Part One
Introduction and Summary

Chapter 1

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Chapter 1

Introduction and Summary

The early 1980s brought hard times to the domestic copper industry. Low prices and slack demand led to mine closings, worker layoffs, and financial losses, which in turn raised questions about the industry's viability. Copper producers responded by modernizing their equipment and cutting costs. By 1987, when prices began to rise, the U.S. industry was profitable again. But what of the future? Copper prices historically have been cyclical, and undoubtedly will fall again. What steps need to be taken now for the domestic copper industry to survive another prolonged downturn? This assessment documents the industry's actions to improve its position so dramatically during the 1980s, evaluates its present–and possible future—competitive status, and discusses options available to Congress (and the industry) to prepare for the next market slump.

Copper is the world's third most widely used metal (after iron and aluminum). Its advantageous chemical, mechanical, and physical properties make it valuable in electrical and telecommunications products, building construction, industrial machinery and equipment, transportation, and consumer products. Copper's strategic uses include ordnance, command-communication-co ntrol-intelligence (C^3I) systems, and military transportation and advanced weaponry systems,

The industry that explores for, mines, smelts, refines, fabricates, markets, and recycles copper is of significant economic importance in its own right. In 1979, when the U.S. copper industry was at its peak, it employed over 90,000 people, with total shipments of the industry's products exceeding $10 billion.[1] Over 25 major mines, 17 smelters, and 22 refineries were in operation. The industry's contribution to gross national product (GNP) was more than $6 billion, with almost 40 percent contributed by copper mining and concentrating; 30 percent by smelters, refineries, and wire mills; and 30 percent by brass mills.[2]

Domestic and world copper consumption began to slide in 1979, and dropped even further during the ensuing recession. The price of copper peaked in 1980, then plummeted over 50 percent by the end of 1984. Despite the market slump, copper production in the rest of the world continued to increase, and world inventories ballooned. Furthermore, the strong U.S. dollar during this period favored imported copper.

By the mid-1980s, domestic mine production had fallen to its lowest level since the 1960s, and the United States lost its position as the world's leading copper producer for the first time in a century. From March 1981 to January 1983, 28 domestic mines closed or cut back production, and U.S. mine capacity utilization hovered around 65 percent. At the end of 1982, the industry had laid off about 42 percent of the total copper work force.

As a result, domestic copper companies lost a lot of money. Amoco Minerals lost nearly $60 million on copper from 1981 to 1985; Asarco lost over $384 million from 1982 to 1985; Phelps Dodge lost $400 million between 1982 and 1984; and Kennecott lost over $600 million between 1982 and 1985. Anaconda simply went out of business.

By 1985, the rest of the economy had rebounded from the recession, but the minerals industry lagged behind. Although demand exceeded world production and inventories began to decline, prices remained low. Only two U.S. copper firms reported profits from their operations, imports were at their highest since 1946, and domestic capacity utilization was still only 73 percent. Some previously closed mines re-

[1]Unless noted otherwise figures in this assessment are in nominal dollars and metric tonnes (1 metric tonne = 1.1 short ton = 2204.6 pounds),

[2]Louis Sousa, *The U.S. Copper Industry: Problems, Issues, and Outlook* (Washington, DC: U.S. Department of the Interior, Bureau of Mines, October 1981).

[3]Inventories are stocks of copper held at refineries and at commodity exchange warehouses awaiting shipment (or, for some copper, at refineries awaiting processing).

opened in 1985, but several major operations closed, including Bingham Canyon—the largest mine in the United States.

The balance-of-trade and other economic implications of these conditions prompted the Technology Assessment Board—the congressional oversight body for the Office of Technology Assessment (OTA)–to ask OTA to undertake a study identifying technical and economic issues related to the decline of the U.S. copper industry. Nine members of the Congressional Copper Caucus subsequently endorsed the request. In particular, the letter of request asked OTA to:

> . . . address the entire structure of the industry, including mining, refining, and smelting technologies. Operational and institutional constraints should also be addressed. The study should also provide recommendations which can be implemented by both government and industry entities in revitalizing our domestic copper industry.

This assessment responds to that request. During the course of OTA's analysis, the U.S. copper industry began its phenomenal recovery from the ravages of 1981-84. In 1985, the price of copper rose slightly, demand remained strong, inventories began to shrink, and world copper production was closer to being in line with demand.

Industry management also took steps to improve their financial situation. They restructured assets and shed a lot of debt. Marginal cost producers either closed permanently or shut down on a long-term care and maintenance basis. The remaining operations cut costs across the board. Labor costs were reduced through wage rate cuts and productivity improvements. Companies made major capital investments at mines, smelters, and refineries to improve operating efficiency. Largely in response to low prices, domestic mines also increased their average ore grade from 0.48 percent to over 0.6 percent by closing marginal mines and changing the mine plans at others.

As a result of this restructuring and capital investment, the U.S. copper companies that survived the industry's depression are now profitable. Many industry analysts question how long this will last, however. **Although financially healthy, the companies are operating at the margin in the sense that they have closed high-cost mines, made most available capital investments in technology, and reduced labor and wage rates to a minimum.** Most analysts consider another price slump inevitable as new mines throughout the world come on line in the early 1990s. **If prices again stay low for several years, copper companies would have to find new means of reducing their costs further (other than closing facilities), or implement other strategies in order to remain competitive.**

Because of the improvements in the industry's condition, OTA structured this assessment around three basic questions aimed at assessing the industry's future. First, what is the present status of the domestic and world copper industry, including relative costs of production and the elements of those costs? Second, what did U.S. copper companies do in order to improve their position so dramatically in the mid-1980s? Third, what options will be available to Congress (and the domestic industry) to enhance their competitive position next time they face the conditions they experienced in the early 1980s?

This assessment is limited, for the most part, to the ***primary*** copper industry—that sector that mines copper ore and processes and refines it to produce 99.99+ percent pure copper. (Box 1-A provides a brief overview of the copper production processes, and defines the terms used by the industry.) The assessment discusses the first stage in fabrication of copper products—the production of copper rod (the precursor of copper wire) —only to the extent that rod mills are integrated with other operations. It does not discuss the downstream fabrication of copper products (e.g., pipe, wire) except in the context of demand in various end-use sectors.[4]

This assessment also does not discuss recycling of copper except to note the extent to which copper scrap is used to meet total demand (i.e., it does not evaluate policy options related to recycling).[5] It also is limited to copper production and

[4]Note that most U.S. copper imports are in the form of semi-fabricated and fabricated products.

[5]An earlier OTA report discussed recycling of several important metals and materials; see U.S. Congress, Office of Technology Assessment, *Strategic Materials: Technologies To Reduce U.S. Import Vulnerability, OTA-ITE-248* (Washington, DC: U.S. Government Printing Office, May 1985).

Box l-A.—Copper Production

Copper is a reddish or salmon-pink metallic element. In ore, the copper usually is linked with sulfur ***(sulfide ores)*** or oxygen ***(oxide ores).*** Ores also contain other metals, including valuable ***byproduct metals (e.g.,*** gold, silver, and molybdenum), and large quantities of valueless rock. Ore typically contains from 0.4 percent to 6 percent copper. For most applications, however, refined copper has to be 99.99+ percent pure. Therefore, a series of operations are performed that result in products with a successively higher copper content (see figures 1-1 and 1 -2).

Copper ore may be mined by either ***open pit*** or ***underground*** methods, or the mineral values may be leached out of the ore ***(solution mining).*** Once the ore has been mined, the copper is extracted from it either by ***/caching (hydrometallurgical*** recovery) or through heat ***(pyrornetahrgical*** methods). in hydrometallurgical processes, water or an acidic chemical solution percolates through the ore and dissolves the minerals. The copper is recovered from the resulting pregnant Ieachate either through ***iron precipitation*** or solvent ***extraction.***

Pyrometallurgical processes employ high-temperature chemical reactions to extract copper. The ore is first pulverized by tumbling it with steel balls in cylindrical mills. The ground ore is then concentrated to eliminate much of the valueless material. The ***concentrates*** contain 20 to 30 percent copper. Depending on the copper minerals and the type of equipment, subsequent pyrometallurgical treatment of the concentrates may take as many as three steps: ***roasting, smelting,*** and ***converting.*** Roasting dries, heats, and partially removes the sulfur from the concentrate to facilitate smelting. The concentrates are smelted to produce a liquid copper ***matte*** (35 to 75 percent copper), plus slag (waste)[1] and sulfur dioxide gas. After smelting, the molten matte is converted into ***blister copper*** (98.5 to 99.5 percent copper), slag, and sulfur dioxide gas.[2] The molten blister is fire refined to further reduce its sulfur and oxygen content and poured into molds. When cooled, it is ***anode copper.***

The final step in the purification process is electrolytic treatment, either through ***electrowinning*** of solvent extraction solutions or ***electrolytic refining*** of copper anodes. The end product, ***cathode copper,*** is 99.99+ percent copper. Cathodes are melted and cast into wirebars or continuous bar stock for wire manufacture, into slabs for mechanical use, or ingots for alloying.

[1] The slag from smelting and converting may be recycled to recover its copper content.
[2] It is called " blister'' because bubbles of sulfu r dioxide form on the surface of the copper during solid ification.

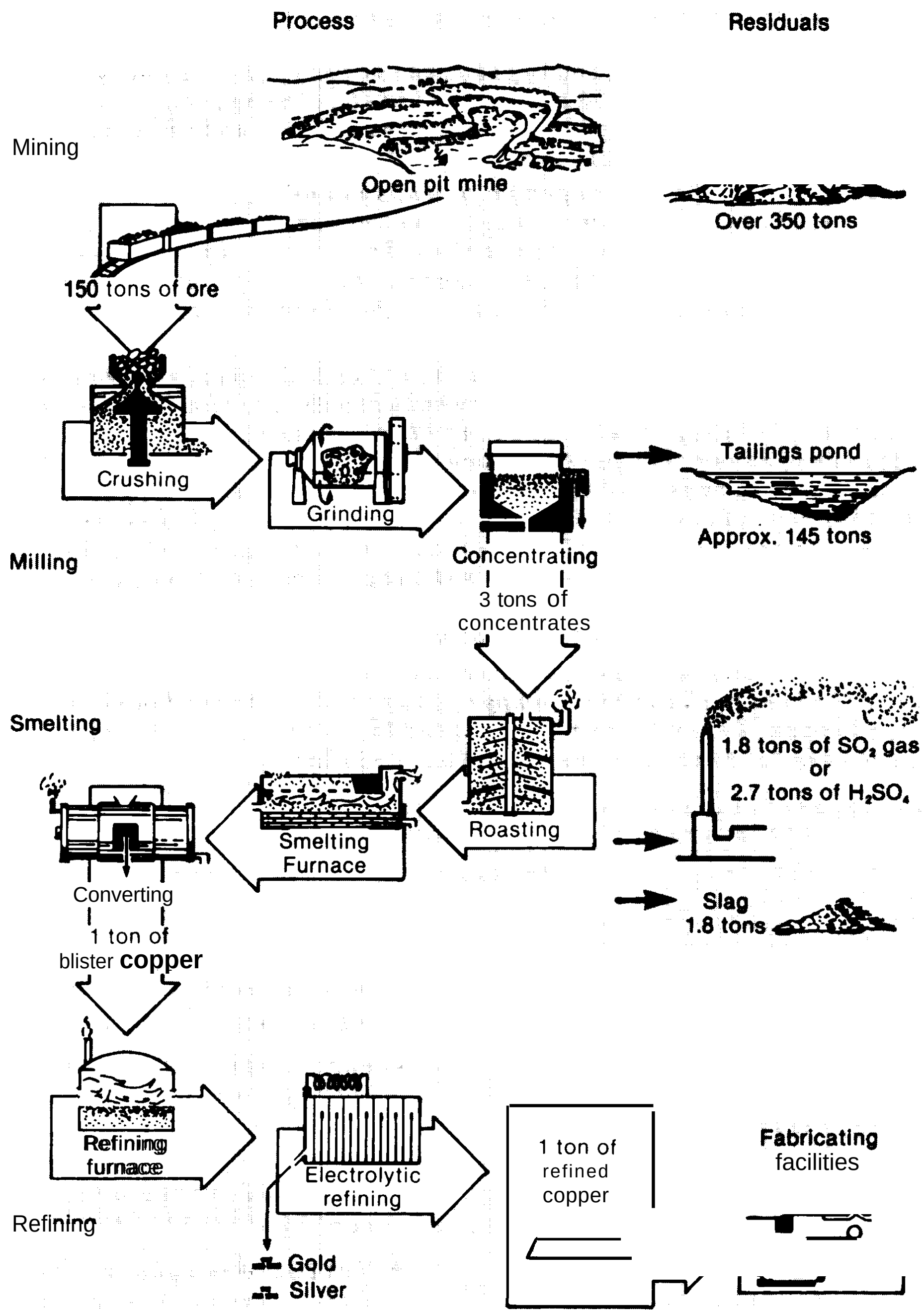
consumption in the market economy countries (also termed the Non-Socialist World: or NSW).[6] A brief description of copper activities in the centrally planned countries is included at the end of chapter 4.

