | 20.1 | 20.9 | 21.9 | 22.1 | 22.0 |
| Total[e] | [r]26.4 | [r]26.2 | [r]27.2 | [r]27.1 | 27.0 |
| Egypt, secondary[e] | 2.6 | 2.7 | 2.5 | 2.5 | 2.6 |
| Finland: | | | | | |
| Primary | 53.5 | 59.2 | 54.5 | 47.9 | [2]49.7 |
| Secondary[e] | [r]5.0 | [r]5.0 | [r]5.0 | [r]6.0 | 6.0 |
| Total[e] | 58.5 | 64.2 | 59.5 | [r]53.9 | 55.7 |
| France: | | | | | |
| Primary[e] | [r]14.7 | [r]17.9 | [r]11.3 | [r]7.2 | 16.3 |
| Secondary[e] | [r]29.0 | [r]24.0 | [r]28.0 | [r]36.0 | 33.0 |
| Total | 43.7 | 41.9 | 39.3 | 43.2 | 49.3 |
| German Democratic Republic:[e] | | | | | |
| Primary | 15.0 | 13.0 | 13.0 | 18.0 | 13.0 |
| Secondary | 60.0 | 60.0 | 61.0 | 62.0 | 62.0 |
| Total | 75.0 | 73.0 | [r]74.0 | 80.0 | 75.0 |
| Germany, Federal Republic of: | | | | | |
| Primary | 209.9 | 238.1 | 195.2 | 192.2 | 257.3 |
| Secondary | 204.3 | 183.9 | 204.7 | [e]234.2 | 218.0 |
| Total | 414.2 | 422.0 | 399.9 | 426.4 | 475.3 |

See footnotes at end of table.

TABLE 43—Continued

## COPPER: WORLD REFINERY PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

| Country | 1985 | 1986 | 1987 | 1988[p] | 1989[e] |
|---|---|---|---|---|---|
| Hungary, primary and secondary[e] | 12.8 | 12.8 | 12.5 | [2]19.2 | 19.0 |
| India, primary: | | | | | |
| Electrolytic | 28.0 | 37.9 | 29.8 | 39.6 | [2]42.0 |
| Fire refined | [e]1.0 | [e]1.0 | 0.8 | 5.2 | [2]0.7 |
| Total | [e]29.0 | [e]38.9 | 30.6 | 44.8 | [2]42.7 |
| Iran, primary[e 4] | 12.0 | 12.0 | [r]30.0 | [r]32.0 | 40.0 |
| Italy: | | | | | |
| Primary[e] | 13.3 | 4.4 | 5.0 | 4.0 | 3.3 |
| Secondary | [r]51.0 | [r]61.0 | 60.0 | 71.4 | 80.0 |
| Total | 64.3 | 65.4 | 65.0 | 75.4 | 83.3 |
| Japan: | | | | | |
| Primary | 802.3 | 827.7 | 871.0 | 854.6 | [2]882.3 |
| Secondary | 133.6 | 115.4 | 109.4 | 100.5 | [2]107.3 |
| Total[3] | 936.0 | 943.0 | 980.3 | 955.1 | [2]989.6 |
| Korea, North:[e] | | | | | |
| Primary | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 |
| Secondary | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Total | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 |
| Korea, Republic of: | | | | | |
| Primary | 140.1 | 157.8 | 154.6 | 168.3 | 171.9 |
| Secondary | [e]11.5 | [e]7.2 | 3.3 | 0.7 | 8.0 |
| Total | [e]151.6 | [e]165.0 | 157.9 | 169.0 | [2]179.9 |
| Mexico: | | | | | |
| Primary: | | | | | |
| Electrowon | 8.0 | 8.0 | 9.7 | 11.4 | 10.0 |
| Other[e] | 96.1 | 67.8 | 100.2 | 98.9 | 112.0 |
| Secondary[e] | 19.4 | 13.7 | 20.2 | [r]19.9 | 22.0 |
| Total[3] | 123.6 | 89.5 | 130.0 | 130.2 | 144.0 |
| Norway, primary[4] | 31.1 | 30.5 | 29.4 | 31.7 | [2]35.0 |
| Oman, primary | 14.0 | 14.5 | 15.5 | 16.5 | [2]15.1 |
| Peru, primary: | | | | | |
| Electrowon | [r]30.9 | [r]29.0 | 26.5 | 21.1 | [2]19.7 |
| Other | [r]230.5 | [r]226.7 | 225.9 | 179.6 | [2]220.0 |
| Total[3] | [r]261.4 | [r]255.7 | 252.4 | 200.7 | 239.6 |
| Philippines, primary | 130.2 | 134.5 | 132.1 | 132.2 | [2]132.2 |
| Poland, primary[4] | 387.0 | 388.0 | 390.0 | 401.0 | 400.0 |
| Portugal, primary[4] | 4.5 | 5.3 | [e]5.3 | [e]6.0 | 6.8 |
| Romania:[e] | | | | | |
| Primary | 33.0 | 32.0 | 30.0 | 30.0 | 33.0 |
| Secondary | 12.0 | 11.0 | 12.0 | 12.0 | 12.0 |
| Total | 45.0 | 43.0 | 42.0 | 42.0 | 45.0 |
| South Africa, Republic of, primary[4] | 164.3 | 158.6 | 152.7 | 139.4 | 145.7 |
| Spain: | | | | | |
| Primary | 101.7 | 130.6 | 100.4 | 108.8 | 115.7 |
| Secondary | 50.0 | 24.5 | 51.0 | 50.0 | 50.0 |
| Total | 151.7 | 155.1 | 151.4 | 158.8 | 165.7 |

See footnotes at end of table.