The assessment is organized as follows:

- the remainder of this chapter summarizes OTA's findings on these questions and presents options for Congress (and industry) to consider;
- Part Two reviews the structure of the domestic and world copper industry and the status of copper markets (chs. 2-4);
- Part Three describes copper production, including the geology of copper deposits, technologies for mining and processing copper ores, and R&D needs for advanced technologies; and energy use and environmental controls in copper processing (chs. 5-8); and
- Part Four discusses the competitive status of the U.S. copper industry, including domestic and international production costs and the factors that influence them, measures of competitiveness and where the U.S. industry stands under each measure, and government policies and industrial strategies that affect competitiveness (chs. 9 and 10).

[6] The Non-Socialist World (NSW) refers to all copper producing and consuming market economy countries. This includes Yugoslavia, but excludes Albania, Bulgaria, Czechoslovakia, Cuba, Democratic Republic of Germany, Hungary, Poland, Romania, and the USSR. China also is excluded from consumption and production figures, but is included in trade figures because of the significant amount of copper imported into China from NSW countries in recent years.

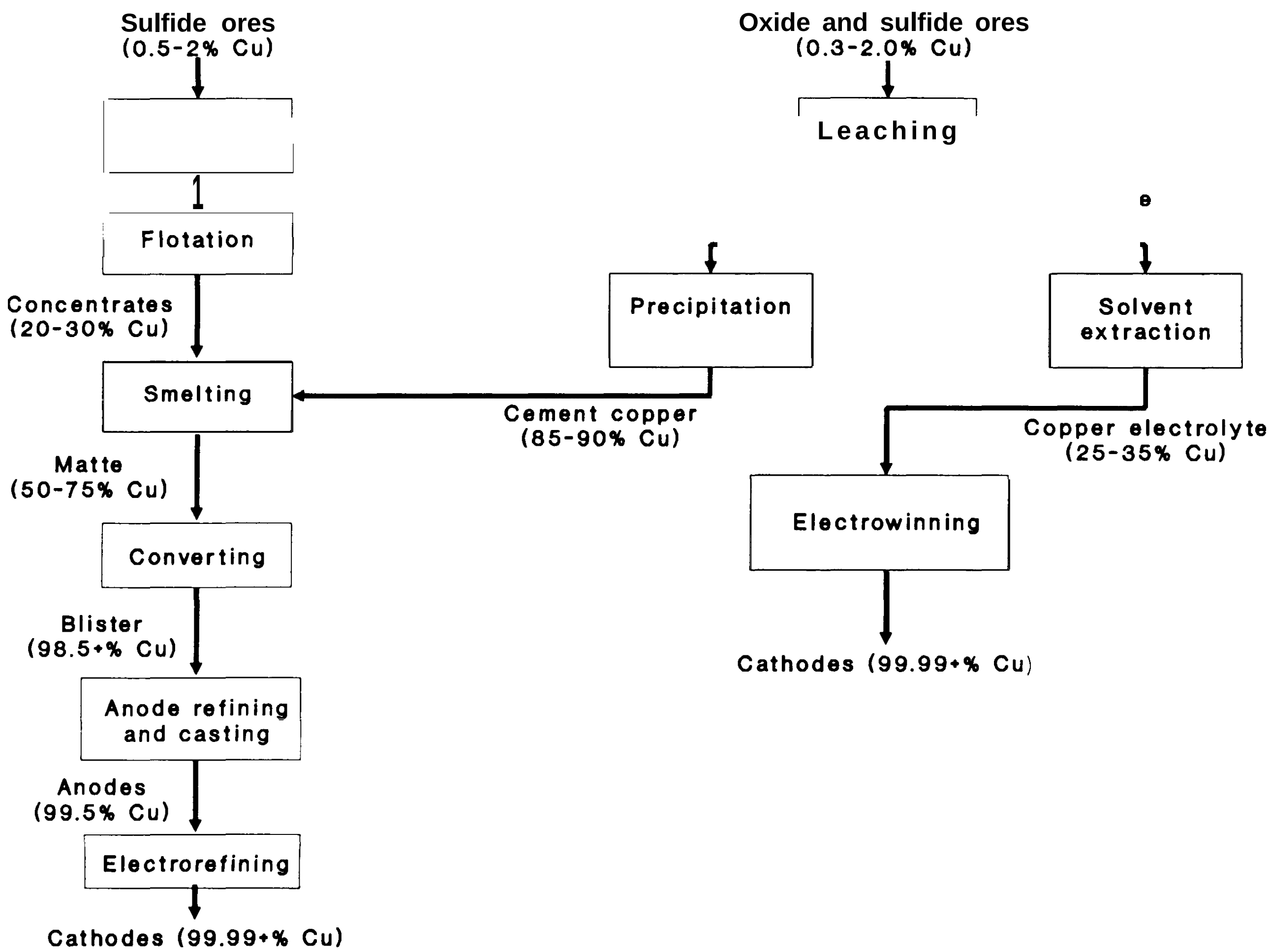
Figure 1.1 —Principal Stages of the Copper Production Process



NOTE: Tonnage of residuals is based on experience in the Southwestern United States assuming an ore grade of 0.6 per. cent copper.

SOURCE: J F McDivitt and G Manners, *Minerals and Men* (Baltimore, MD: The Johns Hopkins University Press, 1974).

Figure 1-2.-Flow Sheets for Copper Production



SOURCE: Office of Technology Assessment.

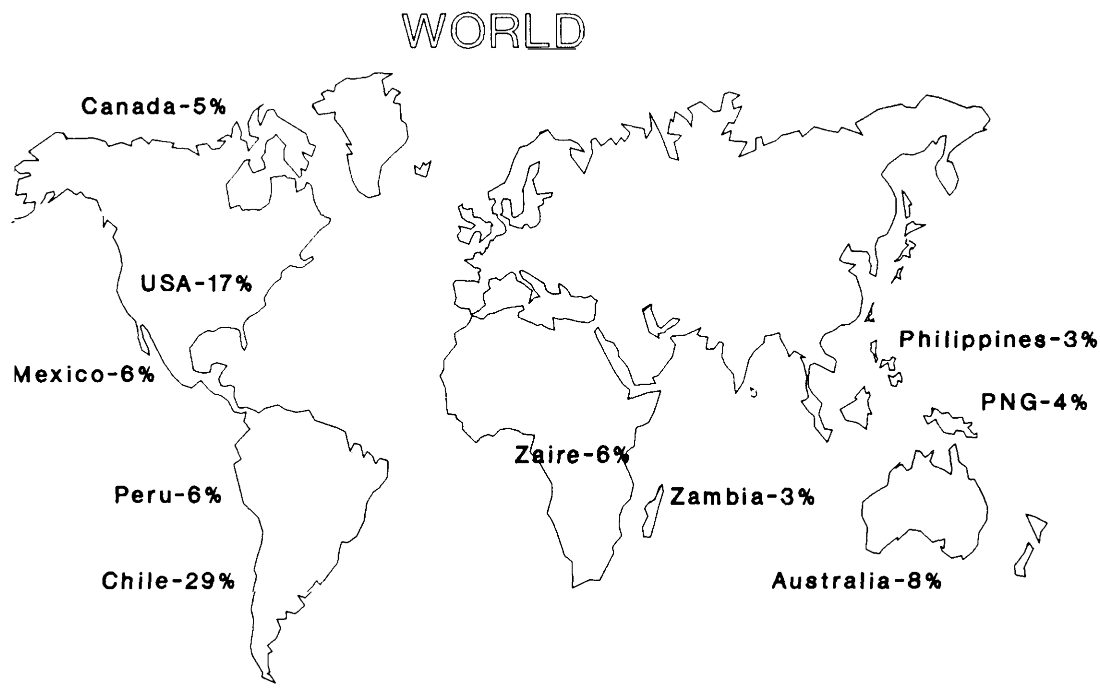
FINDINGS AND OPTIONS

Why Is The Domestic Copper Industry Important?

Copper conducts both heat and electricity very well. It is also strong, wear- and corrosion-resistant, and nonmagnetic. These properties make the metal and its alloys vital in nearly every industrial sector. Moreover, the copper industry contributes billions of dollars to gross national and regional products. Finally, copper is an important strategic metal.

In contrast with its importance, copper is a scarce metal. On average, the Earth's crust contains only 0.0058 percent copper, compared with 8 percent aluminum and 5.8 percent iron. Most commercial copper ore deposits today *contain* from 0.5 to 6 percent copper. Although the United States has one-fifth of the world's recoverable copper reserves (see figure 1-3), our ore grades are relatively low–averaging only 0.65 percent.

Figure 1-3.-Major World Copper Resources

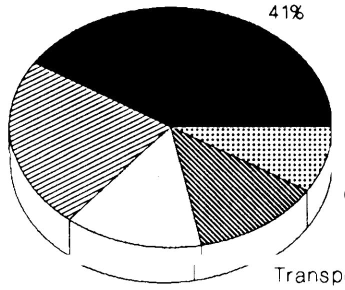


SOURCE" U S Bureau of Mines

The Uses of Copper

In 1986, around 41 percent of copper mill products went to the construction industry (see figure 1-4). Uses there include electrical wiring, plumbing and heating, air-conditioning and refrigeration, and architectural applications (such as gutters and roof and wall cladding). The second largest market—23 percent—was the electrical and electronics industry for telecommunications, power utilities, industrial controls, business electronics, lighting and wiring, etc. Next was the industrial machinery and equipment industry, with 14 percent of total shipments. Virtually all modes of transportation-automobiles, trucks, railroad equipment, aircraft and aerospace, and ships—contain copper. This sector accounted for almost 13 percent of domestic demand in 1986. Radiators, bearings, wiring, electronic devices, and brake linings are only a few of the auto and truck parts made with copper or copper alloys. Finally, miscellaneous consumer goods (ranging from appliances to cooking utensils to jewelry and objets d'art), military ap-

Figure I-4. -U.S. Copper Consumption by End-use Sector, 1986



SOURCE. Copper Development Association

placations, coinage, pharmaceuticals, and chemicals accounted for around 9 percent of consumption in 1986.[7]

Copper's uses—and the industry's fortunes—vary over time. When copper prices remain high for extended periods, some consumers may switch to other metals instead (e. g., aluminum for architectural uses and some wiring). Other substitutions arise from performance considerations (for instance, aluminum in car radiators to reduce weight), or from technological change (fiber optics for telecommunications). When copper consumption drops and prices are low, as happened during the 1982 to 1983 recession, the U.S. copper industry has trouble competing in world markets.

The Economic Importance of the Primary Copper Industry

In 1986, the United States mined 1.15 million tonnes of copper at 87 mines located in 12 States.[8] At 61 of these mines, copper was the primary product, and at the other 26 it was a byproduct of gold, silver, lead, or zinc mining. Fifteen percent of the copper concentrate produced domestically (containing 174,350 tonnes of copper) was exported (see figure 1 **-5).** Nine primary and seven secondary smelters operated in 1986,[9] producing almost 1.2 million tonnes of blister copper—903,000 tonnes from domestic concentrates, 288,000 tonnes from scrap, and 5,000 tonnes from imported concentrates. Twenty-four domestic refineries turned out nearly 1.5 million tonnes of refined copper in 1986, including over 125,000 tonnes from electrowinning plants. Around 27 percent of domestic refinery output was from scrap, and 2 percent was from imported blister and anode.[10] Refined copper imports increased 33 percent in 1986; U.S. net import reliance[11] was 27 percent.

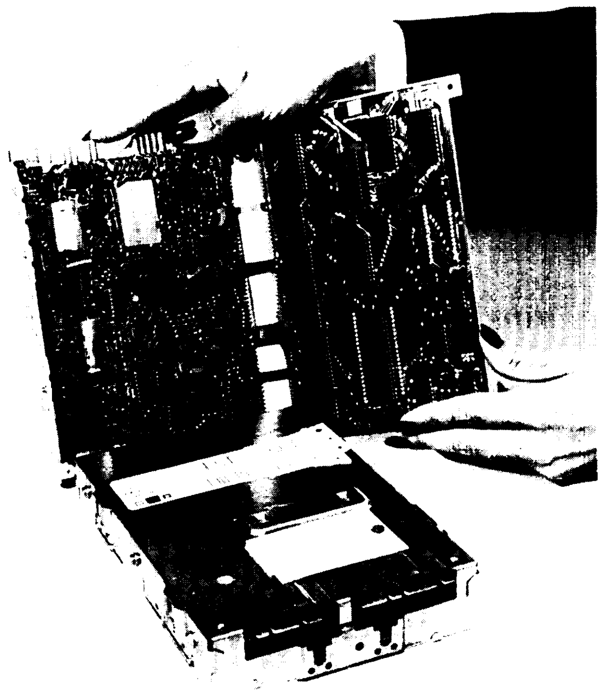


Photo credit: General Motors

Microcomputer for controlling an automobile engine. Over the last two decades, copper use in the electrical and electronics industry has increased significantly due to the growth of electronic devices in computers and telecommunications, consumer products, automobiles, and control devices.

[7]Copper Development Association, "Copper and Copper Alloy Mill Products to U.S. Markets–1 986, " *CDA Market Data,* May 10, 1987.

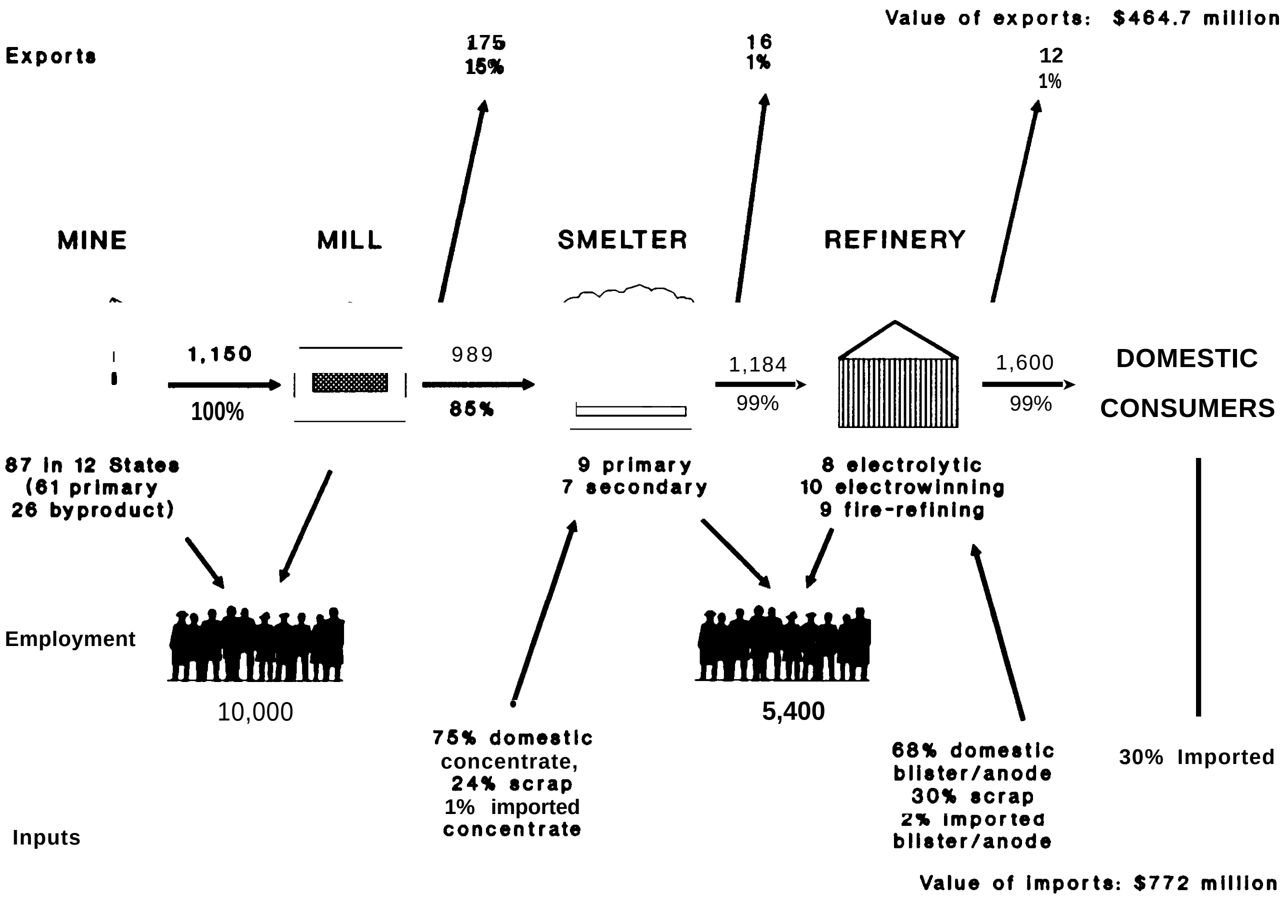
[8]Due to low ore grades in the United States, the domestic industry mined 170 million tonnes of ore to produce the 1.15 million tonnes of copper.

[9]One primary and one secondary smelter closed permanently in 1987.

[10]Janice L. W. Jolly and Daniel Edelstein, "Copper," preprint from 1986 *Bureau of Mines Minerals Yearbook* (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1987).

[11]AS a percent of apparent consumption; defined as imports − exports + adjustments for Government and industry stock changes.

Figure 1-5.-The Copper Industry in 1986
(production numbers in 1000 metric tonnes)



SOURCE: OTA from U.S. Bureau of Mines data.

The value of primary copper produced from domestic ores was $1.67 billion. U.S. exports of concentrates, blister, refined products, and scrap were valued at $464.7 million, while imports of these products into the United States were worth $772 million.[12] To produce these products, the primary copper industry employed over 10,000 mine and mill workers and 5,400 smelter and refinery employees.

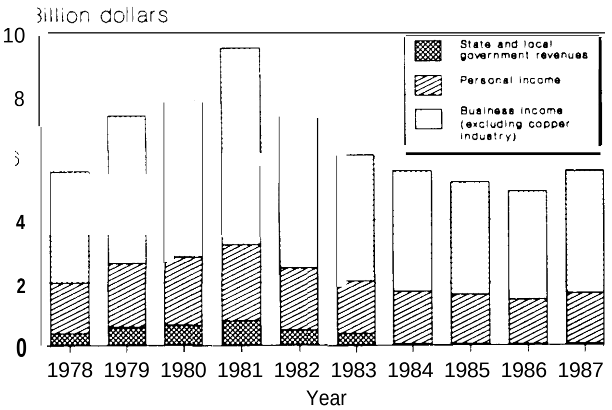
With this magnitude of production and employment, each copper operation contributes substantially to the local and regional, as well as the national, economy. Operations in Arizona–which produce nearly two-thirds of the Nation's copper–contributed $5.8 billion to the State's economy in 1987. Despite the industry's continued recovery, this was still far below the peak contribution of $9.6 billion in 1981 (see figure 1-6). Revenues to State and local government from severance, property, payroll, and sales taxes totaled $56 million; equipment and other supplies sold to the copper industry by Arizona firms were $608 million; and total wages and salaries equaled $292 million.l J

The economic impact of just one mine is shown in the Copper Range Company's estimate that the

[12] Jolly and Edelstein, supra note 10.

[13] Richard Ducote, "Copper's Impact in State Put at $5.8 billion for '87, " *The Arizona Daily Star,* July 27, 1988.

Figure 1-6.-Copper's Economic Impact in the State **of** Arizona, **1987**



SOURCE Richard Ducote. "Copper's Impact in State Put at $5.8 Billion to '87, " *The Arizona Daily Star* July 27, 1986

1986 reopening of the White Pine Mine on Michigan's upper peninsula would contribute $38 million to the economies of three counties during the first year of operation. The mine employed 900 people, adding $18 million to personal income. The analysis projected that mine employees would spend $13 million in retail sales, generating 63 new retail establishments, and creating 576 new non-manufacturing jobs. The mine itself paid $32.3 million directly to vendors during its first year.[14]

The recent contraction of the domestic copper industry also had significant impacts on local and regional economies. permanent closure of the Douglas, Arizona smelter in January 1987 cost the town 344 direct jobs with an annual payroll of $10 million. Throughout Cochise County, up to 680 jobs eventually could be affected, totaling another $11.8 million in lost earnings. In addition to lost jobs and earnings, the sparsely populated county lost one of its major sources of tax revenue; the smelter paid $314,ooO in property taxes alone in 1986.15

Cutbacks in the copper industry also affect the fortunes of its suppliers. For example, the U.S. mining machinery industry experienced substantial excess capacity due to many of the same problems that affected the minerals industry, including reduced mineral demand during the first half of the 1980s, the strong dollar during the same period, and increased competition from imports. Although mining machinery firms have undertaken significant cost reduction measures to remain competitive (including closing plants), several companies have gone out of business.[16]

The Strategic Importance of Copper

Copper is a strategic material—it is essential in the production of equipment critical to the U.S. economy and the national defense. The Department of Commerce estimates that military consumption of copper for ordnance has ranged from 10 percent of total U.S. demand at the height of the Vietnam War to around 1.5 percent during peacetime. In addition, copper wire is a critical component of all command-communication-contro!-intelligence (C^3I) systems. Military transportation and advanced weaponry systems also use significant quantities of copper. Finally, the vast industrial base that supports the national defense requires machinery and goods containing copper.[17]

In 1986, U.S. refined copper imports were around 24 **percent of refined consumption. This is roughly equal to the copper used by the electrical and electronics industry in 1986. The principal sources of imports were Chile, Canada, Peru, Zambia, and Zaire (see** figure 1-7).18 While neither political instability nor hostility is a major concern about the security of supplies from these countries, their imports can be subject to disruption (e.g., due to labor strikes or insecure transportation routes).

As a result, copper is included in the National Defense Stockpile. The current stockpile goal is 1 million short tons. In 1986, the inventory was 22,297 short tons of copper, plus 6,751 short tons

[14] Jolly and Edel Stein, supra note 10.

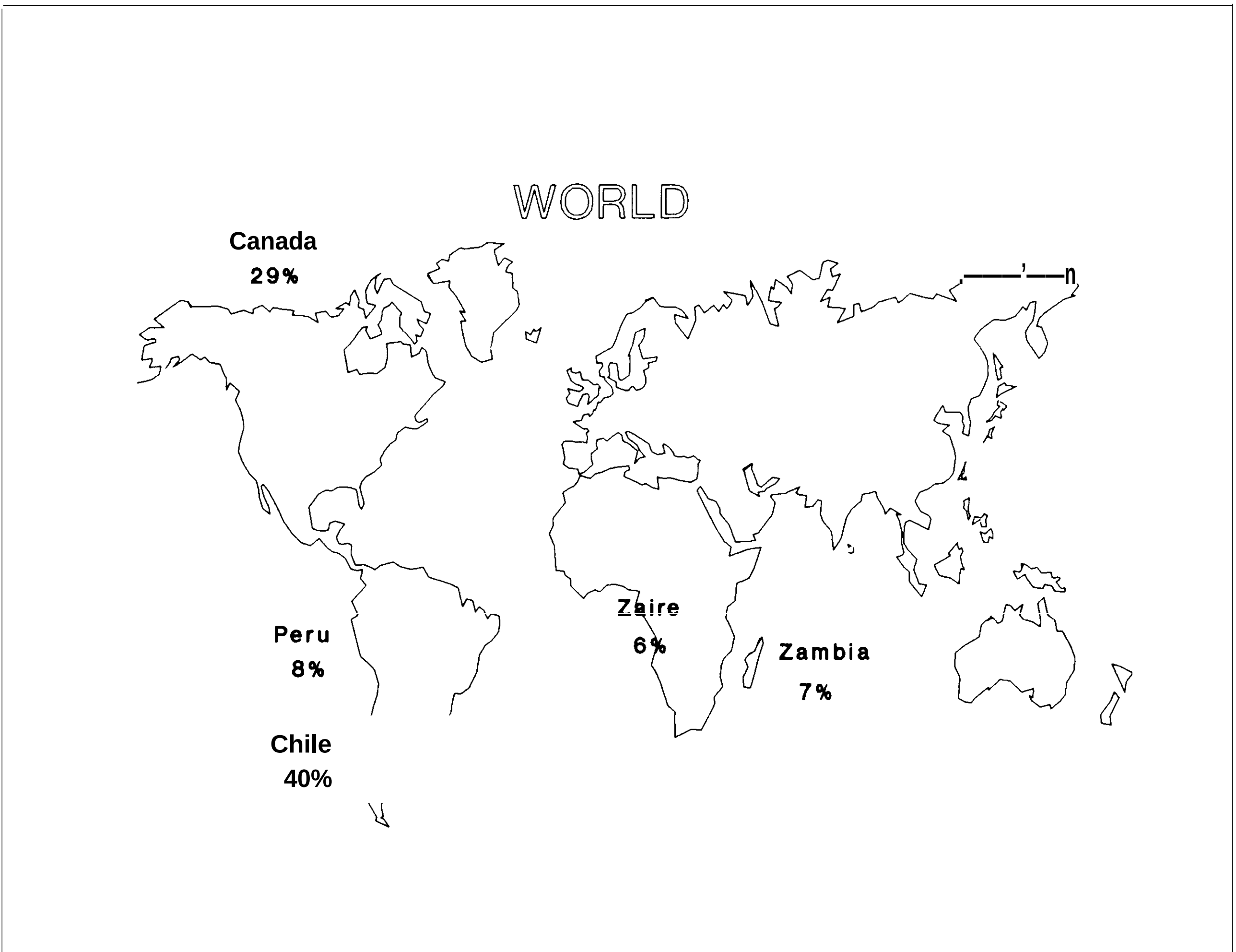
[15] Anthony Opyrchal et al., *The Changing Role of the Nonfuel Minerals Industry in the State and Local Economies of Arizona (1981-1986)* (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1987).