TABLE 43—Continued

## COPPER: WORLD REFINERY PRODUCTION,[1] BY COUNTRY

(Thousand metric tons)

| Country | 1985 | 1986 | 1987 | 1988[p] | 1989[e] |
|---|---|---|---|---|---|
| Sweden: | | | | | |
| Primary | 58.5 | [r]72.8 | 79.9 | 68.3 | 69.7 |
| Secondary | [r]26.0 | [r]19.1 | 12.0 | 22.0 | 25.0 |
| Total | 84.5 | [r]91.9 | 91.9 | 90.3 | 94.7 |
| Taiwan: | | | | | |
| Primary | 46.7 | 50.4 | 47.0 | 43.3 | [2]43.2 |
| Secondary[e] | 8.0 | 8.0 | 10.0 | 10.0 | 10.0 |
| Total[e] | 54.7 | 58.4 | 57.0 | 53.3 | 53.2 |
| Turkey, primary | 60.6 | 75.1 | 75.6 | 68.4 | 68.4 |
| U.S.S.R.:[e] | | | | | |
| Primary | 810.0 | 830.0 | 840.0 | 850.0 | 850.0 |
| Secondary | 143.0 | 145.0 | 147.0 | [r]150.0 | 150.0 |
| Total | 953.0 | 975.0 | 987.0 | [r]1,000.0 | 1,000.0 |
| United Kingdom: | | | | | |
| Primary | 63.9 | 62.4 | 54.0 | 49.3 | 50.0 |
| Secondary | 61.6 | 63.2 | 68.3 | 74.7 | 75.0 |
| Total[3] | 125.4 | 125.6 | 122.3 | 124.0 | 125.0 |
| United States: | | | | | |
| Primary: | | | | | |
| Electrowon | 90.5 | 125.4 | 161.3 | 228.0 | [2]311.9 |
| Other | 966.8 | 948.6 | 965.6 | 1,178.0 | [2]1,164.9 |
| Secondary | 371.8 | 405.9 | 414.7 | 446.0 | [2]476.9 |
| Total[3] | 1,429.0 | 1,479.9 | 1,541.6 | 1,852.0 | [2]1,953.8 |
| Yugoslavia: | | | | | |
| Primary | 101.7 | 99.2 | 98.8 | 105.6 | 110.0 |
| Secondary | 33.8 | 0.8 | 40.1 | 39.8 | 41.0 |
| Total[3] | 135.4 | [r]100.0 | 138.9 | 145.4 | [2]151.0 |
| Zaire, primary | 221.4 | 218.0 | 210.1 | 202.6 | [2]181.9 |
| Zambia, primary:[5] [6] | | | | | |
| Electrowon | 33.2 | [r]51.1 | 69.6 | 51.8 | 50.0 |
| Other | 463.3 | [r]446.5 | 426.6 | 397.7 | 400.0 |
| Total[3] | 496.5 | 497.6 | 496.3 | 449.6 | 450.0 |
| Zimbabwe:[7] | | | | | |
| Primary | 20.4 | 20.4 | 18.8 | 16.1 | [2]15.7 |
| Secondary[e] | 2.1 | 4.9 | 4.2 | 11.4 | 8.3 |
| Total[e] | 22.5 | 25.3 | 23.0 | 27.5 | 24.0 |
| Grand total[3] | [r]9,408.3 | [r]9,601.5 | 9,833.4 | 10,331.7 | 10,726.6 |
| Of which: | | | | | |
| Primary[3] | [r]7,472.2 | [r]7,740.8 | 7,847.7 | 8,126.2 | 8,435.5 |
| Secondary[3] | [r]1,523.2 | [r]1,447.9 | 1,573.3 | 1,676.2 | 1,722.1 |
| Primary and secondary, undifferentiated | [r]412.8 | [r]412.8 | 412.5 | 529.2 | 569.0 |

[e]Estimated. [p]Preliminary. [r]Revised.

[1]This table includes total production of refined copper, whether produced by pyrometallurgical or electrolytic refining methods and whether derived from primary unrefined copper or from scrap. Copper cathode derived from electrowinning processing is also included. Table includes data available through June 27, 1990.

[2]Reported figure.

[3]Data may not add to totals shown because of independent rounding.

[4]May include secondary.

[5]Data are for fiscal year beginning Apr. 1 of that stated.

[6]Electrowon covers only presumably high-grade cathodes reported as "finished product leach cathodes." Other, in addition to electro-refined cathodes, includes "finished product refined shapes" presumably cast from electro-refined cathodes, high grade electrowon cathodes or any blister/anodes and low-grade electrowon cathodes that were fire-refined.

[7]May not include copper-nickel matte (copper content more than 6,000 tons per year) imported from Botswana for toll refining in 1986-89.