[16] International Trade Administration (ITA), A *Competitive Assessment of the U.S. Mining Machinery Industry* (Washington, DC: U.S. Government Printing Office, 1986).

[17] Sousa, supra note 2.

[18] Janice L.W. Jolly and Daniel Edelstein, "Copper, " *Mineral Commodity Summaries: 1987* (Washington, DC: U.S. Department of the Interior, Bureau of Mines, 1987).

Figure 1-7.-Major Sources of U.S. Copper Imports, 1986



SOURCE: U.S. Bureau of Mines data.

of copper contained in 9,645 short tons of brass.[19] over the years stockpile purchases and releases have affected copper supply and price. For example, from 1959 to 1963 stockpile acquisitions combined with copper industry strikes and strong economic expansion to push prices upward .20

The stockpile inventory shortfall often has attracted congressional attention as a means of prodding sluggish markets. Most recently, legislation was introduced in the 98th Congress (1983 to 1984) to purchase copper for the National Defense Stockpile. Opponents argued that the proposed acquisitions were insufficient to reopen any shutdown operations, and would have established a precedent of allowing economic considerations to supersede defense needs.

Purchasing domestic copper for the stockpile when demand and prices are low could help the industry bridge these difficult periods without having to close facilities. Bringing the stockpile up to its goal of 1 million tons, however, would require the purchase of almost 971,000 tons of copper. This is equivalent to 90 percent of 1986

“ibid.

[20]U.S. Department of the Interior, Bureau of Mines, *Minerals Yearbook*, various years.

U.S. primary refinery production, and 15 percent of world production. Even if spread over several years, such purchases could have far-reaching and unintended effects on copper production unless world inventories were very high. It also could cost as much as $2 billion, depending on the price of copper.

How Competitive Is The Domestic Copper Industry Today?

International competitiveness is the ability of companies in one country to produce and sell products in rivalry with those in other countries. American industries and companies also compete among themselves for markets and for resources such as investment capital and quality employees. In its simplest sense, competitiveness is measured by comparing countries' or firms' costs of production and thus profitability. Other measures may consider market share and resource endowments (e.g., ore reserves, capital, or technology),

The copper industry has rebounded from the hardships it endured in the early 1980s, but at the cost of significant restructuring. Domestic companies cut their production costs substantially and now are profitable. The average U.S. net operating cost in 1986 was approximately 54 cents/lb, down from a 1981 level of between 80 and 90 cents/lb. Costs in other major producing countries averaged around **45** cents/lb in 1986 (see figure 1-8). The average domestic producer price in 1986 was 66.05 cents/lb, and the price on the London Metal Exchange averaged 62.28 cents/ lb.[21]

The industry achieved part of these cost reductions through capital investments and other positive actions (e.g., revised mining plans; see below) **that greatly increased domestic productivity. The remainder came from the permanent closure of high-cost facilities. Today, the U.S. industry as a whole is smaller. There are fewer firms producing copper at fewer operations with fewer employees (see** table 1-1),

[21] The domestic producer price is that set in direct producer-consumer contracts. The London Metal Exchange price is a spot market commodity price.

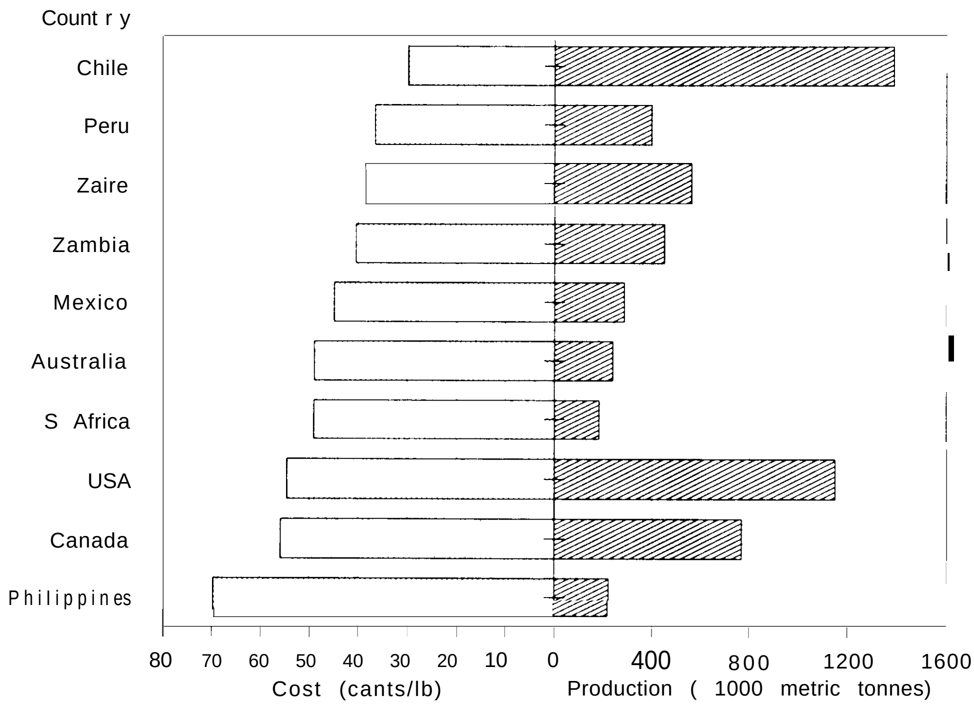
This does not mean the United States is no longer a major player in the world copper industry. We are still the world leader in smelter and refinery production, and rank second in mine production. Expansion throughout the world industry has substantially altered our market share, however (table 1-1). The domestic share of world mine/mill and refinery output declined 24 percent from 1981 to 1986; smelter share dropped 31 percent. In contrast, U.S. consumption as a percent of world demand remained constant. As a result, **U.S. net import reliance grew from 6 percent in 1981 to 27 percent in 1986,**

Losses in market share for industrialized countries are inevitable as other nations develop their resources. However, they do mean less market power. In the copper industry, nationalizations of many operations compounded the market trend (see table 1-2). Because they no longer own and/or control output at those operations, American companies lost much of their ability to influence world production in response to changes in price and demand.

Competitive advantages also can be gained through other resources, including the size and nature of ore deposits, labor, investment capital, and technological capabilities. **The United States has 17 percent of the world's undeveloped copper resources— more than any other single country except Chile (see** figure 1 -3). In particular, we have copper oxide deposits that will be amenable to low-cost in situ leaching when the technology becomes commercial. **On the other hand, our sulfide resources are relatively low in grade because of the age of our mines. This leads to higher production costs because of the expense in handling more material to produce an equivalent amount of copper.** For porphyry ore deposits (the most common), this difference in grade eventually will average out worldwide as other countries' copper industries mature.

Less-developed countries' (LDCs) main competitive advantage is in low wage rates. **While the domestic industry has the highest labor productivity among the world's copper-producing countries (see** figure 1-9), **labor costs are still a much larger share of our production costs than for most of our foreign competitors.**

Figure 1-8.-Average Net Operating Costs for Major Copper Producing Countries



NOTE This chart compares average net operating costs to mine production Net costs equal gross mining, milling, and smelt. ing/refining chargers, includlng transportation, minus byproduct credits The average total cost IS compared to only mine output because, while some countries (e g , Peru) have very little smelting/refining capacity, those charges are attributed to the country i n which the ore is mined

SOURCE U S Bureau of Mines data

Developed countries, on the other hand, tend to be advantaged in attracting investment capital for new mines and technological innovation. The United States undermines this advantage when it contributes to international loans (e.g., through the World Bank) to develop copper resources abroad at interest rates lower than those that LDCs could obtain on the open market. Financing and interest rates will become more important to LDCs as their debt multiplies and they find debt financing more difficult to obtain.

Technology affects competitiveness both through the ability to research and develop innovations and to implement them given available worker skills, While the United States has some advantage over most of our foreign competitors in both aspects, this is largely negated by the rapidity of technology transfer in the world copper industry.

What Contributed to the Domestic Industry's Current Competitive Position?

A wide range of events—both domestic and international—shaped the current competitive status of the U.S. copper industry. Market conditions in the U.S. copper industry began to worsen in 1980, when a labor strike idled a large portion of the industry. In 1981, anticipating strong demand growth, most operations resumed production at full capacity and output increased 30 percent. Instead, there was a global economic recession and demand growth was much lower than expected. oversupply conditions developed quickly. U.S. refined copper inventories increased 54 percent in 1981. The domestic producer price dropped 17 percent–the largest decline since 1975 (see figure 1-1 O). In 1982, domestic consumption declined 23 percent, inventories rose another 43 percent, and the price

Table 1-1 .—Changes in the U.S. Copper Industry: 1981.86
(1,000 metric tonnes)

Measure	1981		1986		Percent change
	Tonnes	Percent of total	Tonnes	Percent of total	
Mine production:					
United States	1,538	230/o	1,147	17%	–250/o
World [a]	6,489	100	6,629	100	2
Primary smelter production:					
United States	1,317	21	908	13	–31
World [a]	6,059	100	6,828	100	12
Primary refinery production:					
United States	1,227	19	1,073	16	–13
World [a]	6,327	100	6,348	100	<1
Refined consumption:					
United States	2,030	27	2,122	27	5
World [a]	7,252	100	7,672	100	6
U.S. imports for consumption:					
Ore and concentrate [b]	39		4		–89
Refined	331	16 [c]	502	24 [c]	51
Unmanufactured [d]	438		598		36
U.S. exports:					
Ore and concentrate	151		174		15
Refined	24		12		–50
Unmanufactured	NA		442		
U.S. net import reliance	6		27		350
Producing copper mines	58		61		5
Total mine/mill employment [f]	30,600		10,154		–66
Operating primary smelters	15		9 [g]		–40
Smelter/refinery employment [f]	14,000		6,100		–56

[a]Market economy countries
[b]Copper content
[c]Percent of U.S refined consumption
[d]Includes copper content of alloy scrap
[e]As a percent of apparent consumption; defined as imports – exports + adjustments for Government and industry stock changes
[f]Includes office workers
[g]One closed in January 1987

SOURCE OTA from Bureau of Mines and World Bureau of Metal Statistics data

Table 1.2.—Recent Government Acquisitions of Copper Capacity

1967 . . . . Gecamines, Zaire	1000/0 nationalization
1969 . . . . Codelco, Chile	51 % takeover of major mines
1969 ....., ... NCCM/RCM, Zambia [a]	51 % takeover of Zambia capacity
1971 . . . . Codelco, Chile	increase—51 0/0 to 1000/0
1974 . . . . Cerro de Pasco, Peru [b]	1000/0 nationalization
1977 . . . . Cerro Verde, Peru	Start-up, 1000/0 government
1979 ..., ...ZCCM, Zambia [c]	Government holding increased to 60°/0
1980 . . . . La Caridad, Mexico	Start-up, 440/0 government

[a]Nchanga Consolidated copper Mines, Ltd (NCCM) and Roan Consolidated Copper Mines, Ltd. (RCM).
[b]Cerro de Pasco renamed Centromin
[c]NCCM and RCM reorganized into ZCCM

SOURCE: Marian Radetski, State Mineral Enterprises (Washington, DC: Resources for the Future, 1985).

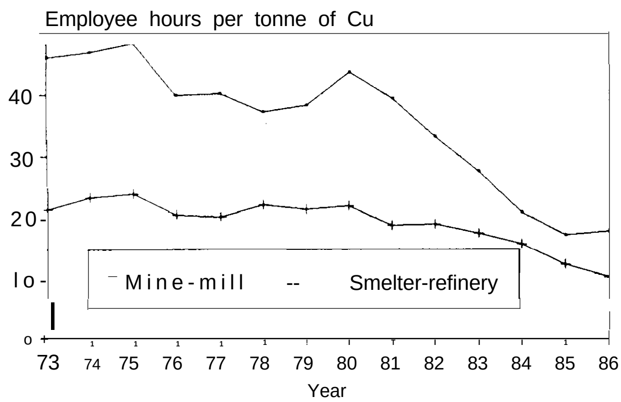
fell to an annual average of 73 cents/lb—a level at which only five or six U.S. mines could operate at a profit. As a result, the pace of mine shutdowns and worker layoffs, which had begun in late 1981, accelerated.

In 1982, domestic mine production declined to its lowest level since the 1960s, and for the first time the United states was not the world's leading copper producer. From March 1981 to January 1983, 28 domestic mines closed or cut

Photo credit: John E. Robison

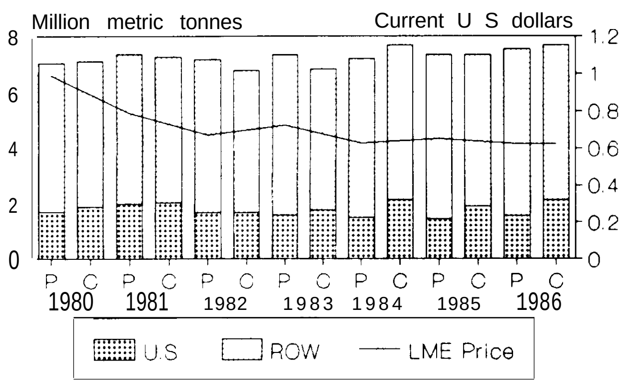
Open pit mining currently accounts for around 75 percent of domestic copper production. While this is a cost-effective extraction method, U.S. production costs are moderately high because domestic mines have to handle larger quantities of material due to our low ore grades.

Figure 1-9.-Productivity in the U.S. Copper Industry: 1973-1986



SOURCE U S Bureau of Mines

Figure 1-1O.-Average Price Compared with U.S. and Rest-of-World Refined Copper Production and Consumption



London Metal Exchange Price
"P" = production, "C" = consumption
SOURCE OTA from WBMS data.

back production, and total U.S. mine capacity utilization hovered around 65 percent. At the end of 1982, about 42 percent of the total copper work force had been laid off.

While U.S. production declined sharply, foreign production increased (see figure 1-1 O). In 1982, more than 60 percent of the copper-producing nations either increased or maintained their levels of production. Mine production outside North America increased almost 8 percent from 1981 to 1983. The intergovernmental Council of Copper Exporting Countries (CIPEC) continued to support its policy of maintaining production in spite of falling prices. The eight CIPEC members—Australia, Chile, Indonesia, Papua New Guinea, Peru, Yugoslavia, Zaire, and Zambia–accounted for 41 percent of world production in 1982, compared with 38 percent in 1981. Chile, alone, increased production 15 percent in 1982 and thereby became the world's leading copper producer. These additional supplies exacerbated the downward pressure on the already weak U.S. market prices. By December 1984, the price had fallen to $0.55/lb, off 62 percent from its high of $1 .43/lb in February 1980.

Several factors contributed to this market picture. First, the strong dollar made U.S. exports less competitive and lowered the price of imported copper compared with its domestic counterpart. Second, the market share of foreign government-owned or controlled capacity increased. Governments—when they set production levels—often are concerned more with social goals such as maintaining employment and foreign exchange than with market conditions. Third, international financing institutions (in which the United States participates) assisted foreign capacity expansions. Finally, compliance with environmental regulations meant higher domestic operating costs (see box 1-B).

Most domestic companies met the challenges posed by these events head-on (see table **1-3).** They made capital investments in new mine, mill, smelter, and refinery technology, and added solvent extraction-electrowinning (SX-EW) capacity (which has low capital, labor, and operating costs). They obtained direct cost reductions through wage cuts in the 1986 labor negotiations and rate cuts in power and transportation contracts. They cut back production at some facilities and closed high-cost operations. Finally, they restructured assets and shed debt through sales/ purchases of copper or other types of business ventures.

New **technology that reduced costs through increased operating efficiency and productivity played a major role in helping the domestic industry regain its competitiveness.** For example, most operations have now installed automated controls at all stages of copper production. While

Box l-B.—The Costs of Smelter Pollution Control

Domestic copper smelters must achieve 90 percent control of their sulfur oxide emissions. The gases from the smelter, roaster, and converter are collected, cleaned, and routed to a plant that converts the sulfur dioxide to sulfuric acid. This requires smelting and converting processes that result in relatively high concentrations of sulfur dioxide in their gaseous emissions (at least 4 percent for the smelter furnace). The sulfuric acid can be sold or used at nearby mines for leaching copper from ores or waste dumps. In the absence of leaching operations, however, it usually is a "red ink" item because the main markets are nearer the Gulf Coast and the transportation cost is prohibitive.

Sulfur oxide emission controls resulted in the replacement of most reverberatory smelting furnaces in the United States with flash, continuous, or electric furnaces, because the reverberatory furnace gas has too low a sulfur oxide concentration for economical recovery. While this brought significant air quality improvements with related (but unquantifiable) health benefits, it also meant substantial capital expenditures for U.S. smelters, and increased operating costs due to the acid plant. Present levels of environmental control entail capital and operating costs of between 10 and 15 cents/lb of copper.[1] In addition to the increased cost, the U.S. industry has lost substantial smelting capacity. Of the 16 smelters operating in the United States in the late 1970s, 8 have closed permanently—most because the capital investment to meet regulations was unwarranted given current and anticipated market conditions.

In contrast, copper smelters in Canada, Chile, Mexico, Zaire, and Zambia–most of our major smelting competitors—achieve only about 1 to 35 percent control, or enough to produce the sulfuric acid needed at nearby leaching operations (see figure 1-11). Japanese smelters achieve 95 percent control as part of government policy to provide sulfuric acid for the Japanese chemical industry. Information regarding the costs of acid production in these countries is not available. However, it is clear that domestic air quality regulation combined with the location of acid markets puts U.S. producers at a competitive disadvantage.

[1]Everest Consulting, Air Pollution Requirements for Copper Smelters in the United States Compared to Chile, Peru, Mexico, Zaire, and Zambia, 1985.

the gains from such innovations will continue until the next generation of technologies comes along, the comparative advantages of such gains are largely negated over time by technology transfer. Most operations also added low-cost SX-EW capacity to reduce their average production costs.

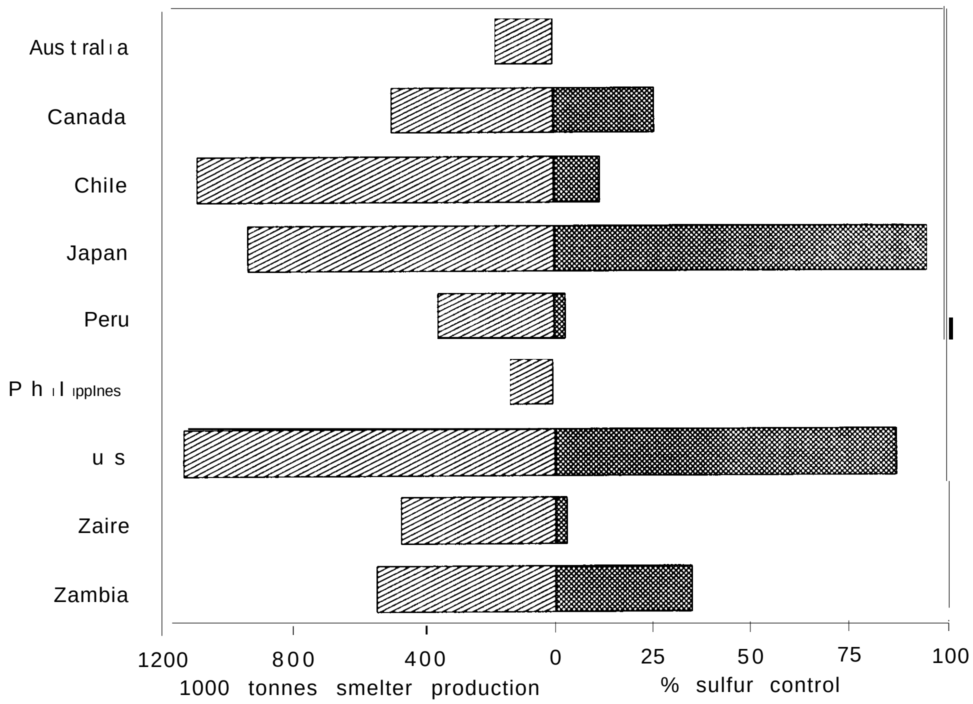
What Are The Likely Prospects For Future Competitiveness?

The domestic industry's current production costs are low enough to ensure profitability into the early 1990s. Indeed, with the largely unforeseen rise in copper prices during 1987 (see box l-C), **copper companies are enjoying excellent profits.** Though rapid price collapses followed similar price advances in 1973-74 and 1979-80, a rapid downturn is not expected during 1988-89 (barring another recession) because inventories currently are low. **But a gradual downward price trend is projected over the next several years as world production grows more rapidly than consumption.**[22]

World copper mine capacity is projected to increase significantly between 1988 **and 1992.** If all planned mine expansions and new projects meet their anticipated production levels by the early 1990s, they will add around 1 million tonnes to annual output–15 percent of 1986 output. Other mines will cut back production or close entirely, however (e. g., the Tyrone mine in New Mexico will exhaust its sulfide reserves in the early 1990s). Future output from Zambia and Zaire are highly uncertain due to the need for significant capital investment in their mines and processing facilities, and because political unrest causes transportation problems. The widespread occurrence of AIDS in these countries also makes it more difficult for operations thereto attract ski I led labor.

[22]Simon Strauss, "Copper: Prices Surged Unexpectedly," *Engineering & Mining Journal,* April 1988.

Figure 1-11.-Sulfur Dioxide Control



SOURCE: Duane Chapman, "The Economic Significance of Pollution Control and Worker Safety Cost for World Copper Trade," Cornell Agricultural Economics Staff Paper, Cornell University, Ithaca, New York, 1987

Photo credit: Manley-Prim Photography, Tucson, AZ

An electrowinning plant. Solvent extraction-electrowinning is one of the technologies that helped U.S. copper companies reduce their costs of production during the 1980s.

Table 1-3.—Strategies Adopted by U.S. Copper Companies in Response to Economic Conditions, 1980-87

Strategy	Amoco Minerals[a]	Arco/ Anaconda[b]	Asarco	Cities Service[c]	Copper Range	Cyprus	Louisiana Land[d]	Inspiration[e]	Kennecott[f]	Magma	Montana Resources	Newmont[g]	Phelps Dodge
Strategies to cut losses (or raise capital):													
Sold copper properties (or shares)		X		X			X	X	X				X
Spun off properties to new company	X											X	
Closed mine(s) for foreseeable future	X	X	X			X						X	X
Closed mine(s) temporarily or cut production		X	X			X	X	X	X			X	
Closed smelter(s) permanently		X	X						X				X
Closed smelter temporarily							X		X				
Toll smelting only								X					
Closed refinery permanently		X							X				X
Closed refinery temporarily							X						
Sold non-copper properties													X
Diversified													X
No longer in U.S. copper	X	X		X			X	X					
Strategies to improve competitive position:													
Bought developed copper properties			X		X	X					X	X	X
Opened new mine(s)			X						X				
Expanded production at existing mine(s)	X		X		X							X	
Major mine modernization									X				
Other new mining technology			X			X			X			X	X
Mill modernization		X							X			X	
Added SX-EW capacity												X	X
Replaced smelter furnace			X						X	X			
Other smelter modernization			X										X
Refinery modernization													
Built new refinery							X						
Improved balance between mining/processing													X
Obtained State/local govt. assistance			X		X						X		
Renegotiated labor costs					X	X					X		X
New labor contract			X					X	X			X	

[a]Copper properties spun off to Cyprus Minerals in 1985.
[b]Closed all properties; Butte, Montana operations sold to Montana Resources in 1985.
[c]Owned Duval; most properties sold or leased to Cyprus since 1985.
[d]Sold to Echo Bay Co. before Northern Copper was formed to own/operate the White Pine mine.
[e]Sold to Cyprus in June 1988.
[f]Sold Ray Mines to Asarco in 1986 and Chino Mines to Phelps Dodge in 1986.
[g]Spun off Magma (including Pinto Valley) as separate company in 1986, but retained a 15 percent interest.

Office of Assessment.

Box I-C.—What Happened to the Price of Copper?[1]

Copper prices rose dramatically in the latter half of 1987–soaring to $1 .45/lb by year's end–and hovered near $1.00/lb in early 1988. In light of the low prices **($0.60** to $0.64/lb) during 1983 to 1986 and the modest increases (to around $0.70/lb) projected by analysts for 1987, this price boom was striking (see table 1-4).2 It resulted from smaller consumer inventories, strong demand, moderate growth in production, and the weaker dollar, which in turn led to dwindling market inventories and increased market speculation.

Consumer behavior. In the early to mid-1980s, copper consumers adopted a policy of maintaining minimum inventories, largely in response to the general economic recession and the huge copper market stocks (1 7 percent of consumption in 1983). As consumers reduced their existing inventories to the new low levels, they masked the strength in copper demand and contributed to keeping the price low. In 1985-86, when industrial activity was improving and copper consumption was rising, the drawdown of inventories resulted in a decline in copper deliveries. The minimum inventory approach was a low-cost, low-risk policy as long as the price remained low and relatively stable, and stocks remained high. In 1987, when prices rose and stocks shrank (to below 10 percent of a year's deliveries), the potential costs and risks of minimum inventories increased. Consumers began building up their inventories, and consumption probably grew at a slightly lower rate than deliveries.

Supply and demand. Copper consumption and deliveries rebounded from the 1982-83 recession in 1984. Production increased much more gradually, however, and copper stocks dropped 32 percent during 1984. Although consumption probably increased further in 1985 and 1986, deliveries decreased because of consumer inventory reductions. Production in these years was more in line with deliveries, so producer and warehouse stocks were drawn down only about 12 percent in 1984 and 8 percent in 1986. The stocks, however, still remained above 10 percent of deliveries.

In 1987, when deliveries regained their 1984 levels, production was slow to react. It quickly became apparent that, contrary to widespread belief, significant capacity (idled during the early 1980s) was not waiting in the wings for improved market conditions. In the first quarter, stocks dropped 21 percent—to 9 percent of 1986 deliveries–and the price began to rise. This led to anticipation of a tighter market, and to increases in consumer inventories and speculative purchases. The trend continued in the second quarter, when stocks fell another 18 percent (to 7.6 percent of 1986 deliveries) and the price topped $0.72/lb. Speculative buying picked up further, and warehouse levels actually rose slightly in the third quarter, while the price hit nearly $0.85/lb. As the year waned, the discrepancy between the growth rates of supply and demand became apparent. At the same time, inventories dropped below 7 percent of a year's deliveries, and near-panic buying ensued. During the fourth quarter of 1987, inventories plummeted 44 percent and prices climbed to $1 .45/lb.

The value of the dollar. Copper typically is priced in U.S. dollars. From 1980 to 1985, the U.S. dollar appreciated relative to other world currencies. When the dollar is high relative to the value of the currencies of consuming countries, **they are able** to purchase less copper for a given amount of money. This can depress demand. The effect can be offset to some extent by the fact that profits are measured in the local currency. Thus, for firms that export, the higher the dollar, the greater the local profits. After peaking in early 1985, the dollar devalued against the currencies of other developed countries. While this reduced foreign companies' profits, it also made copper cheaper. The shift in exchange rates, plus continued growth in worldwide industrial activity, stimulated demand.

[1]Unless otherwise noted, the information in this box is drawn from Simon Strauss, "Copper: Prices Surged Unexpectedly," *Engineering & Mining Journal,* April 1988.

[2]Figures given are London Metal Exchange prices in nominal $U.S. per pound.

Over the same period, world demand growth is expected to slow to around 1 to 1.5 percent annually as the huge debt held by LDCs inhibits their economic growth and thus their copper consumption.

If another recession were combined with sluggish demand and production increases, the price of copper would drop again—perhaps as low as 40 **to** so **cents/lb** (the estimated marginal cost of new large state-of-the-art operations opening

Table 1.4.–Copper Markets: 1983-87

Date	Stocks[a] (1,000 mt)	LME price (U.S. $/lb.)	Refined production (1,000 mt)	Refined deliveries (1,000 mt)[c]
Dec. 31, 1983	1,186.4	64,0	7,416.4	5,489.2
Dec. 31, 1984	802.4	59.9	7,274.8	6,076.0
Dec.31, 1985	701.6	64.0	7,390.9	5,687.8
Dec.31, 1986	645.9	60.4	7,522.8	5,578.1
Mar.31, 1987	514.5	68.2		
June30, 1987	423.9	72.5		
Sep.30, 1987	434.5	84,6		
Dec.31, 1987	243.3	145.4	NA	6,049.7

NA = not available.
[a]As reported by the American Bureau of Metal Statistics forWestern world stocks at refinery warehouses andinthe LMEand COMEX warehouses. Reporting refineries account foran estimated 85 percent of production in market-economy countries.
[b]Primary ,nd secondary.
[c]Deliveries t. refineries as reported t. the American Bureau of Metal Statistics, Data cover only about 85 percent of the Western world copper industry.

SOURCE: World Bureau of Metal Statistics; U.S. Bureau of Mines; Simon Strauss, "Copper: Prices Surged Unexpectedly," *Engineering & Mining Journal,* April 1988.

in the early 1990s). That price is below the current average domestic cost of production. Some of our foreign competitors, however, can operate profitably at that price. Others are likely to continue to produce regardless of demand in order to maintain employment or foreign exchange.

A price drop of this severity would produce roughly the same conditions for the domestic industry that existed during the early 1980s. Higher cost U.S. operations would have the same three choices: shut down, lose money, or find ways to cut costs further. Even with the current high prices, many operations are still struggling to repay their debt from the last recession, and could not afford to lose much money. Moreover, because most companies already have taken advantage of available technological cost-saving measures, they will have fewer options without substantial R&D. Possible actions the government and/or the domestic producers might consider in order to prepare for and bridge such market conditions are discussed in the following sections.

WHAT CAN THE FEDERAL GOVERNMENT DO TO IMPROVE THE PROSPECTS FOR COMPETITIVENESS?

Federal policies with potential impacts on the competitiveness of the domestic copper industry include those related to taxation, trade and foreign aid, defense, the environment, R&D, and general industrial development. The current effects of these policies on the copper industry vary. Some, such as present modest Federal investments in R&D and industrial incentives for education and training, are neutral or provide small benefits.

others, such as environmental regulation, have been very costly to the industry (although beneficial to society as a whole), but their primary impacts (smelter closure, or the capital cost of new smelters and acid plants) have run their course. The industry has made the capital expenditures necessary to comply with current reg-

Photo credit: Jenifer Rob/son

Copper mining generates large volumes of waste. More stringent disposal requirements (e.g., classifying mine waste as hazardous) would entail capital outlays and new mining practices that could lead to further mine closures.

ulations. Barring any further changes in environmental control requirements (e.g., more stringent air quality standards or classification of wastes as hazardous) that would require additional capital outlays, the present burden of compliance is in slightly higher operating costs compared with countries without similar requirements. This disadvantage could even out over the long term if pressure for environmental quality initiatives in LDCs mounted. On the other hand, more stringent environmental regulations could break the domestic industry.

Decisions under various trade initiatives generally have gone against the primary copper industry. As imports grew during the last decade, U.S. producers twice requested and were denied relief through tariffs, quotas, and orderly marketing agreements (bilateral agreements to restrict imports into the United States) under the Trade Act of 1974, Legislation introduced since 1984 would have required the Federal Government to negotiate with foreign producers to reduce their output during periods of low demand/price, and would have classified foreign subsidization of production during oversupply situations as an unfair trade practice. These proposals either did not pass Congress or were vetoed by President Reagan. The U.S.-Canada Free Trade Agreement (which has yet to be ratified; see box I-D) essentially ignores Canadian Government subsidization of copper producers by relegating the issue to a bilateral working group with a 7-year deadline.

Tax policy, on the other hand, is generally beneficial to the industry. For example, before the Tax Reform Act of 1986, the Congressional Budget Office estimated that the U.S. mining industry benefited more than any other sector from preferences designed to reduce its taxes.[23] The two most important tax provisions targeted specifically at the mining industry are depletion allowances and expensing of exploration and development costs .24 Other pre-1986 tax benefits applicable to all industries (but now rescinded) included the accelerated cost-recovery system (ACRS), and the investment tax credit. These measures primarily benefited capital intensive activities, and their repeal will not unduly affect most of the industry's planned modernizations and low-capital cost SX-EW expansions.

In examining these policies to determine what the Federal Government might do to help the copper industry remain competitive, three possible policy goals are apparent. The first is to refrain from interfering in the market; i.e., do nothing. The second goal is to protect the industry from the effects of a significant downturn in prices. The third goal is to promote industry investments in technologies and products that could lower costs and bolster market share in the event of such a downturn.

Option Set 1: Do Nothing

When OTA began this study, several copper industry executives expressed concern about the possible side-effects of government assistance. During their troubled times, they sought government intervention through trade measures to stem the rising tide of copper imports, through tax incentives to help finance plant modernizations, through relief from environmental regulations, even through direct government copper purchases. Yet **once their situation had turned around, the domestic industry was almost pleased that the government had refused aid. They had been left to make it on their own and, for the most part, had succeeded.** This does not mean, however, that they have stopped lobbying for a "level playing field" (e.g., in the U. S.-Canada Free Trade Agreement).

This strategy would maintain the status quo in all the policy areas listed above (i. e., it assumes no major changes in policy with the incoming administration). Except where current policies advantage or disadvantage the domestic industry compared with foreign competitors, this option set is policy neutral. Thus, tax policy would not reinstate investment incentives (even though they were available for pre-tax reform expansions and modernizations), trade relief would continue to be denied regardless of market conditions, environmental regulations would remain in place, and R&D would continue to be modest.

[23] U.S. Congress, congressional Budget Office, *Federal Support of U.S. Business* (Washington, DC: U .S. Government Printing Office, January 1984),

[24] Note that depletion allowances cover foreign production by U.S. firms.

Box l-D.—The U.S.-Canada Free Trade Agreement

The United States and Canada signed an accord in January 1988 that seeks to liberalize trade and investment between the two countries. This bilateral agreement would eliminate all tariffs on goods trade by 1998, reduce nontariff trade barriers, establish rules for bilateral investment, and create a dispute settlement mechanism.[1] To be enacted, the U.S.-Canada Free Trade Agreement (FTA) must yet be approved by the U.S. Congress and the Canadian Parliament.[2]

The FTA is opposed by several major copper producers, represented by the Non-Ferrous Metals Producers Committee (NFMPC),[3] because it phases out the tariff on imports of Canadian copper and it fails to prohibit some Canadian subsidization practices. These producers are concerned that Canadian copper mines and smelters are being modernized with below-market-rate capital made available through various national and provincial government assistance programs. They cite as an example the allotment of C$84 million of government funds, from an acid rain program, for modernization and pollution control at Noranda's copper smelter at Rouyn, Quebec. There also have been suggestions that subsidies may be made available to reopen Noranda's Gaspe copper mine in Murdockville, Quebec (closed in April 1987 because of a fire), and to the Hudson Bay Mining and Smelting Co. copper smelter at Flin Flon, Manitoba. Even with such subsidies, Canadian smelters only recover an average of 25 percent of their SO_2, compared with 90 percent recovery in the United States (see figure 1-11).

The accord does not actually sanction the subsidization programs, but leaves their legality up to a bilateral working group established to iron out the differences between U.S. and Canadian unfair trade law. Until the group finishes its work (up to 7 years), both countries would apply their own antidumping and countervailing duty laws to any disputes that may arise. For cases under these laws that are investigated in the interim, the FTA only comes into play after the U.S. International Trade Commission and Commerce Department (or their Canadian counterparts) have made their final determinations. independent binational panels (instead of the national courts, as is now the case) would review contested determinations for their consistency with the laws of the country that made the ruling.[4]

1 The accord also deals with services trade, business travel, energy and national security concerns, and some outstanding trade Issues.

2 The FTA was approved by the U.S. House of Representatives in August 1988.

3 The NFMPC is a trade association whose members are Asarco, Phelps Dodge, and the Doe Run Co. (a lead producer based in St. Lou Is, MO). Their position on the FTA is outlined in the statement by Robert J. Muth, President, before the Mining and Natural Resources Subcommittee of the Interior and Insular Affairs Committee of the U.S. House of Representatives, Mar. 10, 1988. In addition to subsidies, the NFMPC IS against the FTA because it weakens judicial review in unfair trade cases.

4 In the United States, an unfair trade case can be concluded once the ITC and the Commerce Department have made their findings. Quite often, however, the determinations of these agencies are challenged before the U.S. Court of International Trade.

Without major market changes in the interim, a severe price slump likely would have the same results as in the early to mid-1980s. The highest cost producers would shut down, and others would cut back their conventional mine output and rely more on leaching and SX-EW production. Operations that have paid off their debt and accrued capital during the current high prices might buy facilities from firms that cannot survive periods of red ink.

Technological innovation alone probably is insufficient to change this picture. Even if advanced technologies were to bring further significant cost reductions to the domestic industry, rapid technology transfer and the insensitivity of many foreign producers to drops in price/demand would mean at least temporary cutbacks in the domestic industry. **It will -likely take a combination of technological innovation and a more stable and secure market share.**

Option Set 2: Protect the Industry From World Market Changes

This group of options incorporates many initiatives promoted by the copper industry in the past, including protectionist measures, direct subsidization, and product support. **Protectionist measures under tax and trade policies** might encompass:

- tax breaks for copper consumers related to the difference in cost between foreign and domestic copper to encourage them to "Buy American";

- trade relief through tariffs, quotas, and orderly marketing agreements, etc. for copper imports from foreign government-subsidized capacity that contributes to oversupplies in world copper markets;
- pollution import tariffs for blister and refined products based on foreign producers' degree of air quality control; and
- requiring U.S. representatives to the International Monetar"y Fund to ask for a ban on loans or other financial aid to countries that subsidize excess capacity or do not adjust production in response to market changes, or at least to vote against such loans.

Direct government subsidization could be introduced under defense or mineral policy. Congress could invoke the Defense Production Act (DPA) to support modernization of domestic copper capacity as part of preparedness policy (e.g., Title III loan guarantees to expedite production in the event of a national emergency). This option would be supported both by the fact that copper is a strategic commodity and by the long leadtime (typically 6 months to 3 years) needed to reopen shutdown mines or bring new mines on line. Military consumption of copper for ordnance alone quadrupled between 1965 and 1966, requiring the release of 550,000 tons from the National Defense Stockpile. DPA loans were then offered in 1967 to 1969 to stimulate domestic copper production.

A comprehensive minerals industry policy that would maintain a specified level of productive capacity at a cost commensurate with the value of the minerals to national security and the economy could be established under the Mining and Mineral Policy Act of 1970.

Direct product support might include domestic content requirements for imported products containing significant amounts of copper (e.g., automobiles); mandated use of domestic copper by government contractors (for instance, in Federal construction projects or defense contractor products); purchases of domestic copper to meet the National Defense Stockpile goal of 1 million short tons; and increased domestic copper content in coinage.

This set of options, singly or in combination, would help the domestic copper industry maintain its competitive position in the face of adverse market conditions. However, when the underlying objective is to promote competitiveness by aiding industry adjustment to changing markets, protectionist policies tend to be counterproductive. They mask the market signals and eliminate an industry's need to adjust.[25] They also may be costly to other sectors of the domestic economy (e.g., brass and wire mills and other copper consumers).

Moreover, protectionist policies distort markets in ways that usually require increasing protection. For instance, Orderly Marketing Agreements (bilateral agreements to restrict imports into the United States) typically are used to give American firms time to adjust to new market situations. However, restricting imports from one country can stimulate increased production elsewhere. Also, limiting the volume of imports encourages foreign producers to move into higher value goods, or to alter the composition of the goods they produce to escape the quantitative limits on certain imports. Thus, such import restrictions simultaneously insulate American producers from incentives to adjust to foreign competition and provide powerful inducements to our competitors to adopt strategies that make them even more competitive.[26]

Protectionist policies, therefore, should be contemplated only when linked to an explicit and monitored plan for adjustment with a timetable. Alternatively, it may be more economically efficient to provide direct subsidies or exceptional tax arrangements to maintain domestic production during the market adjustment period.

Option Set 3: Promote Investments in Competitiveness

The alternative to protectionist policies are those that actively promote domestic competitiveness. Rather than insulating an industry from the impacts of market situations after they arise,

[25] John Zysman and Laura Tyson (eds.) *American Industry in International Competition: Government Policies and Corporate Strategies* (Ithaca, NY: Cornell University Press, 1983).
[26] Ibid.

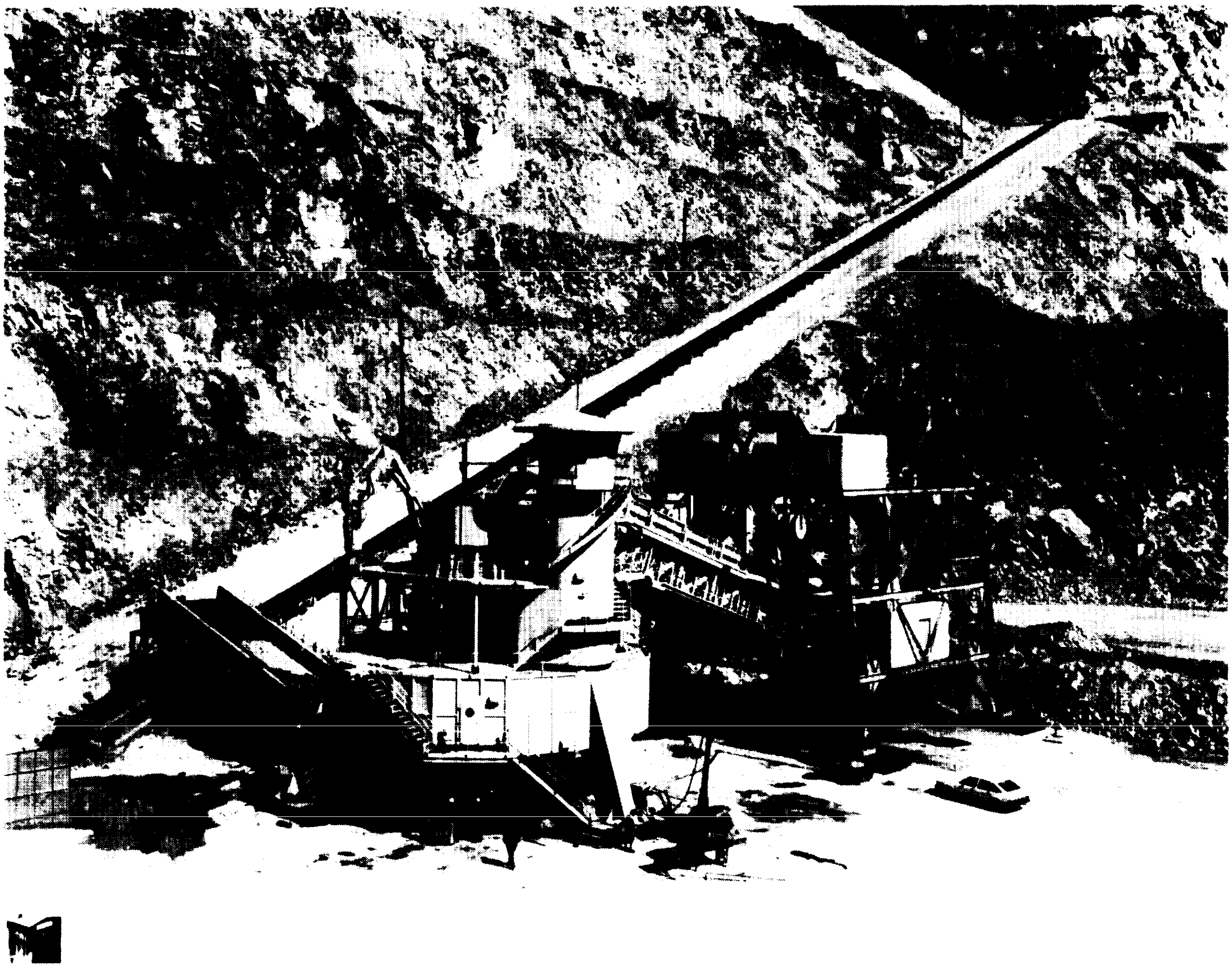


Photo credit: Manley-Prim Photography, Tucson, AZ

Conveyor systems coupled with in-pit ore crushers are particularly advantageous for U.S. mines because of our high truck haulage costs.

such policies aim to anticipate market changes and promote government and private investments that will foster future competitiveness. Policy-makers thus need an understanding of the target industry's operations and the factors that contribute to its competitiveness (or lack thereof).

Because technology transfer is almost instantaneous in the copper industry, the first place to search for a technological advantage is in resources or aspects of production that are common in the United States but rare elsewhere. For example, North America has copper oxide ore bodies that are particularly suitable for leaching and solvent extraction -electrowinning. The lowest cost copper (<30 cents/lb) currently is produced using this technology in combination with mine waste dumps containing very low-grade resources, but for which the mining cost has already been incurred (see box l-E). However, research is underway on methods to leach ore in place (i. e., without ever having to mine it). When developed and proven in the field, in situ solution mining could provide a significant cost advantage for the U.S. industry. Labor-saving innovations also would benefit the domestic industry because our labor costs are so high. While these innovations could be copied elsewhere, the relative advantage would not be so great.

The U.S. industry also is at a disadvantage in materials handling: mines have to haul more ore because of our lower ore grades, The combined energy, labor, and other costs make our transportation charges very high. Some mines are replacing trucks with conveyor systems coupled with in-pit ore crushing machines. While this technology is likely to be applied wherever in the world electricity is cheaper than diesel fuel, it benefits U.S. mines because of our high truck haulage costs. A more radical technological cost-saver might use artificial intelligence to develop some form of "driverless truck. "

Policies that would promote development of these technologies include government investment in R&D and in education and training. Because most companies already have taken advantage of available technological innovations, radical rather than incremental research is needed.

There is no comprehensive Federal policy toward research and development (whether for minerals or industry as a whole) .2' Congress might authorize R&D as part of legislation in specific policy areas (e.g., as in the Mining and Mineral Policy Act of 1970), although actual appropriations may fall short of the authorization. R&D funding for minerals and materials also may be provided as part of an agency's general program responsibilities. The Bureau of Mines and Geological Survey (USGS) –both within the U.S. Department of the Interior–sponsor (and often carry out) most of the Federal R&D on copper production and related technologies.

The Bureau of Mines total R&D budget for FY 89 is expected to decrease by $10 million to $86 million. The proposed decrease was in applied research, which the Reagan Administration believes is the responsibility of private industry. Only about one-third of their present mining research budget goes to mining technology (figure 1-1 2a); of that, less than half could aid the competitiveness of the minerals industry (figure 1 -12b). The Geological Survey's total R&D budget for FY 89 is projected to be $224 million, a decrease of$12 million from FY 88, About 75 percent of the USGS research budget is for geological and mineral resource surveys and mapping, [28]

Federal R&D support also could be introduced through tax incentives. Firms, however, could interpret a general R&D tax deduction or credit broadly to the detriment of Federal revenues. A provision targeted toward investments in commercial-scale (or nearly so) demonstration projects—the most expensive aspect of R&D—for promising technological innovations could be very effective,

Some Federal (and private) R&D money goes to support research programs at universities, including the State mineral institutes and the Bureau of Mines mineral technology centers. The mineral institutes originally were administered by the Office of Surface Mining under the Surface Mining Control and Reclamation Act; responsibility subsequently was transferred to the Bureau of Mines. Almost every budget request since 1982 has proposed to abolish the institutes. Congress also has enacted special initiatives to provide seed money for research centers. One example is the new Center for Advanced Studies in Copper Research and Utilization at the University of Arizona, whose mandate focuses primarily on copper product applications (e.g., ceramic superconductors), but also includes process technologies (e.g., in situ solution mining).

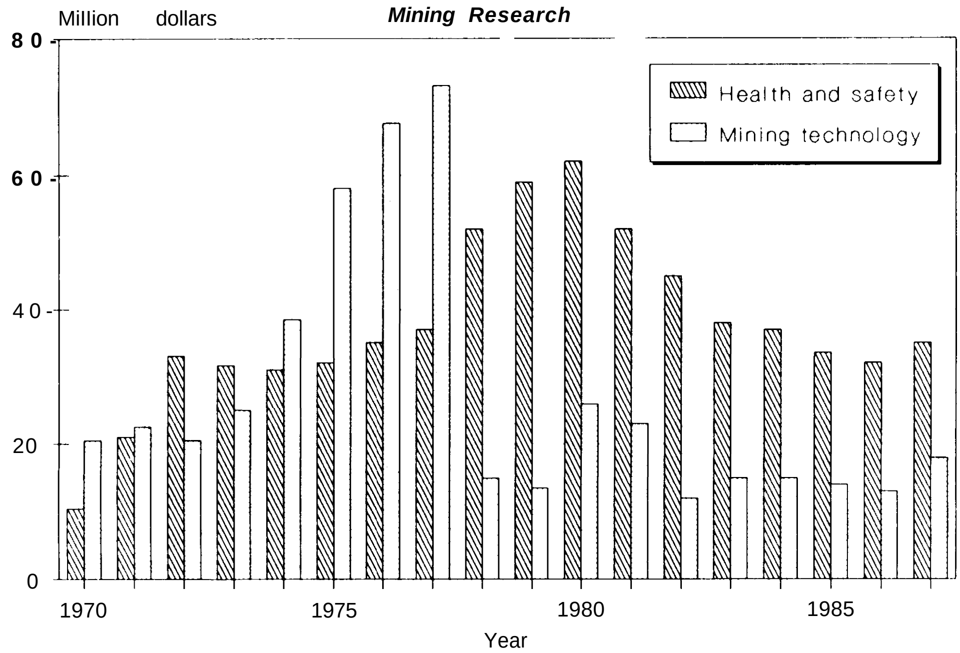
Research funding for universities not only provides a valuable source of technological innovation for the minerals industry, but also supports education and training for the next generation of industry employees. While enrollment in mining and other engineering disciplines historically has been cyclical (and currently is low due to the poor economic performance of the minerals industry during the early 1980s),29 evidence of Federal support for truly innovative **R&D** could at-

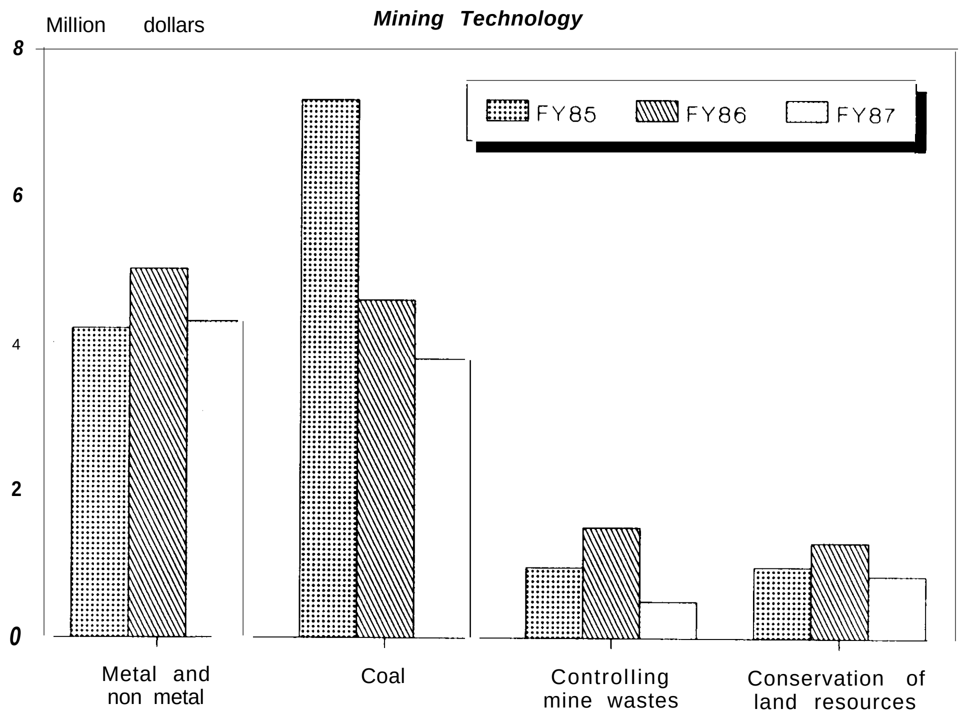
[27]Although the United States spends more on R&D than any other country, it continues to lag behind some of its competitors in the share of gross national product devoted to civilian R&D. Japan spends nearly 3 percent of its GNP on R&D; the U, S, share is only slightly above 2.5 percent. see "R&D Scoreboard, " *Business Week*, June 22, 1987

[28]Office of Management and Budget, *Budget of the United States Government, Fiscal Year 1989* (Washington, DC: U. S. Government Printing Office, 1988).

[29]In 1978, 3,117 undergraduate students were enrolled in 26 mining engineering programs in the United States, By 1987, the number of programs had dropped to 19, with additional closings and mergers expected, As a result, significant shortages of mining engineers are predicted at least through 1992. Eileen Ashworth, "Where Have All the Graduate\ Gone, 'r *LANDMARC,* January/February 1988,

Figure l-12.-Trends in U.S. Bureau of Mines R&D





SOURCE: U S. Department of the Interior, Bureau of Mines, *Technical Highlights: Mining Research 1987* (Washington, DC: U S. Government Printing Office, 1988) tract high-quality students. Policies supportive of continuing education and training also would address high domestic labor costs by improving prod activity. JO

The high cost of compliance with environmental regulations—especially air quality control requirements—also adversely affects domestic competitiveness. Marketing the sulfuric acid byproduct of air pollution control is a major cost of compliance. Unless copper companies can use the acid at a nearby leaching operation, they lose money on it because the primary markets for sulfuric acid are on the Gulf Coast and transporting the acid there is not cost-effective. This has been less of a problem in the last several years because of the growth in leach production in the Southwest. If a sulfuric acid market imbalance were to reappear, the Federal Government might counteract it through options that could facilitate cheaper transportation to the Gulf Coast (e.g., amending the anti-trust laws to allow joint marketing or transportation agreements). This might create a sulfuric acid surplus in the Southeast, however. Promoting industrial development of sulfuric acid users near the smelters is another possibility, but could be limited by water availability.

Research into more cost-effective means of pollution control also could help, but promoting control abroad would be more equitable. A positive approach to accomplishing this is through International Monetary Fund loan incentives for environmental controls (e.g., variable interest rates based on the degree of control). More protectionist-oriented strategies would include refusing to support international loans for projects that fail to achieve a certain level of control. As noted in box 1-D, the industry also is concerned about government subsidies for pollution control at Canadian smelters.

The strong dollar during the early to mid-1980s also adversely affected the domestic copper industry by favoring imports. This argues for Federal macroeconomic policies that support low interest rates and a devalued dollar, and thus promote exports.

Finally, domestic producers are sensitive to market signals, while many of their competitors ignore those signals in order to continue promoting social goals such as employment and foreign exchange. One alternative to the protectionist responses discussed previously is continued active support for the Copper Producer/Consumer Forum, and for international trading codes under the General Agreement on Tariffs and Trade (GATT) working group on trade problems affecting nonferrous metals. Both of these provide forums for voicing concerns to the LDCs about the market effects of their production strategies during recessionary conditions. [31]

Also included in this set of options are policies that actively promote the U.S. copper industry and its products, whether through research on new products, through advertising, or through direct purchasing support (e.g., use of domestic materials in Federal buildings, and coinage). While these might have a small impact on competitiveness, they can be important symbolically.

[30] An additional means of "leveling the playing field" for labor costs is to actively promote industrial development, and thus higher wages, in LDCs.

[31] The United States also might consider joining the Intergovernmental Council of Copper Exporting Countries (C IPEC), and use it as an educational forum. Participation in such consortia historically has been antithetical to U.S. political philosophy, however.

WHAT CAN THE COPPER INDUSTRY DO TO MAINTAIN OR IMPROVE ITS COMPETITIVENESS?

Although they continue to seek government support to ensure future competitiveness, domestic copper companies are well aware that such support is not always (or even often) forthcoming. Thus, during the recent downswing, the industry made significant capital investments in new technology and took other actions to improve their own position. As noted previously, however, the next time the price drops it is likely to go lower and may stay lower longer. To be competitive under those conditions, **domestic producers will need cost-saving technological innovations beyond those now being demonstrated (e.g., in situ solution mining) or a captured market. This will require investments in R&D now, as well as new ways of thinking about their product.**

R&D spending in the copper industry is low, averaging less than 1 percent of sales in 1986. This compares with an average for the whole metals and mining industry of almost 2 percent of sales, and a national industrial average of 3.5 percent of sales.[32] The copper industry considers mineral exploration to be their research; they rely on equipment vendors for process technology R&D and consumers for product research. **The Industrial and Mining Machinery sector also lags behind the national average in R&D expenditures,** however. Furthermore, the U.S. mining machinery industry consistently lost market share to foreign competitors throughout the early and mid-1980s, and now is operating with substantial excess capacity .33 If this trend continues, their R&D expenditures can be expected to decline. At the same time, the growth of foreign equipment suppliers will mean that more R&D is likely to focus on foreign mining and processing problems.

One option for increasing the level of R&D on process technology is for the industry to actively pursue cooperative research ventures involving producers, vendors, universities, and government agencies. Anti-trust and patent concerns about such ventures were addressed in the National Cooperative Research Act of 1984 (Public Law 98-462). In 1987, a group of universities took the lead in forming the Mining and Excavation Research Institute (MERI) under the umbrella of the American Society of Mechanical Engineers. MERI's goal is to unite universities, industry, and government to provide coordination and leadership in long-range research. Industry members contribute $5,000 annual dues and participate through the Industry Advisory Panel. Government funding is still being sought. In 1988 the American Mining Congress appointed a steering committee to plan cooperative research .34 A perennial concern in cooperative research is the continuity of funding from all parties once a project is underway.

The domestic copper industry still faces competition for markets, both from imports and from other metals and materials (e.g., aluminum). **Two basic options are available to offset further market losses—expand sales in current markets or develop new products and uses for copper and market them aggressively.**

The companies argue that marketing would be futile because they already are selling all the copper they produce. In the same breath, they complain about idle capacity. Simultaneously developing new markets and capturing a larger share of them could address both problems.

One key to expanding sales is marketing based on product differentiation. Superior quality—including customer service—may command higher prices in the marketplace, making production costs less significant. Although, copper traditionally has been considered a fungible commodity of uniform quality, different producers experience different rates of customer returns for breakage and other quality-related factors. Product differentiation based on quality is likely to become more important as specialty copper alloys and high-technology applications such as superconducting materials occupy an increasing share of the end-use market.

Similarly, **copper has properties that make it superior to the materials that often are substituted for it.** Copper industry associations have publicized copper's advantages in response to specific market threats (e.g., aluminum wiring in houses), **but neither individual companies nor the associations routinely advertise copper in order to reverse or prevent such substitutions.** In contrast, one of copper's major competitors—the aluminum industry–regularly advertises both

[32] "R&D Scoreboard, " *Business Week,* **June** *22,* 1987.
[33] ITA, supra note 16.

[34] Carl R. Peterson, "Tremendous Opportunities Exist for Major Technology Advances, " *AMC Journal*, June 1988. Possible institutional frameworks for cooperative minerals industry R&D are discussed in U.S. Congress, Office of Technology Assessment, *Western Surface Mine Permitting and Reclamation* (Washington, DC: U.S. Government Printing Office, OTA-E-279), June 1986; see also Jenifer Robison, "Bridging the Research Gap," speech presented to the American Mining Congress Coal Convention, May 1986.

its product and its innovative research programs in the trade press.

Product research also could forestall substitutions and expand markets. Associations representing the primary copper industry publicize promising new applications, but do little direct research. Yet other metals in decline have found cooperative R&D with major consumers on new products very promising. The steel industry, for example, started a cooperative research program with U.S. auto makers to deal with the substitution of materials in, and foreign capture of markets for, steel parts in cars.

Finally, a "Buy American" campaign backed up with ads about the problems faced by the domestic copper industry could be very effective—especially if aimed toward the effects of imports on domestic capacity and employment. Foreign products and components not only threaten present domestic employment and market share, but also advance foreign manufacturing expertise and thus future foreign market share.

Box I-E. —Technological Innovation and R&D Needs

The last boom in technological innovation for copper production occurred in the first two decades of this century, when open pit mining, flotation concentration, and the reverberatory smelter were adapted to porphyry copper ores. Instead of great leaps forward, technological innovations of the last 65 years have largely consisted of adaptations of other types of technology to mining (e.g., computers, conveyor systems), plus incremental changes that allowed companies to exploit lower grade ores and continually reduce the costs of production. Economies of scale have been realized in all phases of copper production. Both machine and human productivity have increased dramatically.

Most copper producers have taken advantage of available technological advances. They have modernized their mining and milling equipment, installed new smelter furnaces, and updated their refineries (see table 1-3). Most operations also are now computerized, from truck dispatching, to underground remote control systems, to online monitoring and automatic controls in milling, smelting, and refining. The resulting cost savings are substantial. For instance, Asarco reduced its production cost at the Mission Mine 28 percent between 1981 and 1984, largely by modernizing the truck fleet and flotation cells and adding computerized systems.

The major recent innovation that contributed to the domestic industry's revival, however, is leaching/SX-EW. Phelps Dodge (PO) reduced its overall production cost at the Tyrone Mine as much as 11 cents/lb between 1980 and 1985 by adding leaching/SX-EW.[1] The process was so successful that PD expanded the Tyrone electrowinning plant, increasing its output to about 32,000 tonnes in 1986. Expansion to a total capacity of 50,000 tonnes/yr is scheduled for 1988 -89.2 To further benefit from this strategy, PD is adding two other SX-EW plants at Morenci and Chino. Other companies have made similar SX-EW capacity additions.

Some additional production cost savings may be achieved through innovations now undergoing site-specific demonstration and engineering. These include in-pit crushing and conveying, column flotation cells, and autogenous grinding. Still, major economic growth in the industry will require radical, rather than incremental, technological change. It also will require new technologies that compensate for inherent domestic disadvantages (e.g., low ore grades, high labor costs).[3] Possibilities are an underground continuous mining machine, in situ solution mining of virgin ore bodies (including sulfide and complex ores), alternative grinding methods, and a truly continuous smelting process.

[1] United Nat Ions I ndustrial Development Organ ization (UN I DO), *Technological Alternatives for Copper, Lead, Zinc and Tin in Developing Countries*, report prepared for the First Consultation on the Non-ferrous Metals 1 ndustry, Budapest, Hungary, July 1987.

[2] "Phelps Dodge Has Something to Smile About," *Engineering and Mining Journal*, Aug. 1987.

[3] George S. Ansell, "Blending New Technology into an Established Industry," paper presented at the American Mining Congress Mining Convention, San Francisco, CA, Sept. 1985.